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Summary for Policy Makers

Status of Power System Transformation 2018

Advanced Power Plant Flexibility

INTERNATIONAL ENERGY AGENCY

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Summary for Policy Makers

Introduction

This document summarises the main policy-related messages of the report *Status of Power System Transformation – Advanced Power Plant Flexibility*. The full report presents findings of the Advanced Power Plant Flexibility (APPF) Campaign.[1] Launched at the 8th Clean Energy Ministerial (CEM) in Beijing in June 2017, the work of the campaign seeks to build strong momentum and commitment to implement solutions that make power generation more flexible, in line with growing system needs for flexibility. This report focuses specifically on the role of power plants in delivering flexibility in power systems, although it notes many of the myriad other pathways for power systems to enhance flexibility. The CEM campaign will continue with a broader scope on power system flexibility, covering concepts and experiences around power plants, grids, demand side resources and storage over the next 12 months.

Rather than providing a comprehensive summary of the full report, this Summary for Policy Makers (SPM) provides a concise overview of power system transformation (PST) and system flexibility, highlights key insights about the role of power plants in providing system flexibility, and provides actionable steps for policy makers. Based on a wealth of real-life case studies and data, the report describes a variety of practical measures that can help unlock power plant flexibility, and details how these tools can be combined into a comprehensive implementation strategy.

Background

Driven in many contexts by increasing intensity and frequency of high-impact events, and a higher share of variable renewable energy (VRE) in daily operations, **power system flexibility is an increasingly important topic for policy makers** and system planners to consider. It is one aspect of power system transformation (PST),[2] which also includes incorporation of VRE generation, growth in distributed energy resources, and the application of demand response and other modern technologies. PST is crucial for ensuring electricity security in modern power systems. Power system flexibility is defined as the ability of a power system to reliably and cost-effectively manage the variability and uncertainty of demand and supply across all relevant timescales, from ensuring instantaneous stability of the power system to supporting long-term security of supply. A lack of system flexibility can reduce the resilience of power systems, or lead to the loss of substantial amounts of clean electricity through curtailment of VRE.

Importantly, power systems are already designed with the flexibility to manage variability and uncertainty, but requirements may grow and change over time. A number of investment, operational, and policy interventions can be made to make modern systems more flexible, facilitating cleaner, more reliable, more resilient and more affordable power systems. Power system flexibility can be conceptualised as having three “layers”: the hardware and infrastructure

[1] More information is available on the CEM website: http://cleanenergyministerial.org/campaign-clean-energy-ministerial/advanced-power-plant-flexibility.

[2] Power system transformation (PST) is the active process of creating the policy, market and regulatory environments, as well as establishing operational and planning practices, that accelerate investment and innovation in and the use of smart, efficient, resilient and environmentally sound technology options.

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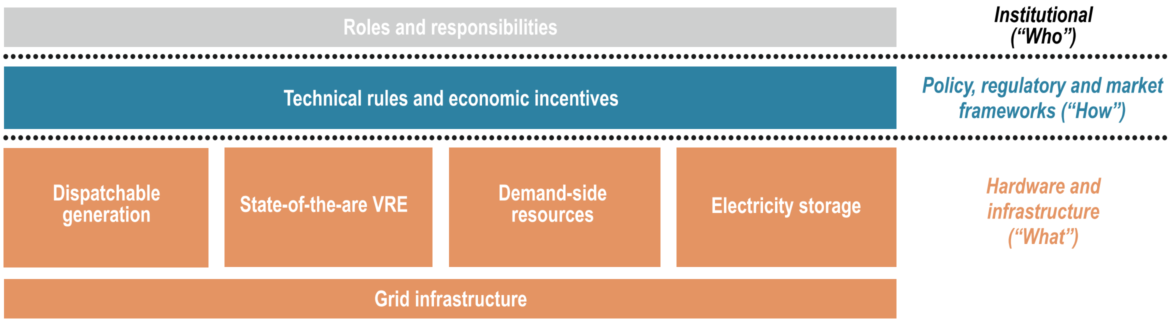
available to provide physical flexibility (the "what"); the policy, regulatory and market frameworks which incentivise the provision of flexibility (the "how"); and the institutional roles and responsibilities of entities who provide, incentivise, or manage flexibility (the "who").

