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How Can Energy Storage Catalyze the Electricity Policies of Gulf Cooperation Council Members? Issues and Options

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1. Introduction

Saudi Arabia and other Gulf Cooperation Council (GCC) members are working in parallel to reform their electricity markets and achieve ambitious renewable energy deployment goals (Appendix Sections 1 and 2). The motivation for this agenda is multifaceted, and increasing economic efficiency is one of several reasons for these efforts. By introducing markets in the power sector (i.e., liberalizing this sector), these countries aim to reduce the sector's reliance on the public budget. The private sector can finance generation and network expansion and reduce electricity prices. In turn, these countries can rationalize their domestic fuel prices. Furthermore, renewable energy generation can help GCC countries to reduce emissions and develop clean energy industries. They can also mitigate the impacts of rising domestic oil and gas demand on their economies and boost their hydrocarbon exports (Dyllick-Brenzinger and Finger 2013).

However, countries simultaneously transitioning to both markets and the greater use of renewables face market design and regulatory issues. These parallel agendas may be difficult to reconcile; renewables targets may complicate the market-based reform process (Blazquez et al. 2018; Keay 2016; Poudineh, Sen, and Fattouh 2020). This challenge may imply a potential incompatibility that may undercut both policies' objectives. Initial electricity market designs are evolving to handle renewable energy mandates, but no consensus on the appropriate process has been reached.

This study analyzes the implications of deploying new energy storage in this context. Storage technologies are rapidly reducing costs and improving performance (BNEF 2020). Additionally, research and development (R&D) investments in storage are a public good, and developing a clean energy industry is an important part of industrial policy. Although storage services can facilitate the integration of renewables and market restructuring policies, deploying this novel technology raises additional regulatory issues. Energy storage plays various roles in the electricity supply chain by providing both regulated and market-based services (see Appendix Section 1). For example, storage is currently regarded as a consumer when charging and as generator when discharging power. Thus, storage is at risk of making duplicate payments for network use. Additionally, the definition of balancing services, which storage can help to provide, is evolving.

To address these multiple aspects of storage, rethinking overall electricity market design in the context of greater deployment of renewables may be necessary. No off-the-shelf electricity market design is applicable to GCC countries given their policy priorities and current context. Standard market designs are end states, and the pathways to achieving them have not necessarily been defined. Thus, Saudi Arabia and its regional partners have an opportunity to develop new market structures. They can design harmonious market reforms and renewables policies considering the newest available technologies. Regardless of the direction of this market design, however, it will have important consequences on the deployment and use of storage facilities. These consequences, in turn, will affect the overall success of the energy transition.

1. Introduction

The main public policy implications of our analysis of energy storage in the GCC context are:

> As technologies, markets and power systems evolve, regulatory rules and market designs must be revisited to ensure that they accomplish policymakers' objectives.

> Storage technologies can cost-effectively integrate renewables when combined with other options, such as demand response and transmission investments.

> If storage is properly deployed, it can also reduce transmission congestion, enhance regional electricity trading and reduce supply costs.

The remainder of the paper is structured as follows. Section 2 discusses regulatory challenges that may arise with the deployment of storage. Section 3 presents ways that storage can help GCC countries achieve their various political economy objectives and identifies potential trade-offs between several options. Section 4 concludes and offers key policy implications.

2. Regulatory and Market Design Issues

This section explores the regulatory and market design issues that will arise in any country when storage is incorporated in the power sector. We discuss electricity market design, transaction costs and electricity market reforms.

2.1. Electricity markets are "manufactured" markets

Electricity markets are designed markets; they do not develop organically (Felder 2020). A regulatory implication of this fact is that "designed" markets do not naturally change to integrate potentially disruptive technologies, such as storage or renewables. When disruptive technologies emerge, the existing market model may require recalibration or even redesign to support these technologies' adoption and achieve policymakers' desired outcomes. This challenge is not exclusive to storage technologies. However, for any technology, it calls for revisions to current designs, and additional elements may be needed to avoid undercutting market outcomes.

