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Electricity Markets in MENA:
Adapting for the Transition Era

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Contents

Figures and Tables

Abstract

Resource-rich economies in the Middle East and North Africa (MENA) are pursuing two parallel strategies with regard to their electricity sectors: (i) increasing the role of renewables and integrating them into their power generation mix to mitigate the impact of rising domestic oil and gas demand on their economies and to boost their hydrocarbon export capacities; and (ii) conducting power sector reforms to attract investment in generation capacity and networks, remove subsidies, and improve operational efficiency. These goals imply that the design of power sector reforms (including regulations governing wholesale and retail markets and networks) needs to be carried out with a view to the possibility of a rising share of non-dispatchable resources. The lack of an integrated approach to simultaneously address these two strategies is likely to lead to several misalignments between renewables and the various components of future electricity markets, when the share of intermittent resources increases in the generation mix. The key challenge is that the 'ultimate model' that will reconcile these two goals (liberalization and integrating renewables) is as yet unknown, and is still evolving due to uncertainties around the development of technologies, institutions, and consumer preferences. We argue in this paper that resource-rich MENA countries can, however, move towards adopting a transition model of electricity markets, the individual elements of which can eventually be adapted to suit either centralized or decentralized future electricity sector outcomes. We outline the key components of this model for the wholesale market, retail market, and network regulation, considering the objectives of governments and the specific contexts of the region.

Acronyms and Abbreviations

ACL	Free Contracting Environment (Brazil)
ACR	Regulated Contracting Environment (Brazil)
ANEEL	National Agency of Electrical Energy (Brazil)
CCEE	Electricity Market Operator (Brazil)
CSP	concentrating solar power
DNO	distribution network operator
DSO	distribution system operator
DSP	distribution system platform
FEC	firm energy certificate
GCC	Gulf Cooperation Council
IPP	independent power producer
ISO	independent system operator
IWPPs	integrated water and power producer
MENA	Middle East and North America
OECD	Organisation for Economic Co-operation and Development
PV	photovoltaic
R&D	research and development
RPI-X	Retail Prices Index less X, X being expected efficiency savings
SGIP	Self-Generation Incentive Program (California)
TGC	tradable green certificate
TSO	transmission system operator
VIM	vertically integrated monopoly

Units of measure

GW	gigawatt
GWh	gigawatt hour
MW	megawatt
kWh	kilowatt hour

1. Introduction

Resource-rich economies in the Middle East and North Africa (MENA) have strong motivations, beyond decarbonization, to increase the share of renewables in their power mix. These countries are at a stage of development where economic growth, robust population growth, rapid urbanization and economic prosperity have led to soaring domestic electricity demand, with increasing amounts of liquid fuels (crude oil, fuel oil, and diesel) and natural gas diverted to the power sector at prices below international levels (Lilliestam and Patt, 2015). The rapid rise in domestic energy consumption results in suboptimal utilization of the resource base and puts many of these countries on a fiscally unsustainable path given their dependence on oil and gas export revenues. This is exacerbated by underpriced energy vectors, inefficient state-owned utilities, and power sectors that are heavily reliant on government budgets for investment and operation. Therefore, governments need to increase the share of renewables in the generation mix not only to boost hydrocarbon export revenues, but also to enhance security of supply,[1] diversify the energy mix, and restructure the power sector in order to attract private capital and improve efficiency.[2] In the long term, renewables can help reduce the region's per-capita emissions (amongst the world's highest) (Poudineh et al., 2018), as well as contribute to economic diversification, which is the ultimate strategy for economies of the region positioning themselves for the energy transition.