Figure SPM.1 • Relevant dimensions for understanding and unlocking system flexibility



Key point • **Technical, economic and institutional layers mutually influence each other, and a comprehensive approach offers greater opportunities to enhance power system flexibility.**

As shown in Figure SPM.1, there are many resources capable of providing system flexibility. While other reports have addressed many of the other options (for example, see 21CPP, 2014, IEA, 2014 and IEA, 2017), **this report focuses on just one type of flexibility resource: power plants – including thermal fleets and VRE**. Each option that may increase power system flexibility presents both advantages and challenges within the unique system in which it resides; this report examines a diversity of valuable experiences from around the world to learn about the various considerations associated with enabling flexible power plant resources.

Key insights for policy makers

- Power plants are one option to provide system flexibility, but many other options are available in modern power systems. Other technology sources of flexibility are strong and smart grids, demand response and storage. Mobilising technically available flexibility in practice may call for changes to operational practices, fuel and power purchase contracts, regulatory incentives and market design. Evaluating all options on an even footing during strategy and planning activities enhances the robustness of decisions.
- Experience and examples highlighted in this report establish that many, if not all, power plant technologies can operate flexibly and across multiple timescales of power system operation. Flexible power plant operation can take many forms, from rapidly changing plant output, to starting and stopping more quickly, to turning plant output down to lower levels without triggering a shutdown.
- The role of existing thermal power plants is transitioning in many modern power systems toward more flexible modes of operation and, at times, reduced operating hours. While such plants offer increasingly important services to the system, reductions in energy sales raise concerns about plant financial viability and the need to re-evaluate how they are rewarded in many markets.
- Significant system flexibility lies latent in many power plants; global experience suggests a range of known strategies are available to unlock that flexibility, many of which are non-technical. Often, no technical changes or capital investments are required to access this plant flexibility. Instead, modifications to system operational procedures or market and regulatory incentives can unlock power plant flexibility
- Generators that were initially designed and operated as "inflexible" have been successfully engineered into highly flexible assets, often without major capital investment. Modest changes to power plants, including retrofitting certain power plant components, can "flexibilise" power plants. The opportunity to implement these strategies is quite distinct for each power plant fleet, and should be periodically assessed.
- Emerging power plant technology systems are being designed with flexibility in mind. Pursuing more technically and economically flexible power plant investments today may serve as a hedge against a future of uncertain flexibility needs.
- Smart contract structures for new or enhanced system assets allow for positive net benefits over time. Designing contracts with sufficient flexibility leaves headroom for lower-cost energy sources such as VRE and energy efficiency, and assets that provide critical system services, to enter the market while mitigating the risk of stranding thermal assets.
- Incorporating regular flexibility assessments into planning and strategy dialogues is key. Practices and technologies advance over time. Periodically refreshing the cycle of assessment and planning helps support system flexibility.
- Established decision support tools can be used to assess flexibility requirements, understand the value of proposed changes, and plan for the future. Policy makers can help facilitate a transparent and collaborative planning environment that employs global best practices.

Well-designed policy, market and regulatory frameworks are critical to unlock power plant flexibility.

Considerations for policy makers

1. **ASSESS** – Commission assessments of system-wide flexibility requirements, opportunities and barriers, including the role of power plant flexibility. Periodically refresh these assessments to inform both near- and long-term decision-making and planning processes.

2. **ENGAGE** – Engage with stakeholder communities to strengthen technical, policy and institutional capabilities to enhance power system and power plant flexibility. Engage with international communities to share best practices.

3. **ENHANCE** – Enhance the use of available power system flexibility options by adapting a range of market, regulatory and operational best practices at the system level.

4. **UNLOCK** – Update regulations, policies and practices that govern power system operation to unlock latent flexibility. These options include more flexible power purchase agreements with independent power producers and fuel supply contracts for thermal generators.

5. **INCENTIVISE** – Seek fair and appropriate remuneration for all assets that can provide flexibility to the power system through changes in policy, regulatory and market frameworks.

6. **ROADMAP** – Enhance planning procedures to incorporate future expectations of system flexibility requirements; ensure consideration of all possible flexibility options to mitigate the long-term costs and operational impacts of power system transformation.