Creating a new market is difficult. Electricity market design draws on expertise from economics, operations research, engineering and computer science. With these tools, a designer conceives of a market structure and rules to provide consumers with reliable electricity at the least cost. This aim can be achieved by incentivizing decisions that lead to short-run and long-run efficiency. These two types of efficiency can be thought of as making the best use of existing resources and promoting efficient investments in new resources.

Electricity markets are becoming increasingly complex owing to unique physical characteristics of electricity that do not exist in other markets and the underlying economics (Felder 2020). Any electricity market design should be able to produce price signals to guide efficient operations and investments across several market components. The energy component of the electricity market includes the day-ahead, real-time and forward energy markets. Additionally, other products in this market include ancillary services, flexibility, reliability, capacity and green certificates.

Electricity market design has another inherent limitation. According to neoclassical economic theory, an input's remuneration should equal the value of the output produced by an additional unit of that input (i.e., the value of input's marginal product). As a corollary, this remuneration leads to the efficient deployment of all available technologies. Because electricity markets are engineered, however, even benevolent market designers may determine compensation for each technology, possibly by omission, based on limited information.

This limitation affects the provision of storage. For instance, flat retail prices reduce the incentive for storage on the distribution system. A lack of access to hourly or five-minute prices on the wholesale level also hinders storage. As such, these investments are subject to a version of the Averch-Johnson effect; over-remunerated technologies are over-deployed, and under-remunerated technologies are under-deployed (Averch and Johnson 1962). Rapidly evolving storage and other power system technologies will only compound the problem of incomplete information for policymakers.

This issue is relevant because the owners of storage in an electricity market earn revenue through arbitrage at different segments of the value chain. The price benchmark against which these owners arbitrage is the outcome of a market engineered by a planner. Thus, it may not capture all of the complexities of a perfect market. Furthermore, planners of existing markets may not have accounted for currently emerging technologies, such as storage, in their designs. This issue is cyclic; as technology continually improves, market design falls behind, and additional changes are constantly required. Existing payment regimes are therefore unlikely to adequately remunerate storage devices, and storage is arbitraging with non-optimal prices almost by definition. Its deployment will necessarily be different from the social optimum. Policymakers interested in cost-effectively achieving their policy objectives via electricity markets cannot assume that an optimal market design is easy to implement.

2.2. Transaction costs hinder storage development

Storage provides multiple services that create positive externalities, which private investors may not be able to fully monetize. Among these services are black starts, inertial response and the avoidance of thermal generation unit starts. These services increase the system's efficiency, which leads to lower fuel consumption and potential emissions reductions (Ruz and Pollitt 2016). One possible reason that firms cannot monetize these services is because of high transaction costs, which can prevent the formation of new markets (Arrow 1999; Williamson 2008). High transaction costs can lead to a so-called "missing money" problem, which, in turn, leads to underinvestment. For storage, high transaction costs may result from the lack of disaggregated data, as some unmonetized storage services are procured as by-products of bilateral power contracts. As a result, it is difficult for new storage technologies to value their services (Ruester et.al, 2012) because they incur additional transaction costs. Such costs may include search, monitoring, bargaining and enforcing costs. This potential problem with storage is similar to the capacity remuneration problem whereby restrictions to energy price fluctuations prevent investments from reflecting their full value.

The specific dynamics of this issue are as follows. Storage revenues come primarily from arbitrage. In the generation segment, for instance, storage devices store electricity when prices are low and release it when prices are high. In other words, they store electricity when the availability of renewables is high relative to demand and release electricity when it is low. Initially, storage owners identify numerous arbitrage opportunities and earn high revenues. However, a counterbalancing feedback loop arises. High profits incentivize additional investments in storage, which further flatten the demand curves, eroding the arbitrage opportunities.

This situation is specific to neither the power sector nor storage, and it should not be considered a problem. In the absence of any market failure, storage is deployed efficiently if the marginal contribution equals the marginal cost. A problem only arises if marginal benefits are not fully reflected. In this case, deployment is below the efficient level, as investors are unable to monetize all of the contributions of their investments.

