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JASON BLACK

# DESIGNING SOLUTIONS IN SYSTEM-FRIENDLY RENEWABLE ENERGY COMPETITIVE PROCUREMENT

## Scaling Up Renewable Energy Project

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# DESIGNING SOLUTIONS IN SYSTEM-FRIENDLY RENEWABLE ENERGY COMPETITIVE PROCUREMENT

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## SYSTEM-FRIENDLY COMPETITIVE PROCUREMENT AS AN OPPORTUNITY TO INCREASE THE SYSTEM VALUE OF ADDED RENEWABLE ENERGY GENERATION CAPACITY

Early experiences with auctions have focused on minimizing generation costs by awarding projects with the lowest tariff per unit of electricity generated. As auction programs mature and the share of variable renewable energy (VRE) in power systems increases, the procurement of renewable energy (RE) with high system value to the power system becomes an important policy objective. The concept of system value goes beyond considering only the power generation costs of an awarded project. System value refers to the contribution of a generation technology to reducing relative system costs for electricity supply.

The integration of increasing shares of VRE creates system challenges. These include the temporal mismatch between VRE generation and demand (its timing), the intermittency of VRE generation (its quality), and the physical distance between VRE generation and demand centers (its location). System-friendly procurement design aims at increasing the system value of VRE by mitigating the adverse effects on the power system's supply adequacy, the requirement for balancing services, and the need for grid infrastructure upgrades or extensions that can result from the inherent characteristics of VRE.

System-friendly design solutions are a tool to achieve certain objectives in both power systems with developed markets and less liberalized ones. In countries with less liberalized power sectors, procurement design elements can create price signals for system services that are otherwise not provided by VRE generation. In more developed markets, these design solutions can coexist with wholesale and ancillary services markets and enable the supply of VRE with power characteristics specially tailored to the procuring entity.

Figure 1 presents an overview of VRE system challenges, resulting system impacts, and design solutions in competitive procurement. Time-based incentives support RE generation that more closely matches the power demand curve. Location-based incentives steer the location of RE projects to specific areas or grid connection points to avoid the concentration of projects in areas that are resource rich but costly to connect. Virtual hybrids,<sup>1</sup> or supply-side aggregators, bundle a portfolio of diverse generation and potential storage assets at different grid connection points, which are dispatched by virtual control systems for the provision of firm and dispatchable power.

Finally, physical hybrids<sup>2</sup> combine technologies such as wind and solar installations and potential storage to offset the technology-specific intermittencies of VRE and allow for a more efficient utilization of land and transmission capacity.

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<sup>1</sup> Virtual hybrids can also incorporate demand response resources in addition to the bundling of power producers and storage units to provide demand- and supply-side flexibility.

<sup>2</sup> Physical hybrids can also combine dispatchable technologies such as biogas/-mass power plants. This paper focuses primarily on the combination of solar and wind installations and potential storage.

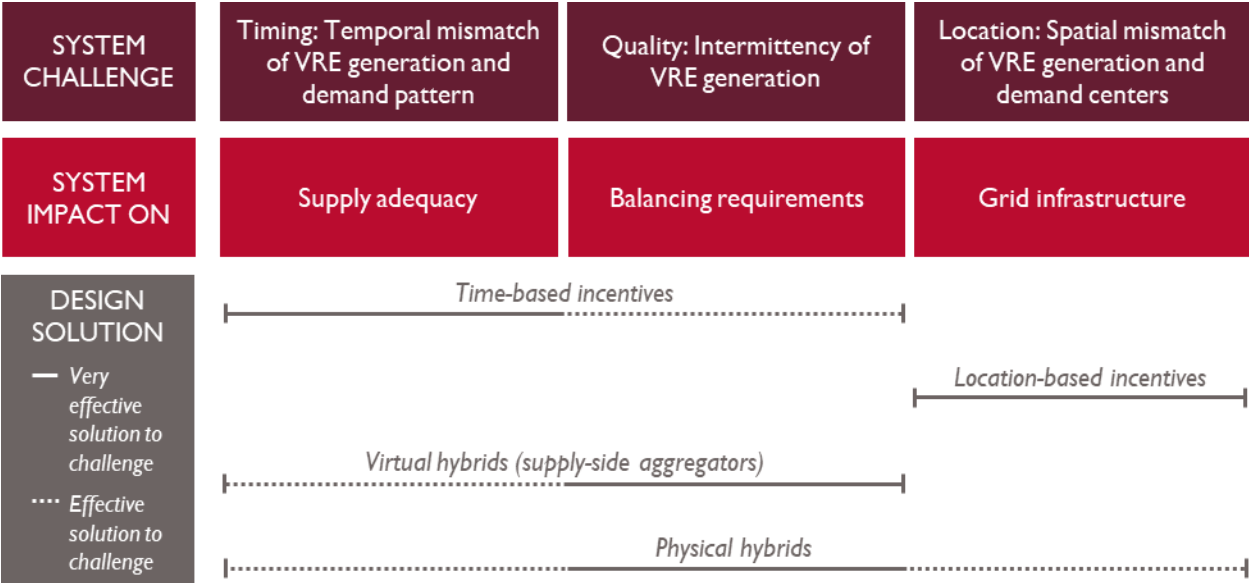


Figure 2. Overview of system integration challenges of VRE and suitability of design solutions