Consideration 1 – ASSESS

How urgently does the power system need additional flexibility? What options are available today or in the future to increase power system flexibility? What market or regulatory barriers could be addressed to unlock latent flexibility? To answer these questions, policy makers, system operators and utility planners can undertake a process to create a detailed inventory of available options to access or deploy additional power system flexibility. While it is important to take an inventory of all available options across the system, the focus of this report is on options for additional power plant flexibility. At a high level, taking an inventory of potential power plant flexibility measures requires a series of actions:

Assess how flexible the system is today relative to what is required. Understanding the current status of the power system's flexibility requirements is a useful starting point to prioritise efforts.

Estimate requirements for system flexibility in the near and long term. An understanding of future requirements can inform how urgently various actions may be required to enhance system flexibility.

Assess the potential to unlock latent power plant flexibility through changes to market rules, regulations, contracts or policies. These assessments help identify potential institutional or market barriers to accessing physical flexibility that power plants are otherwise technically capable of providing.

Survey the potential for power plant retrofits and changes to operational practices that may enhance power plant flexibility. This survey should contain not only technical information of flexibility measures, but data on the cost and lead time for implementation. Lead time-related information is particularly important for informing procurement timelines and ensuring sufficient flexibility is available to the system in the future.

Characterise the landscape of available technology for deploying new flexible power generation infrastructure or retrofit projects, including plant repowering. Facilitating the deployment of new flexible power generation takes time, with planning and procurement activities beginning years before plants are required.

Box SPM.1 • Flexibility inventory as part of the German electricity market 2.0 process

Against a background of increased flexibility requirements, the German government has undertaken a comprehensive reform of the country's electricity market. In June and July 2016, the Bundestag and the Bundesrat adopted the Acts on the Further Development of the Electricity Market and on the Digitalisation of the Energy Transition. These acts put the rules in place for competition between flexible supply, flexible demand and storage, and also enable innovative business models to be developed for use within the electricity market 2.0. The design of this legislation was accompanied by a comprehensive assessment of the availability and need for different flexible resources. This allowed for the identification of existing, cost-effective sources of flexibility.

Consideration 2 – ENGAGE

Thoughtful and deliberate engagement – both at the domestic and international levels – can help build political, institutional and technical momentum in the transition towards more flexible and modernised power systems. Policy makers can consider a variety of actions for engagement on power system flexibility that fit their specific goals, priorities and available resources. Options include:

Embrace global learning environments for flexibility. International engagement in established forums – such as the Advanced Power Plant Flexibility Campaign and the 21st Century Power Partnership – can help policy makers understand issues quickly, prioritise solutions and implement decisions.

Disseminate assessment results widely to ensure that power system stakeholders understand near- and long-term flexibility needs. Dissemination of accurate and high-quality data facilitates investment decisions and helps maintain sound analysis capabilities among a broader community, including potential investors, academia, research organisations and other advisors to government decision makers.

Facilitate domestic capacity building through international learning and exchange. Many global best practices are emerging in the form of policy solutions, planning practices and decision support tools. Supporting international engagement for ministry, regulatory and utility staff can enhance human capacity and ensure that domestic stakeholders are working cohesively.

Promote domestic analysis by facilitating data sharing and issuing public grants for clean energy research on system flexibility. Policy makers can issue calls for proposals to allow the research and analysis community to directly answer their questions about promoting system flexibility. Analysis activities will not only serve to strengthen human, technical and institutional capacity, but also help inform policy priorities and next steps for policy making.

Convene and participate in domestic and international workshops to share information on and discuss power system flexibility issues and opportunities. Workshops can help raise awareness of system flexibility issues, review analysis and assessment results, advance dialogue around the evolution of market structures, build local capacity, and help enhance investment environments.

Engage directly with power plant operators and original equipment manufacturers (OEMs) to discuss the future flexibility requirements of the power system. Such dialogue can help communicate policy objectives and power system transformation goals to plant owners, highlight power plant flexibility as a potential avenue for performance and revenue improvement, help policy makers understand the requirements of plant operators, and inspire power plant flexibility retrofit concepts from OEMs.

Box SPM.2 • The Clean Energy Ministerial APPF Campaign

The APPF Campaign is a joint initiative of the Clean Energy Ministerial (CEM) Multilateral Wind and Solar Working Group and the 21st Century Power Partnership, with the International Energy Agency acting as the main technical partner. The Campaign is co-led by the governments of the People's Republic of China ("China"), Denmark and Germany, and it brings together 11 additional CEM members – Brazil, Canada, the European Commission, India, Indonesia, Italy, Japan, Mexico, Saudi Arabia, South Africa and the United Arab Emirate – as well 13 industry and non-governmental partners. Through a series of high-level policy events, expert workshops and technical site visits, the APPF Campaign highlights current success stories of power plant flexibility and strategies to unlock power plant flexibility.