Historically, this problem has been addressed in at least three ways. First, policymakers have tried to internalize externalities by assigning property rights or prices on externalities, effectively creating markets. This solution establishes a market for the relevant external benefit or cost and leaves the involved parties to adjust their behavior accordingly. Second, Coase (1991) argues that firms exist to incorporate all activities that are too costly to buy in the spot market. Thus, a firm will expand to absorb these services, which is another way of internalizing externalities. Based on Coase's argument, either one firm or a vertically integrated firm may offer storage services. Elshurafa (2020) states that a vertically integrated firm is more efficient because benefits can be translated into cost reductions along the entire value chain. A third policy option is setting a subsidy or fee whereby storage owners are compensated for the value of the positive externality. This solution compensates for unpriced services and pushes the deployment of storage to its efficient level. However, it requires being able to sufficiently quantify the amount of external benefits.

2.3. Storage and electricity reform

The third regulatory challenge is more of a caution than a problem. In a strict sense, the technological features of storage do not fit well with the standard electricity reform model. This issue should by noted by countries that want to follow this standard model.

Two key components of the standard reform model are the privatization of state-owned assets (if applicable) and the unbundling of the value chain. This unbundling can include the sale of utility generation assets to independent power producers. Additionally, the standard reform model includes the introduction of competition and the establishment of an independent system operator (ISO) or transmission system operator (TSO) that guarantees non-discriminatory access. Other possible structural changes in the electricity reform process can include the removal of subsidies. Proponents argue that reforms following these steps will increase generation and operational efficiencies, shift investment risks from ratepayers to shareholders and attract new capital sources.

Importantly, storage complicates the implementation of this process. Unbundling rules aim to remove conflicts of interest between the electricity market's different functions. For example, these rules imply that transmission companies cannot own generation plants, as they have incentives to restrict third-party access to the grid. Storage can participate in many segments of the value chain, as Appendix Section 3 shows, and straightforward vertical unbundling is likely difficult or even impossible. Storage can offer both financial and strategic arbitrage opportunities from multiple positions. Arbitraging opportunities are present both within (i.e., against generators) and between levels of the value chain (i.e., switching from generation to transmission).

For example, a conflict of interest may arise if a storage operator uses storage for both generation and transmission. The expected profits from generation and transmission partly depend upon the congestion in the system. Transmission and energy storage are therefore competitors instead of complements. The existing congestion in a power system can positively impact energy arbitrage opportunities, thereby increasing profits from energy storage. Similarly, a limited transmission capacity can also increase the need for reliability services and, thus, can further increase the profits from energy storage.

At one extreme, these conflicts of interest can be avoided by restricting the range of services provided by storage. Clearly, such restrictions will reduce private investors' interest in storage. They also require substantial monitoring and very detailed rules that make storage more expensive to operate. An easier solution is for a single entity to own and operate generation, transmission and storage, as mentioned earlier. This alternative helps to internalize transaction costs, but it is fundamentally at odds with the goal of establishing competitive electricity markets. As a result, wholesale electricity markets will be inefficient, leading to underinvestment in generation and reduced revenues from the sale of generation.

We also note that storage makes decisions regarding privatization and the role of the ISO more difficult. We discuss these issues in more detail in Section 3.3.

3. Policy Objectives and Storage:
Options and Consequences

In this section, we place the discussion of storage and energy market reform in the context of GCC countries' electricity policies. We assume that GCC countries are liberalizing their electricity sectors and increasing renewables to achieve four broad political economy objectives. The first is for prices to reflect costs, which would allow these countries to increase domestic fuel prices without inflation and large consumer welfare reductions. The second is to allow private participation in this sector, which would help to increase investments and liberate public finances (Williams and Ghanadan 2006). In contrast, the primary objective of the standard reform model is increasing economic efficiency. The third objective is to deploy renewables not only to lower in-country emissions but also to release hydrocarbon resources from the domestic power sector. Releasing these resources would allow these countries to sell them at international prices. The fourth objective is to incentivize the development of domestic clean energy industries through the push for renewables. Any renewable energy and liberalization policies should reflect these four objectives.