System integration challenges of VRE differ across power systems: countries are well advised to assess the suitability of design solutions for their procurement programs within the broader framework of a national least-cost renewable generation plan and a grid modernization plan that is regularly updated. Indeed, system integration of VRE needs to be combined with measures outside competitive procurement design, such as well-planned grid expansion and upgrade processes, adequate system operation procedures and market practices, as well as power system planning.<sup>3</sup>

As countries plan to increase the share of VRE, power systems need to become more flexible. Such flexibility options relate to grid upgrades and wider balancing areas, demand-side resources, dispatchable generation, and energy storage. Box I illustrates how system integration challenges of VRE and the need for flexibility differ across countries.

**BOX I: SYSTEM INTEGRATION CHALLENGES OF VRE DIFFER ACROSS COUNTRIES**

Which system-friendly competitive procurement solutions suit a country depends on specific power system characteristics, such as demand patterns, generation fleet, transmission infrastructure, and the share of RE in the power mix.

**Power Demand Growth:** Countries experiencing a strong increase in power demand, which often occurs in developing countries, will likely prioritize RE contribution to supply adequacy as they require additional firm generation capacity to meet growing peak demand. In contrast, countries with a rather constant or less strong growth in power demand, often industrialized countries, will likely prioritize procurement elements that mitigate the intermittency of VRE generation to reduce the flexibility needed for the residual power system.

**Power System Flexibility:** Countries with higher shares of baseload generation, such as coal, typically have lower flexibility in their power fleet than those countries where gas or large-scale reservoir hydropower plays a more prominent role as those technologies can adjust their power generation faster to the intermittent generation of VRE.

<sup>3</sup> “Grid Integration Toolkit,” Greening the Grid, <https://greeningthegrid.org/Grid-Integration-Toolkit/quick-reads>.

## BOX 1: SYSTEM INTEGRATION CHALLENGES OF VRE DIFFER ACROSS COUNTRIES (CONTINUED)

In countries with a single-buyer power market, often developing and emerging countries, specifications in power purchase agreements (PPAs), such as the definition of minimum load levels above what would otherwise be technically feasible, can lower the flexibility of the dispatchable generation fleet. Large countries or countries that are interconnected well with neighbors can profit from spatial smoothing effects over larger geographical areas to address balancing and supply adequacy.

**RE Share in Power System:** System challenges associated with the deployment of VRE described above increase with the share of VRE in the annual power supply. Hence, the importance of system-friendly design elements within RE procurement increases with a higher share of VRE.

## INCREASING THE MATCH BETWEEN THE TIMING OF VRE GENERATION AND POWER DEMAND

System-friendly competitive procurement can enable a better temporal match between VRE generation and power demand. The generation of VRE is weather dependent, resulting in variable seasonal and intraday patterns. Hence, VRE electricity is often delivered when it is abundant instead of when it is most needed during evening peak demand periods (“timing” challenge). This temporal mismatch is less relevant in countries or regions where peak power demand coincides with the generation profile of VRE resources. For example, in Germany solar PV installations deliver power during the day at times when demand is at a peak.<sup>4</sup>

This system challenge affects the power system’s supply adequacy, which is the ability of the power system to meet power demand reliably during all hours of the year. Procuring more dispatchable, low-cost RE to meet demand, including peak demand periods, can help address this challenge. Options to incentivize the procurement of more dispatchable RE include time-based incentives, such as price adjustment factors and supply blocks.

Time-of-day and time-of-year price adjustment factors are designed to reward or punish electricity generation supplied at specific times of the day or year. The adjustment factor is typically applied to the actual price paid to the producers and not to the bid price offered. By increasing or decreasing the price paid per kilowatt hour (kWh) of generation, energy policy planners seek to reward supply that more closely matches demand. Price-adjustment factors have been introduced, for example, in competitive procurement programs in the state of California and the emirate of Abu Dhabi (see Box 2 and Box 3).