Consideration 3 – ENHANCE

Power plant flexibility is one of several factors that contribute to system-wide flexibility. In practice, enhancing system-wide flexibility via operational procedural changes, promoting increased flexibility in load management, organising transmission upgrades or promoting other strategies are also important components of a comprehensive approach to realising system flexibility. Achieving many of these options may reduce the need for additional power plant flexibility and may be more cost-effective than power plant-focused interventions. As informed by assessment exercises, policy makers can pursue a variety of options to boost system-wide flexibility:

Embolden system operators to study the feasibility of "faster" power system operation. By increasing the frequency of how often power plants are scheduled and dispatched, system-wide flexibility can be greatly enhanced while simultaneously increasing overall system efficiency and cost-effectiveness.

Increase communication and coordination between neighbouring balancing areas, potentially through joint operations of day-ahead and real-time energy markets. Access to diverse generation resources over a wider geographic area can reduce the flexibility required from individual power plants. This can be achieved both through increased institutional cooperation and, if appropriate, building additional interconnection infrastructure.

Embolden system operators to transition toward centralised VRE forecasting systems. The more accurately wind and solar power plant outputs can be forecast, the more efficiently and cost-effectively the system can be operated. Using centralised VRE forecasting systems – which integrate state-of-the-art daily, hourly and subhourly forecasts, and insights from meteorological research institutions and individual VRE generators – is an emerging best practice.

Incentivise adoption of technologies that "flexibilise" demand. By adopting market rules which encourage flexible demand and storage deployment and reward them for providing flexibility services, policy makers can help boost system flexibility and reduce the operational requirements of power plants.

Adopt advanced strategies to increase available grid capacity. Targeted investment in high-voltage transmission lines, distribution networks, digital control systems and certain network infrastructure components can help boost system flexibility and reduce operational constraints placed on power plants.

For a more exhaustive discussion of policy and operational approaches to increase system-wide flexibility; see, for example, 21CPP, 2014; IEA, 2014 and IEA, 2017.

Box SPM.3 • Reducing flexibility requirements via improved forecasting systems in Japan

With 6 gigawatts (GW) of installed photovoltaic (PV) capacity, a 16 GW peak load and an 8 GW minimum daytime load, Japan's southernmost- island, Kyushu has the highest VRE penetration of any power system in Japan. Along with developing sophisticated operational strategies to manage the power system, improving solar forecasting has been identified as one of the key goals for reducing system flexibility needs. The power utility Kyushu Electric Power Co. has taken a range of steps to reduce solar forecasting error, and is also working to more accurately account for risks associated with this error during system planning exercises.

Consideration 4 – UNLOCK

Unlocking flexibility in existing generation assets can be a cost-effective solution, but may require policy or regulatory modifications. Measures to unlock flexibility tend to be capital-light in nature, but nevertheless have economic implications. Thus, decisions on specific actions are best informed by assessment activities and, as necessary, cost-benefit analysis. Within that context, the following actions may be considered for unlocking power plant flexibility from existing generation assets:

Review "must-run" requirements for power plants. In some jurisdictions, power plants are granted minimum generation quotas (e.g. China) or fall within government regulations that require plants to operate above a prescribed minimum load factor (e.g. India). Relaxing certain must-run constraints can help unlock latent flexibility in power plants.

Oversee review of electricity and fuel contracts and propel changes that would enhance flexibility. Power plants may be under contract structures that restrict their ability to operate flexibly. Long-term take-or-pay fuel contracts are common in gas- and coal-fired generation, and may serve as an economic disincentive to flexible operation. Generators themselves are also commonly under long-term take-or-pay power purchase agreements (e.g. hydropower, VRE), which lead to a similar disincentive. More flexible contractual arrangements can help unlock flexibility while also leaving headroom for the introduction of lower-cost resources at a later date.

Promulgate rules that allow VRE resources to provide reserves. VRE resources are technically capable of contributing to the reserves of a power system, but uncommonly do so due to a lack of regulatory requirements or economic incentives. Allowing VRE to contribute reserves can help unlock these resources as important contributors to system flexibility, but may require the introduction of a compensation scheme or regulatory requirement for VRE.