3.1. Electricity liberalization and the deployment of renewables

When coupled with the intermittent capacity of renewables, storage can smooth and, thus, increase the integration of renewables. In this way, it can help GCC countries reduce their demand for hydrocarbons and improve their fiscal sustainability. Except in Dubai, which has nuclear generation, most of the electricity demand in this region is met almost entirely by liquid fuels and natural gas. These fuels are sold at prices above their production costs but below international price levels. Domestic use of these fuels may not be the most welfare-enhancing option. Public finances in GCC countries rely on oil and gas export revenues. Thus, when more liquid fuels are consumed domestically, these countries are more likely to deviate from sustainable fiscal paths, and vice versa (Lilliestam and Patt 2015).

Blazquez et al. (2017) find that 20% penetration of renewables in Saudi Arabia's domestic market will increase oil exports by 2.8%. Although releasing more Saudi oil into international markets will eventually lower oil prices, the overall impact on the Saudi economy will be positive. Blazquez et al. (2021) use a dynamic stochastic general equilibrium model to understand how Saudi Arabia can capture these welfare benefits. Specifically, they show that this capacity of renewables must be financed by the private sector and not by re-allocating public expenditures. This result reinforces the objective of restructuring the power sector to enable private investments as opposed to public financing.

Deploying storage may trigger a virtuous circle. On one hand, renewables can increase arbitrage profits for storage because they increase price volatility and the frequency of zero or near-zero wholesale prices. On the other hand, storage can increase the profitability of renewables by reducing curtailment when excess renewables are available. This improvement is particularly important for solar plants, as they are productive when the sun shines, particularly in GCC countries with abundant solar insolation. Storage can also help to increase prices when they are low (i.e., renewables' availability is high) and reduce prices when they are high (i.e., renewables' availability is low). Thus, it can smooth renewables' revenue streams, making investments less risky. This outcome should translate into an overall reduction in procurement costs for renewables.

The degree of penetration of renewables capacity matters for storage's economic viability. Deploying storage may not be cost-effective if the penetration of renewables is low. In this case, market prices are almost always set by conventional technologies, for which peak and off-peak prices differ less than relative to renewables. Without renewables, the marginal cost savings and arbitrage opportunities are so small that they are offset by the cost of operating storage. Thus, an important condition for the economic viability of deploying storage in GCC countries is having sufficient private investment in renewable energy capacity.

3.2. Increase fiscal revenues

In GCC countries, the revenues collected by utilities are insufficient because of low electricity tariffs. Thus, utilities must depend on national government budgets for their investment requirements. The second broad policy objective is therefore to work toward fiscal sustainability. One way to achieve this goal is to sell the assets owned by public utilities to independent power producers. Other strategies include promoting new private investments that can liberate fiscal income for other needs and reducing fiscal support for electricity consumption. Electricity tariffs that reflect costs can enable the owners of privatized assets to recoup their investments, which is necessary to induce these investments.

As explored in the previous section, deploying storage in generation can both facilitate and hinder the objective of fiscal sustainability. Replacing regulated tariffs with market prices for wholesale power means that consumers would most likely have higher electricity bills. Deploying storage as generation in preparation for this reform can complement successful capacity tenders for renewables by increasing the efficient use of generation capacity (Bellini 2021). In this scenario, storage helps with the policy objective of achieving a general electricity price reduction by improving production efficiency. This price reduction increases the feasibility of reducing subsidies at the margin and can help to improve fiscal sustainability.