### BOX 2: TIME-OF-DAY ADJUSTMENT FACTORS IN CALIFORNIA

California’s Renewable Auction Mechanism, implemented between 2011 and 2015, defined three “product types” of electricity to be procured:<sup>5</sup>

- “Peaking as-available” for technologies with a diurnal generation profile such as solar PV
- “Non-peaking as available” for technologies with low or negative correlation with the demand profile such as wind and small-scale hydro
- “Baseload,” including dispatchable plants such as geothermal and biomass

PPA contracts provided a fixed price per unit of production \$/MWh, adjusted by time-of-day factors to reward generation that is produced at times of peak demand. The power procured under the program supported the three largest investor-owned utilities in the state of California in the achievement of their Renewable Portfolio Standards goals. However, since 2017 the three main investor-owned utilities in California defined time-of-use rates from 4 p.m. to 9 p.m. to reflect the shift in peak demand from the afternoon to the early evening.<sup>6</sup>

<sup>4</sup> “Recent Facts about Photovoltaics in Germany”, Fraunhofer ISE,

<https://www.ise.fraunhofer.de/content/dam/ise/en/documents/publications/studies/recent-facts-about-photovoltaics-in-germany.pdf>

<sup>5</sup> “Auctions for Renewable Support in California: Lessons Learnt,” AURES,

[http://auresproject.eu/sites/aures.eu/files/media/countryreports/pdf\\_california.pdf](http://auresproject.eu/sites/aures.eu/files/media/countryreports/pdf_california.pdf).

<sup>6</sup> “Time Matters – Frequently Asked Questions”, Energy Upgrade California, <https://www.energyupgradeca.org/time-of-use-faqs/#:~:text=The%20peak%20demand%20period%20is,of%20business%20during%20this%20time>

### BOX 3: TIME-OF-YEAR ADJUSTMENT FACTORS IN ABU DHABI

In 2016, the Abu Dhabi Water & Electricity Company (ADWEA) conducted a site-specific solar auction, yielding bid prices as low as \$24.2/MWh. For electricity delivered between June and September, when Abu Dhabi's generation fleet struggles to meet the seasonal demand due to an increased air-conditioning demand, successful bidders receive a remuneration that is 1.6 times higher than for electricity delivered from October to May. According to 2017 statistics from the International Renewable Energy Agency (IRENA), the 60 percent markup on tariffs applied during the summer months corresponds to a 20 percent higher remuneration overall.<sup>7</sup>

**Supply blocks** require producers to guarantee continuous delivery of electricity during certain periods or otherwise face penalties. Time-specific supply blocks limit the supply commitments of VRE installations to the times of day or year when they effectively generate electricity.<sup>8</sup> Box 4 presents an “implementation checklist” with key factors that enable the implementation of time-based incentives.

### BOX 4: IMPLEMENTATION CHECKLIST FOR TIME-BASED INCENTIVES

**Information on Power System Characteristics:** Current and projected hourly/seasonal demand and generation patterns, at the transmission level.

The system operator and the procuring entity rely on **information that is accurate and updated** as demand and generation patterns change.

Chile implemented supply blocks in its 2017 competitive procurement round to guarantee a continuous supply of electricity to distribution companies, while allowing bidders to choose the timeframe for their supply commitments. The experience in Chile also highlights the importance of having a coordinated approach to planning transmission grid upgrades and RE development through competitive procurement. The curtailment of solar and wind generation reached 14 percent between 2015 and 2017, among the highest in the world.<sup>9</sup>

A considerable share of VRE generation was lost partly because the existing grid infrastructure did not keep pace with solar and wind growth. Following the commissioning of two transmission lines in 2018 and 2019, curtailment decreased to an average of two percent.<sup>10</sup> A continued expansion of the transmission grid and the launch of an ancillary services market are part of Chile's strategy to integrate increasing shares of VRE.

<sup>7</sup> “Renewable Energy Auctions,” International Renewable Energy Agency (IRENA), [https://www.irena.org/media/Files/IRENA/Agency/Publication/2017/Jun/IRENA\\_Renewable\\_Energy\\_Auctions\\_2017.pdf](https://www.irena.org/media/Files/IRENA/Agency/Publication/2017/Jun/IRENA_Renewable_Energy_Auctions_2017.pdf).

<sup>8</sup> “Renewable energy auctions. A guide to design”, International Renewable Energy Agency (IRENA), [https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/Jun/IRENA\\_Renewable\\_Energy\\_Auctions\\_A\\_Guide\\_to\\_Design\\_2015.pdf](https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/Jun/IRENA_Renewable_Energy_Auctions_A_Guide_to_Design_2015.pdf).

<sup>9</sup> “Grid merger: Chile curbs curtailment, stabilizes prices,” BloombergNEF, <https://about.bnef.com>, 2020.

<sup>10</sup> Ibid.