Box SPM.4 • Assessing the value of more flexible power purchase agreements for power plants in Thailand

The Thai power system includes features that make it relatively flexible from a technical standpoint, including strong transmission grids and relatively high shares of hydropower and combined-cycle gas turbine generation. However, from an economic standpoint many of these generators are inflexible, operating under take-or-pay power purchase agreements and fuel supply agreements. As an input to the Power Development Plan process in Thailand, the International Energy Agency performed a grid integration study to assess the impact of existing VRE targets on the Thai power system, while also considering the impact of various flexibility strategies, including relaxation of take-or-pay contracts. To that end, it found that long-term annual operational costs could be reasonably reduced if natural gas procurement arrangements and power purchase contracts were made more flexible.

Consideration 5 – INCENTIVISE

Economic incentives experienced by power plants may need to be revised to encourage more flexible generation behaviour. Interventions that cause existing plants to operate more flexibly may result in reduced operating hours and increased wear-and-tear costs from cycling and ramping. These changes may cause financial stress for individual power plants that were designed and financed under different operating assumptions.

With the goal of more fairly rewarding assets for the flexibility services they provide, the interventions below can help not only to unlock latent power plant flexibility, but also to enhance investment signals for new flexible generation resources. Importantly, flexibility remuneration solutions must be adapted to the specific circumstances of each power system and its broader goals. Nevertheless, various approaches are being employed around the world that merit examination and further consideration – and awareness of these solutions is an important first step in the process of adapting and customising them to the unique political, system and market conditions of each power system. In that context, this report offers several options for consideration, organised by market context:

Competitive energy markets

Improve the design of wholesale energy markets. Energy markets can provide price signals that indicate the value of electricity generation in different locations and at different times. Encouraging power plants to participate in energy markets can help to extract flexibility from existing resources by more accurately valuing energy production at different times.

A sudden surge in market prices – for example because of the unexpected failure of a large power plant or a VRE forecast error – will provide a strong incentive for power plants to respond quickly and increase their output or start up. Conversely, in the case of an unexpected surplus of power, market prices can become very low and even negative – a strong economic signal to reduce output. This mechanism, together with the opportunities coming from system services markets (see below), has been a primary economic driver for retrofitting power plants in Europe.

Certain markets also rely on high wholesale market prices during times of scarcity to incentivise new generation capacity. Such "scarcity pricing" creates the incentive for market participants to provide capacity when it is most needed by the system.

Implement market instruments that remunerate all relevant system services. Shifting flexibility requirements in power systems may call for new types of market products that provide appropriate remuneration for system-critical services. This can take the form of competitive procurement from system operators or the establishment of new products that can be traded directly.

Implement capacity mechanisms that value flexibility. Capacity mechanisms remunerate power plants (and, in some cases, flexible demand resources) for their availability to provide energy, serving as a supplement to the payments they receive from selling energy. It may be possible to structure capacity payments around a range of relevant operational parameters of flexibility, including quick-start capability, faster ramp rates, or ramp rate control capabilities.

Regulated markets

Allow cost recovery for retrofit investments. If a proposed retrofit project for a regulated power plant is considered cost-effective and appropriate for the system, regulators can consider allowing retrofit costs to be passed through to ratepayers. Ideally, such regulatory decisions are informed by cost-benefit analysis that evaluates multiple flexibility measures.

Provide financial incentives that encourage new power plants to utilise high-flexibility components. In some cases it may be appropriate to offer direct financial incentives to encourage new power plant investors to use high-flexibility technical components. Paying an incremental incentive upfront may reduce the need for more expensive flexibility investments in the future. In financial terms, spending additional ratepayer or taxpayer funds upfront to ensure flexible technologies are utilised may be considered a hedge against a range of uncertain futures with different flexibility needs and costs.