However, storage has a few drawbacks for fiscal sustainability as well. Lower initial electricity prices would also reduce interest in new investments in generation capacity. To counteract this effect, storage can relieve congestion and enhance transmission capabilities, which may incentivize early investments in the liberalization process. Nevertheless, deploying storage can reduce the total revenue from privatization. It accelerates the decline in the value of old liquid power plants that provide balancing services, intensifying potential problems with stranded assets. Conventional plants would have lower sales and receive lower prices on average when the curtailment of renewables is lower. Careful quantitative analyses of the various options tailored to specific countries are needed to understand the relative magnitudes of these competing effects.

3.3. Ownership of storage

Determining who should own and operate storage facilities is a key policy issue. The standard reform model suggests selling assets owned by public utilities in segments that are prone to competition, such as generation. However, that rule is difficult to apply to storage facilities because they can participate in both competitive and regulated segments. Moreover, even within competitive segments, some governments have decided not to sell certain assets, such as nuclear generation plants and large hydroelectric plants, for strategic reasons. Mexico's electricity reform in 2014 serves as an example of this phenomenon. The question therefore arises as to whether storage should similarly remain in public hands. If storage is privately owned, governments may ask whether the owners of assets in competitive segments, such as generation, should also own storage. As an alternative, they may allow only private third parties to own storage.

To address these questions, we assume that a single profit-maximizing firm entirely owns both generation and storage. As this firm has market power in production, it would underinvest in generation to create artificial scarcity by withholding capacity, leading to higher wholesale prices. Prices would rise significantly, providing more arbitrage opportunities for storage owners. Storage can help to counteract market power and reduce the price markup. However, if electricity prices are above the efficient level partly because of storage, the firm would overinvest in storage capacity. These investments are again passed on to consumer prices. If this firm is also the only storage operator, its storage division would not be a price taker. This division would try to modulate price escalations when it buys power and price reductions when it sells power. As a result, it would underinvest in storage capacity. Both generation and storage capacity would become scarcer, likely leading to more frequent price hikes. These impacts would ultimately translate into higher prices for consumers.

This example suggests that storage can mitigate pre-existing market power in generation as long as storage is publicly owned or is not owned by generators. We also highlight a potential risk when generators with market power own storage. However, using storage to address generators' market power is an expensive solution; tackling the source of market power directly is best.

Additionally, the ownership of storage used in regulated sectors, transmission and distribution is similarly not straightforward. The implications of the ownership decision depend on the various models that can be applied to this segment, including the TSO and ISO models. Under the former model, the operator is fully unbundled from the system even if transmission assets remain under a public company's ownership and control. The latter model involves a wholly independent operator with no interest in the ownership of transmission, distribution, generation or retail assets.

By this definition, an ISO has no financial interest in storage. In contrast, a TSO owns storage to improve both transmission investments and operations and views storage as a transmission asset. Storage can benefit a TSO by helping to reduce congestion. Investing in storage can help to defer more costly transmission investments. If the transmission and distribution benefits of storage are not valued, it would be underemployed.

Finally, storage has some special characteristics that may justify public ownership. Storage provides services beyond pure arbitrage effects; it enables the deferral of capacity investments, offers flexibility and improves supply security. Some of these services may not be fully captured by market designs and, thus, constitute positive externalities. In terms of environmental gains, storage can help to reduce carbon emissions by smoothing the integration of renewables, depending on the system's generation mix. In R&D terms, early adopters can benefit from learning by doing. One can therefore argue that storage should be supported by public investment, especially in countries that are introducing renewables very rapidly. Public ownership of storage may also be appropriate if storage costs are falling and performance is improving or if there are market power concerns. Additionally, if learning about storage offers benefits that only public investment can capture or if nascent clean energy industries are being developed, public ownership may be appropriate.

3.4. Financing storage

The issues around financing storage encompass the issues discussed in the previous three subsections. An important question is whether oil savings should finance the deployment of renewables indirectly through the addition of storage capacity. If storage remains privately owned, it is important to determine whether the government should finance it. In this case, it is also necessary to understand the potential impact of this public financing on the objective of achieving healthier public finances.