**TABLE I. INTRADAY AND SEASONAL SUPPLY BLOCKS IN CHILE**

DESIGN	<p>Distribution companies provide demand projections for the next ten years for energy, reactive power, and peak demand. The regulator aggregates the projected supply requirements and conducts the competitive procurement.</p> <p>The supply blocks consist of three intraday (12–8 a.m. + 11 p.m.–12 a.m.; 8 a.m.–6 p.m.; 6–11 p.m.) and four, three-month seasonal blocks. Each of the blocks has a base (annual energy requirement) and a variable component (10 percent of the base component). Generators can submit bids from a single project or a portfolio of projects.</p> <p>Supply blocks transfer generation risks to the RE producer, and production deviations are settled at spot market prices. Hourly and seasonal supply blocks allow RE producers to concentrate their contractual commitments to the times of the day or year when they effectively generate electricity.</p>
RESULTS	<p>The competitive procurement successfully contracted the hourly and quarterly electricity requirements of distribution companies. Awarded bids, all of which are backed by new RE projects, will provide continuous power within the defined block at an average cost of \$32.5/MWh—the lowest price ever recorded in the country. As a reference, the average spot market price in 2017 was considerably higher, roughly \$55.1/MWh in the Central Interconnected System (SIC) and \$57.4/MWh in the Norte Grande Interconnected System (SING).<sup>11</sup></p> <p>Bids from solar projects were the most competitive at \$21.5/MWh, followed by wind at \$32.9/MWh. This result allows distribution companies to receive electricity at a lower cost than with thermal technologies, which had the second highest average bid prices submitted at \$75.4/MWh, after biomass at \$77.9/MWh. Bids from solar with battery storage averaged \$36.5/MWh. Although a very competitive result, these bids were not awarded due to restrictions specified by the bidders.</p> <p>Competitive procurement effectiveness will also depend on the timely commissioning of the contracted projects and the actual delivery of electricity in the defined blocks. The six-year project realization period means projects need to be commissioned by January 2024. Therefore, an assessment of the project’s success or failure currently is not possible.</p>

Virtual hybrids (supply-side aggregators) and, to some extent, physical hybrids also can be suitable measures to address supply adequacy. Virtual hybrids can enable the shifting of VRE supply to cover peak demand periods in the evening through a portfolio that combines different generation and storage assets. By combining solar and wind, physical hybrids can partially contribute to supply adequacy by extending the supply period a plant can guarantee. If combined with storage or dispatchable RE such as biomass, physical hybrids’ contribution to supply adequacy can be similar to that of virtual hybrids.

<sup>11</sup> Until November 2017, there were two large interconnected grid systems Chile that are since interconnected: The Central Interconnected System (SIC) and the Norte Grande Interconnected System (SING), in addition to the Medium Systems (SSMM) of Aysén and Magallanes. “Anuario estadístico de energía”, Comisión Nacional de Energía (CNE), <https://www.revistaenergia.com/wp-content/uploads/2018/06/AnuarioCNE2018.pdf>.

## REDUCING THE INTERMITTENCY OF VRE GENERATION

System-friendly competitive procurement can reduce the intermittency of VRE generation. The highly intermittent resource availability of VRE leads to variable electricity generation, which in turn increases the variability of the residual or net load. The residual load refers to the portion of the current power demand that is left after subtracting the output of VRE sources. A more variable residual load demands more frequent and flexible cycling and ramping of conventional power plants. Although VRE generation can be forecasted, some uncertainty in forecasts remains (“quality” challenge).

These system challenges affect the power system’s balancing requirements—day-ahead forecasting errors and short-term variability of RE output cause intraday adjustments, requiring the operation of a flexible residual system and reserve capacities that can respond within seconds to minutes. By procuring firm generation capacity via virtual hybrids (supply-side aggregators) or physical hybrids, the need for balancing in the system can be reduced.

Virtual hybrids that bundle diverse VRE and dispatchable RE generation and potential storage assets at different grid connection points aim to provide a firm and dispatchable generation capacity. Fluctuations in the generation of a single VRE plant included in the virtual hybrid can be balanced by ramping up and down power generation of dispatchable generation and storage units and the output complementarity and spatial smoothing effects of VRE resources sited in different locations. Box 5 presents an “implementation checklist” with key factors that enable the implementation of virtual hybrids.

### BOX 5: IMPLEMENTATION CHECKLIST FOR VIRTUAL HYBRIDS

#### Regulatory Framework:

- Option A: Virtual hybrids are allowed to participate in a wholesale power market and/or ancillary services market.
- Option B: RE generators are responsible for forecasting and committing to forecasted generation. The virtual hybrid would offer forecasting and power trading services to reduce transaction costs for individual power plants.
- Option C: Larger consumers can choose virtual hybrids as power suppliers (corporate PPAs).