Box SPM.5 • Establishing a remuneration mechanism for thermal power plants following decreases to minimum generation requirements in China

In response to significant VRE curtailment in certain regions of China, the China National Energy Administration requested that the Electric Power Planning & Engineering Institute conduct research on the pathways for enhancing power system flexibility in the period 2016-20. The study found that nearly 220 GW of thermal power capacity could be retrofitted by replacing old equipment or improving operations to improve flexibility and significantly reduce VRE curtailment rates. The goal of retrofitting some or all of this 220 GW of capacity was codified into China's 13th Five-Year Plan for the power sector. A new revenue stream has been set up in Northeast China to provide an incentive for more flexible operations. Power plants can bid into a new market platform to adjust their output flexibly. The bidding rules in the market are set to give plants the incentive to behave more flexibly, while providing plants with sufficient remuneration to maintain their competitiveness.

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Consideration 6 – ROADMAP

PST is an iterative, multi-year, multi-decadal process. Among other factors, its success hinges on good long-term planning practices. It is an emerging good practice to accompany longer-term PST goals with a long-term system flexibility strategy. In practice this means modifying how system planning is done, both with respect to the decision support tools and methods employed, and the specific questions asked during planning processes. This long-term strategy may also include a review of the alternative risks of developing too much, or too little, flexibility, allowing for the treatment of uncertainty in the process. This report highlights several steps for policy makers to facilitate long-term planning that strives to minimise the economic and operational impacts of PST:

Encourage regularly planned system adequacy assessments to include technical flexibility assessments. It is normal practice for utilities and system operators to regularly assess the reliability and adequacy of their power systems – these assessments often happen at predetermined intervals (e.g. annually) and are often performed in response to specific regulatory requirements.[3] Creating a regulatory requirement to ensure these exercises also include a technical flexibility assessment would help to ensure that system flexibility insights can be used to inform long-term planning exercises.

Facilitate the creation of a comprehensive system-wide flexibility inventory. Assembling a clear picture of options to increase system flexibility – including power plant flexibility measures – helps to ensure that planning exercises are informed by the best possible data on options for the future. To that end, policy makers and regulators can consider requiring the creation (and periodic updating) of system-wide flexibility inventories.

Request the use of state-of-the-art decision support tools for long-term planning exercises. Traditional long-term planning techniques may not consider aspects of flexibility with sufficient detail to consistently propose an adequately flexible and reliable least-cost power system. Incorporating operational modelling methods into long-term planning exercises can help identify more optimal investment plans and uncover specific power plant flexibility characteristics that may be required for the power system in the coming decades.

Encourage the integration of generation and transmission investment planning during long-term planning exercises. While transmission and distribution investments are already considered during most system planning exercises, they are often considered separately from generation investment exercises. However, network investment decisions have strong implications for system flexibility requirements. Policy makers and regulators can help ensure that transmission and distribution planning processes are better integrated with generation planning, particularly as the latter begins to include a more holistic consideration of system flexibility.

Assess the costs and benefits of demand-side resources (DSR) and electricity storage options. DSR and electricity storage options are key hardware and infrastructure components for providing system flexibility. Importantly, they can have an impact on the requirement for power plant flexibility. In long-term planning processes, the costs and benefits of DSR and storage options should be taken into consideration due to their high flexibility potential.

One strategy to address issues of uncertainty during planning exercises is to perform sensitivity analysis where the impact of uncertain factors, such as future fuel prices, VRE deployment,

[3] For example, the South African grid code imposed by the National Energy Regulator of South Africa requires that Eskom (the vertically integrated utility and system operator) publishes a "Medium-Term System Adequacy Outlook" annually, which provides a five-year outlook of the ability of the generation fleet to reliably meet demand.

technology costs and public policy, are explored. The India Greening the Grid Study (GTG, 2017), for example, performed a modelling exercise for a range of likely 2022 VRE deployment scenarios, including scenarios where government VRE targets were both under- and overachieved. Through systematic sensitivity analysis around VRE deployment, the study found that the current system has sufficient flexibility to meet India's 2022 target of 160 GW of VRE.

Box SPM.6 • Using sensitivity analysis to assess the feasibility of India's 2022 renewable energy target

One strategy to address issues of uncertainty during planning exercises is to perform sensitivity analysis where the impact of uncertain factors, such as future fuel prices, VRE deployment, technology costs and public policy, are explored . The India Greening the Grid Study (GTG, 2017), for example, performed a modelling exercise for a range of likely 2022 VRE deployment scenarios, including scenarios where government VRE targets were both under- and overachieved. Through systematic sensitivity analysis around VRE deployment, the study found that the current system has sufficient flexibility to meet India's 2022 target of 160 GW of VRE.

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