If storage can pay for itself by enabling additional oil exports and if no other allocation of this resource is better, then oil savings should finance storage. Karanfil and Pierru (2021) find that the opportunity cost of a barrel of oil likely ranges between $15 and $25. These values apply to projects with a short-term impact on domestic oil demand. However, the range of opportunity costs is much wider for projects that have long-lasting impacts on domestic oil demand. These opportunity costs are also very sensitive to constraints on production. Investments in energy efficiency or renewables fall into this category.

International experience shows that even when the penetration of renewables is large, arbitrage profits are several orders of magnitude below the costs of investments (Andres-Cerezo and Fabra 2021). If policymakers want to boost investments in storage, they must complement storage owners' market revenues with public support owing to storage's high capital costs. However, GCC countries are aiming to reduce the subsidization of their electricity sectors. Subsidizing renewables and storage in addition to fossil fuels will increase fiscal pressure when oil prices are low (Poudineh, Sen, and Fattouh 2018).

Fully addressing these questions will require quantifying the various components. A quantitative analysis is necessary to determine whether to allocate new oil revenue streams to storage. In addition, the opportunity cost of a barrel of oil should be quantified. The value of R&D to a country as a public good and the economic benefits of developing an infant industry must also be quantified.

Conclusion

Incorporating storage within their energy systems can offer many benefits to the GCC countries aiming to simultaneously deploy renewables and liberalize their power sectors. However, policymakers and regulators must also be aware that storage creates new regulatory challenges. Ignoring these challenges may lead to unnecessary transition costs. Investments in storage may also hinder their ultimate policy objectives in some circumstances. We define these objectives as phasing subsidies out, reducing electricity prices, relieving public finances and releasing oil to sell in international markets.

In this section, we highlight some implications of this discussion.

Electricity markets are "constructed." The practical consequence of the fact that electricity markets do not develop organically is the potentially inefficient deployment of storage. Both over- and underinvestment may arise. A critical mass of storage can smooth production over time, reduce generation costs and flatten the price curve. Production efficiency may improve, and wholesale prices may fall. The effect on retail prices depends on the extent of subsidies to the utility to pay for overinvestments in storage. Unfortunately, the costs of investing in energy storage remain high despite falling substantially over the past decade. Furthermore, by reducing prices, storage also reduces the value of privatization, which may detract from the policy objective of achieving fiscal sustainability. However, inadequate remuneration may result in too little investment, which is also costly. Not fully using a readily available technology results in lost benefits.

Transaction costs may prevent market formation. Some storage services may not be monetized or fully priced. The missing money problem may arise, leading to underinvestment in storage. Even if storage is used to complement transmission, the market design may not properly account for all the services that storage provides in this segment. Thus, investments in storage for this end would be too low. Inefficient transmission levels have implications for new investments in generation. If the unmonetized storage service is used in generation, then storage will not be fully deployed for this end. This outcome may delay the penetration of renewables and thus, the release of oil to relieve public finances.

Storage does not fit well with the standard reform model. If governments overlook this mismatch, the resulting misalignments may undercut their reform objectives, such as lowering prices. However, as mentioned earlier, markets also experience misalignments when transitioning to high levels of renewables. This predicament provides an opportunity to design a market at the outset by integrating renewables, storage and market mechanisms. A key issue for liberalization and market design is determining who should own storage. Storage is considered a standalone unit outside of ancillary services and is viewed as a transversal segment in the value chain. Continuing to view storage as an ancillary service may hinder understanding and delay its deployment.

Evolving and emerging technologies require policymakers to continually adjust and reform the power sector. Storage is one of many technologies that are rapidly changing and can fundamentally transform the electric power sector. Other technologies, such as electric vehicles, smart grids and hydrogen production, also need to be considered holistically with storage. These technology changes will likely require market and regulatory reforms as policymakers pursue their multifaceted policy agendas.

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Appendix

1. Electricity reform efforts in GCC countries.

Saudi Arabia envisions developing a competitive electricity market and giving choices to consumers in sourcing their services.