**Metering Infrastructure:** Real-time communication between the VPP operators and assets is needed.

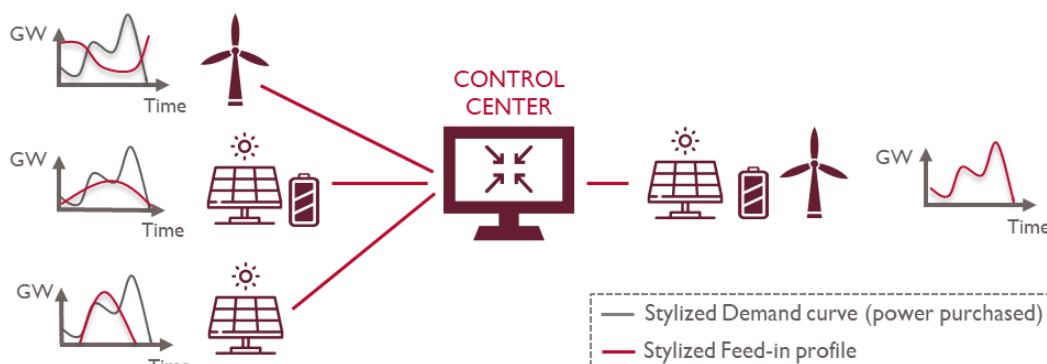


Figure 3. Simplified representation of a virtual hybrid

The virtual power plant (VPP) Next Kraftwerke in Germany bundles intermittent VRE and other energy generation, storage, and demand-side resources in a portfolio to provide balancing energy services.

### BOX 6: VIRTUAL POWER PLANT NEXT KRAFTWERKE IN GERMANY

The virtual power plant Next Kraftwerke in Germany has a portfolio of around 8,700 assets that include solar PV, batteries, combined heat and power (CHP), biogas, hydro, emergency generators, and customer loads.<sup>12</sup> Since 2012, RE producers can participate in the balancing energy market in Germany. The products procured by the grid operator are primary reserve (delivered within 30 seconds), secondary reserve (delivered within 5 minutes), and tertiary reserve (delivered within 15 minutes and up to 1 hour).

As of 2016, Next Kraftwerke provided aggregated power of 67 MW as primary reserve, 67 MW as secondary reserve, and 1,160 MW as tertiary reserve,<sup>13</sup> thereby reducing the provision of these products by thermal generation. These balancing energy products are supplied by biogas and hydropower installations, emergency generators (using diesel), and CHP plants.<sup>14</sup>

Physical hybrids can reduce the intermittency of power output for the same hour throughout the year compared to single-technology wind or solar PV plants. A more stable and firm electricity feed-in can reduce grid integration costs by reducing the need for extensive cycling of conventional power plants to meet residual load and balance out VRE forecast errors. Box 7 presents an implementation checklist with key factors that enable the implementation of physical hybrids.

### BOX 7: IMPLEMENTATION CHECKLIST FOR PHYSICAL HYBRIDS

**Resource Availability:** Identification of sites with both adequate wind and solar resources and land availability.

**Regulatory Framework:** If RE producers bear grid connection costs, these are likely priced into their bids. Grid connection cost savings resulting from a higher utilization of common grid infrastructure, compared to wind-only or solar PV-only installations, can increase the price competitiveness of physical hybrids.

Physical hybrids in India currently aim at an efficient utilization of land (i.e., MWh/m<sup>2</sup>) and grid connection capacity (i.e., MWh/MW), as well as reduction in the intermittency of VRE generation to increase grid stability and reduce residual load following costs.

<sup>12</sup> “Navigant Research Leaderboard: VPP Platform Providers, Assessment of Strategy and Execution for 15 Companies Leaderboard: VPP Platform Providers,” Navigant Research, 2020.

<sup>13</sup> “Presentation at Buergerdialog Stromnetz”, Next Kraftwerke, <https://www.buergerdialog-stromnetz.de/assets/Uploads/Prasentation-Next-Kraftwerke-GmbH.pdf>

<sup>14</sup> “Products - Power producers”, Next Kraftwerke, <https://www.next-kraftwerke.de/virtuelles-kraftwerk/stromproduzenten>

**TABLE 2. SOLAR-WIND PHYSICAL HYBRIDS IN INDIA<sup>15</sup>**

DESIGN	<p>The competitive procurement organized by the Solar Energy Corporation of India (SECI) for solar-wind hybrid projects in 2019 focused on a minimum generation requirement, coupled with penalties.<sup>16</sup> The minimum generation requirement was defined in the form of a capacity utilization factor (CUF)<sup>17</sup> of at least 30 percent. Penalties applied if the actual generation fell below 90 percent or above 20 percent of the declared CUF. If SECI decided to off-take excess generation beyond the 120 percent CUF threshold, it could do so at the full PPA tariff.</p> <p>In October 2019, India issued new draft guidelines for its solar-wind hybrid procurement.<sup>18</sup> While the minimum CUF remains at 30 percent, bidders can now revise the CUF defined at the time of signing of the PPA during the first three years of operation. This supports compliance with the CUF by allowing bidders to consider plant performance and better site measurements during plant operation.</p> <p>India has also implemented the competitive procurement of physical hybrids in combination with time-based incentives. SECI held an auction in 2019 for hybrids with assured peak power supply.<sup>19</sup> Successful projects receive a peak and an off-peak tariff. Energy generated during off-peak hours (9:01 a.m.–6 p.m. and 12:01–5:59 a.m.) will be remunerated with a flat, administratively set, off-peak tariff payment of 2.70 INR/kWh (\$35.9/MWh). For energy generated during peak hours (6–9 a.m. and 6 p.m.–12 a.m.), producers will be remunerated with a peak tariff determined through competitive procurement.</p>
RESULTS	<p>In the first competitive procurement round held at the central level in 2018, SECI awarded 840 MW split between two projects at 2.67 INR (\$35.5/MWh<sup>20</sup>) and 2.69 INR/kWh (\$35.7/MWh).<sup>21</sup> In the second round, held in 2019, SECI awarded a 600 MW project at 2.69 INR/kWh (\$35.7/MWh), and a 120 MW project at 2.70 INR/kWh (\$35.9/MWh).<sup>22</sup> Solar PV generation was contracted for as low as 2.50 INR/kWh (\$33.2/MWh) in 2019,<sup>23</sup> and wind for 2.51 INR/kWh (\$33.3/MWh) in 2018.<sup>24</sup> In comparison, the National Thermal Power Corporation (NTPC) reported an average cost of generation of 3.42 INR/kWh (\$45.4/MWh) in 2018, with a large majority of its operational capacity based on coal- and gas-based power plants.<sup>25</sup></p> <p>Currently, grid connection costs are not charged to RE producers in India. Instead, grid connection costs are socialized, that is they are passed on to the consumer. Therefore, RE producers are not yet compensated for the system value of hybrid installations. From 2022 onwards, RE producers will be required to pay for grid connection costs. The system value of physical hybrids would be priced in and compensated, making hybrid projects more competitive with single PV and wind installations that also need to pay for grid connection costs.</p>

The intermittency of VRE generation increases the variability of the residual load. Time-based incentives can, to some extent, reduce the intermittency of VRE generation and therefore the need for ramping of conventional power plants. The intermittency of VRE causes other conventional power plants to be more flexible by requiring them to more quickly ramp power up and down and operate at lower output levels. By incentivizing the supply of electricity when it is most valuable to the system, tariff adjustments or supply blocks can help reduce the residual load to be met by load-following generators. VRE installations combined with batteries allow the bulk shifting of RE power for a better load following.

<sup>15</sup> “System-friendly competitive renewable energy procurement in India,” USAID, 2019.

<sup>16</sup> “Request for Selection (RfS) Document for setting up of 2500 MW ISTS-connected Wind-Solar Hybrid Power Projects (Tranche-I),” SECI, 2018.

<sup>17</sup> A capacity utilization factor (CUF) refers to the ratio of the actual output from a plant over a year to the maximum possible output under ideal conditions.

<sup>18</sup> Ministry of Renewable Energy, <https://www.india.gov.in/website-ministry-new-and-renewable-energy>.

<sup>19</sup> Solar Energy Corporation of India, [https://seci.co.in/web-data/docs/tenders/RFS%20for%201200%20MW%20RE%20Projects%20with%20Peak%20supply\\_final%20upload.pdf](https://seci.co.in/web-data/docs/tenders/RFS%20for%201200%20MW%20RE%20Projects%20with%20Peak%20supply_final%20upload.pdf).

<sup>20</sup> 1 USD = 75.3 INR as of June 10, 2020. Source: Oanda Currency Converter

<sup>21</sup> “India’s First Mega Solar-Wind Hybrid Auction Sees Lowest Tariff of ₹2.67/kWh Prateek,” MERCOM India, <https://mercomindia.com/seci-solar-wind-hybrid-auction-results/>.

<sup>22</sup> “Tariffs remained unchanged in hybrid auction,” India Times, <https://economictimes.indiatimes.com/industry/energy/power/adani-green-energy-renew-power-only-bidders-in-hybrid-auction/articleshow/69420860.cms>.

<sup>23</sup> “SECI’s 750 MW Solar Auction for Rajasthan Sees Lowest Tariff of ₹2.50/kWh,” MERCOM India, <https://mercomindia.com/seci-750-solar-auction-rajasthan/>.

<sup>24</sup> “₹2.51/kWh Wins SECI 2 GW ISTS Wind Auction,” MERCOM India, <https://mercomindia.com/seci-2gw-wind-auction/>.

<sup>25</sup> “Mahindra Susten Emerges as Lowest Bidder in NLC India’s 20 MW Solar with BESS Auction,” MERCOM India, <https://mercomindia.com/mahindra-ii-bidder-20mw-bess-nlc-auction/>.

## CLOSING THE GAP BETWEEN VRE AND GRID INFRASTRUCTURE DEVELOPMENT

System-friendly competitive procurement can reduce the gap between where power is fed into the grid (at the best RE resource sites) and where it is needed (demand centers). Good RE resources are often located far away from demand centers; thus, RE installations are often built where physical resources and land availability are highest (“location” challenge).

This system challenge can have an impact on the grid infrastructure. Scaling up RE often requires grid expansion and enforcements to access high-quality solar and wind resources remote from the existing transmission grid. In addition, a geographic concentration of RE deployment may cause congestion in the transmission grid, leading to increased curtailment rates of RE. At the same time, grid development can be expensive and requires a well-planned, multiyear process.