Abu Dhabi in the United Arab Emirates (UAE) and Oman set electricity sector laws that initially focused on three areas. They separated competitive and non-competitive business segments, created market structures based on a single buyer model and gave third parties open network access to trade electricity. Over the years, these reform strategies have been further expanded. They now include the partial privatization of the transmission and distribution business and the creation of a spot electricity market in Oman. Abu Dhabi's strategy includes a wide range of activities and services across the energy sector.

Kuwait's and Qatar's efforts are limited to using independent power producers for generation and the associated unbundling (Dyllick-Brenzinger and Finger 2013).

To date, none of these countries has proposed a retail energy market as part of its liberalization efforts; their implementation is being phased in.

2. Drive for renewables in the GCC.

In 2018, Saudi Arabia revised its clean energy goals. It increased its 2023 renewables target from 9.5 gigawatts (GW) to 27.3 GW (including 20 GW of photovoltaic power and 7 GW of wind power). It also changed its 2030 target to 58.7 GW (40 GW of photovoltaic power, 16 GW of wind power and 2.7 GW of concentrated solar power).

In addition, Saudi Arabia announced the Green Saudi Initiative and the Green Middle East Initiative on March 28, 2020. These initiatives aim to reduce carbon emissions by more than 60%. This joint effort will achieve the reduction of more than 10% of global contributions.

Kuwait is targeting meeting 15% of its electricity demand with renewables by 2030.

UAE is targeting an energy mix with 50% of energy from clean sources (44% renewable and 6% nuclear energy) by 2050 (UAE 2017).

3. Storage services.

Storage provides a vector of services to the power system and, thus, has multiple potential revenue streams:

- **Generation and load:** Energy storage can be treated as generation when discharging and as load when charging.

- **Coupled with renewables:** Storage can help to integrate intermittent renewable energy generation into the system. By storing electricity when renewable energy generation is high and releasing it when it is low, storage is key to balancing electricity systems dominated by renewables. The intermittency of solar and wind power can also increase storage arbitrage opportunities by increasing price volatility.

- **Transmission and distribution:** Energy storage can complement the transmission and distribution infrastructure and can be used to defer investments in both. Currently, transmission investment planning processes generally do not account for non-transmission alternatives (Khastievaa et al. 2019).

- **As capacity:** Storage has value as capacity and should be allowed to participate in any capacity remuneration mechanism. However, determining the amount of firm capacity that an electricity storage unit provides is challenging. The definition of capacity must include storage such that its capacity benefits are valued.
- **Other storage services:** Storage offers frequency control over cycles per second through regulation (Arup 2020).

Notes

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About the Authors

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Dr. Rolando Fuentes was a research fellow focusing on business and regulatory models for the Utilities of the Future project. He has extensive experience in the energy and environmental sectors as an academic and policymaker. Rolando was the director of international negotiations at the Mexican Ministry of Energy and later became director of hydrocarbons projects. Before joining the Mexican government, he was a fellow of the London School of Economics, where he lectured and taught courses in Environmental Impact Assessment and Environmental Policy, and supervised master's dissertations. Rolando has also been an associate of the Oxford Institute of Energy Studies and IHS Cambridge Energy Research Associates (IHS CERA), and was a recipient of the British Chevenning Scholarship in 2001.

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Prior to joining KAPSARC, Shahid was an associate director at TERI, an independent research institution working in the areas of energy, environment and sustainable development. As part of his managerial responsibilities, he was responsible for defining, providing direction for, and implementing the research agenda. He immensely enjoyed working in a team, guiding and mentoring fellow colleagues. As an energy specialist with research and consulting experience, Shahid has worked on various aspects of electricity market reforms covering a range of issues around energy-economics, energy-policy/regulation, energy-markets, energy-sustainability, pricing, DSM especially related to the electricity industry in India and abroad. He has interacted widely with policymakers, regulators, utilities (public and private), multi-lateral & bi-lateral organizations, and international research institutions. He also contributed to a number of government reports aimed to facilitate transition of the energy sector, and gave representation as an energy sector specialist in a number of national and international expert groups/task forces.

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