**Location-based incentives** aim at steering the location of projects to specific areas and grid connection points to avoid the concentration of projects in areas that are resource rich but costly to connect. Figure 4 shows the different ranges of location-based incentives. The signal provided by these mechanisms can be based on price or quantity. They include a bonus/penalty for bids located in areas with available/insufficient grid capacities (e.g., Mexico), RE development zones (REDZ) with simpler permitting processes (e.g., South Africa, Philippines), capacity quotas at the regional or grid connection point level (e.g., Kazakhstan, planned design in Vietnam), or site-specific competitive procurement (e.g., Bangladesh).

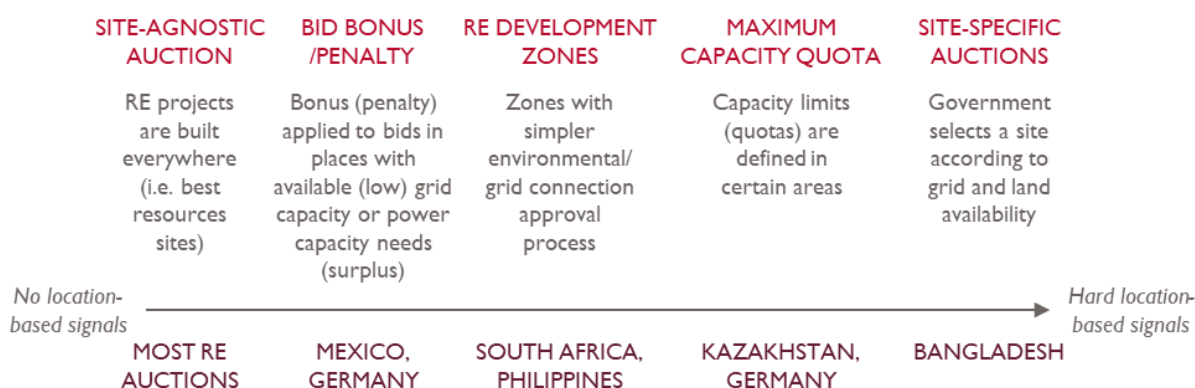


Figure 5. Competitive procurement and range of location-based incentives

### BOX 8: IMPLEMENTATION CHECKLIST FOR LOCATION-BASED INCENTIVES

#### CAPACITY QUOTAS

**Information on Power System Characteristics and Project Planning:** Identification of potential substations with available capacities (or where minimal upgrades would be needed), adequate solar RE resources, and suitable land around the substations. Forecast of power demand in the surrounding region to anticipate future system needs.

#### BID BONUS/PENALTY

**Information on Power System Characteristics:** In its simplest form, a bid bonus or penalty can be defined based on the difference in grid investment costs required to connect a RE generator between two regions or areas. This approach does not account for grid congestion costs caused by VRE in the system, as it is limited to the grid connection only.

Kazakhstan defined capacity quotas at multiple nodes of the system to minimize new transmission costs and ensure the system could absorb the electricity generation resulting from the auction. The power system in Kazakhstan has surplus generation capacity.

**TABLE 3. CAPACITY QUOTAS IN KAZAKHSTAN**

DESIGN	<p>The auction documents contain information on the land plots allocated for the construction of RE installations and grid connection points indicating the maximum permissible capacity and the number of possible connections. The grid connection points are provided by the transmission grid operators to the Ministry of Energy and are reserved until the winning bidders conclude a grid connection agreement. Bidders also need to specify the minimum permissible volume of installed capacity for their installation with their bid.</p> <p>If the volume of bids exceeds the maximum permissible capacity at this connection point, bids will be excluded from the preliminary list of winners in the descending order of prices until the maximum permissible installed capacity for the connection point is met. A partially satisfied bid, that is, a bid whose capacity is only partly covered within the maximum permissible capacity, will be awarded if the reduced volume of partially satisfied bids is greater than or equal to the minimum permissible volume of the bid.</p>
RESULTS	<p>The competitive procurement in Kazakhstan contracted 857.93 MW of RE projects that will be located at nodes with sufficient grid capacities to help minimize the need for grid expansion. More than half of the volume awarded went to wind projects (500.9 MW), followed by solar (270 MW), hydro (82.1 MW), and one 5 MW project for biogas. The lowest awarded bids were for hydro (\$35/MWh), wind (\$47/MWh), and solar (\$49/MWh). Seven rounds (out of 20) were canceled because of an insufficient number of participants and offered volume. Public information on how many bids were excluded or partially awarded due to the capacity quotas is not available.</p>

Physical hybrids can result in a more efficient use of land and grid infrastructure per unit of VRE generation. By using a common grid connection infrastructure, physical hybrids can help reduce grid connection and transmission costs. Moreover, co-locating solar PV and wind installations by, for example, installing solar PV panels in the shadow-free area available around wind turbines, could reduce the pressure to find suitable land. However, this is subject to enough availability of sites with both good wind and solar resources.

Planning transmission grid upgrades and RE development through competitive procurement should run in parallel. The suitability of physical hybrids, including those with storage, should be assessed in light of the costs of expanding the transmission grid to connect the installation. Grid modernization is a multi-year process that often requires substantial investments. Steering RE development to areas close to demand centers, rather than developing areas with good solar and wind resources, can therefore have a higher system value. An optimization model that finds the least-cost investment and dispatch solution over a 20-year planning horizon, for example, can help policymakers assess the suitability of design solutions and measures outside competitive procurement programs, to minimize system costs.

## KEY TAKEAWAYS FOR POLICYMAKERS

Generation costs alone do not reflect the costs of integrating VRE generation into the power system. Competitive RE procurement with system-friendly design elements considers RE power characteristics that reduce the system costs for electricity supply in the award decision.

System-friendly design solutions are a tool to achieve certain objectives in both power systems with developed markets and less liberalized ones. Which system-friendly design solutions suit a country depends on power system characteristics, such as the demand patterns, the existing generation fleet, the transmission infrastructure, and the share of RE in the power mix.

### TIME-BASED INCENTIVES

#### SOLUTION

Time-based incentives encourage electricity generation from VRE during peak demand and can, therefore, support supply adequacy (“timing” challenge of VRE) and, to some extent, reduce the balancing requirements from conventional generators (“quality” challenge of VRE).

#### APPLICATION

Information required to calculate time-based incentives includes the current and expected future hourly load of the system, as well as the current and expected future availability of generation capacity and its expected daily and seasonal generation patterns. Procuring entities can use this information to define peak and off-peak supply periods, for which tariff adjustments (for time-of-delivery commitments) or penalties (for supply shortages in the case of supply blocks) apply.

### LOCATION-BASED INCENTIVES

#### SOLUTION

Location-based incentives introduce price- or quantity-based signals in the auction to steer the location of projects to specific areas or grid connection points to avoid the concentration of projects in areas that are resource rich but costly to connect (“location” challenge of VRE).

#### APPLICATION

Required planning by the relevant authorities for project-specific auctions or the use of capacity quotas includes the identification of potential substations with available capacities (or where minimal upgrades would be needed), good RE resources, and suitable land around the substations. This should be supplemented with a forecast of power demand in the surrounding region to anticipate future needs of the system.

## VIRTUAL HYBRIDS

### SOLUTION

Virtual hybrids (supply-side aggregators) reduce the need for balancing requirements for the residual system (“quality” challenge of VRE) and enable time-shifting of VRE generation to peak demand periods (“timing” challenge of VRE).

### APPLICATION

The implementation of virtual hybrids requires the existence of a wholesale power market or a more liberalized power sector that allows large consumers to choose virtual hybrids as their power suppliers (corporate PPAs). Moreover, if RE generators are responsible for forecasting and committing to forecasted generation, a virtual hybrid could offer forecasting and power trading services to reduce the transaction costs for individual power plants.

## PHYSICAL HYBRIDS

### SOLUTION

Physical hybrids can reduce the intermittency of electricity generation compared to single-technology wind or solar PV plants (“quality” challenge of VRE). They also enable grid connection cost savings from a higher utilization of common grid infrastructure (MWh/MW) by co-locating solar with wind capacities (“location” challenge of VRE). Moreover, physical hybrids support supply adequacy by extending the installation’s supply period, compared to single-technology wind or solar PV plants (“timing” challenge of VRE).

### APPLICATION

The implementation of physical hybrids requires the identification of sites with both adequate wind and solar resources and land availability. In addition, if RE producers bear grid connection costs, these will likely be priced into their bids. Grid connection cost savings resulting from a higher utilization of common grid infrastructure, compared to wind-only or solar PV-only installations can increase the price competitiveness of physical hybrids.

## MEASURES BEYOND COMPETITIVE PROCUREMENT DESIGN

**System integration of VRE goes beyond competitive procurement design.** In countries planning to increase the share of VRE, power systems need to become more flexible. Such flexibility options relate to electricity transmission between regions, demand-side integration, dispatchable generation, and energy storage.

**Planning transmission grid upgrades and RE development through competitive procurement should run in parallel.** Countries are well advised to assess the suitability of design solutions for their procurement programs within the broader framework of a national least-cost renewable generation plan and a grid modernization plan that is regularly updated.



**Design solutions are not a substitute for market mechanisms but a tool to procure RE power with specific characteristics.** Well-designed ancillary services markets, good forecasting, and shorter time intervals between gate closure and dispatch can reliably and more cost efficiently supply the ramping capacities needed to address the intermittency of VRE. The costs of remunerating hybrid installations, including those with storage, or using time-based incentives should be assessed in light of the role markets can play in the delivery of ancillary services.