Parallel to renewables policy, several MENA countries have begun undertaking power sector reforms. These reforms were initially planned with the aim of restructuring the energy sector, allowing private-sector participation, removing energy subsidies, and reducing the sector's reliance on the public budget. However, renewables targets complicate the process of reform, especially if governments wish to move the electricity sector towards market-based approaches. The challenge facing these countries is how to design a reform model that helps them attract investment and improve efficiency, while at the same time integrate a rising proportion of intermittent resources. Failure to find the right model is likely to frustrate reform efforts and governments may find themselves in need of making significant changes to the electricity market at later stages. For example, inadequate tariff design structure, following the removal of subsides, could lead to difficulty in recovering the fixed costs of the power system. It may also lead to the regressive distribution of costs among ratepayers. Furthermore, introducing significant renewables without a proportionate increase in the flexibility of the power system (both in generation and in the grid) typically leads to curtailment and/or lower system reliability. Moreover, integrating demand-side resources faces a significant hurdle when ownership and operation of the national electricity grid are not decoupled. There are many examples of potential friction if reforms are designed independently of renewables policies (see Peng and Poudineh et al. [2017] for more detail on these misalignments).

Experience around the world has typically been of reforming countries adopting the 'OECD model' of reforms,[3] namely unbundling the electricity sector from a state-owned, vertically integrated monopoly into its functional components—generation, transmission, distribution, and retail supply—and introducing competition into generation and retail supply (for example through wholesale markets, retail competition, and privatization).

In many jurisdictions that pioneered power sector liberalization, including those in Europe, Australia and the United States (Texas) among others, energy is the only commodity that is traded in liberalized

[1] Some of these countries, such as the United Arab Emirates and Kuwait, are already net importers of natural gas.

[2] Blazquez et al. (2018) show that renewables deployment (along with shifting power generation from oil to natural gas and increasing the administered price of oil) is among the most cost-effective ways of reducing oil consumption in Saudi Arabia, with significant net benefits to society.

[3] Pioneered in the 1980s and 1990s by member countries of the Organisation for Economic Co-operation and Development (OECD).

electricity markets.[4] Prices in energy-only markets are set according to the system's marginal cost (Sen, 2014). This model relies on market price signals to organize both short-term coordination for dispatching, and long-term coordination for investment in generation capacity (Roques and Finon, 2017; UKERC, 2010). However, in practice it has turned out that that it is difficult to achieve both objectives through price signals in energy-only electricity markets, for two principal reasons:

- First, such a design ignores market imperfections around short- versus long-term coordination (Roque and Finon, 2017). The interests of market participants are not aligned, weakening their incentive to contract forward and share risk. Retail competition allows consumers to switch suppliers at short notice; even if this does not happen, it constrains retail companies' ability to sign contracts with generators exceeding the duration of their contracts with customers. There is also no financial market for forward hedging. These imperfections increase the cost of capital for investors, potentially leading to inadequate or suboptimal generation mix and frequent price volatility.
- Second, decarbonization (a major objective in OECD countries) has exposed weaknesses in the wholesale market model around its compatibility with the intermittency of renewables. Marginal-cost-based price formation in energy-only markets has little relevance for renewable generation technologies, as what distinguishes renewable plants (in a market for dispatch) is their location and ability to provide flexibility and balancing services, rather than their marginal costs (which are all close to zero) (Keay, 2016). Zero marginal cost renewables in energy-only markets also lead to price volatility (and sometimes to zero or negative prices).[5] The simultaneous operation of renewables and traditional generation within competitive wholesale markets has led to market breakdown and the distortion of electricity price signals, especially when renewables receive out-of-market payments. Furthermore, the decentralized nature of small-scale renewables implies that assets are transferred away from utilities to 'prosumers' or private on-site generators, impacting the earnings (return on assets) of traditional utilities.

The issue is not limited to wholesale market design; the entire package of reforms practiced in the OECD is under question. There is a growing consensus that imposing the OECD reform model onto countries with no regard to contextual heterogeneity creates further complexity. The original objectives of the OECD model were to achieve higher efficiency, lower consumer prices and consumer choice, whereas in non-OECD countries the model was implemented to resolve the inadequacy of investment and removal of the electricity supply constraint on growth (Williams and Ghanadan, 2006). Context is particularly important for MENA countries, as the adoption of more market-based approaches results in political challenges (for example if prices were to be based on marginal costs, this would require the removal of subsidies and would lead to much higher electricity prices), whereas moving towards a fully subsidized renewables programme (in addition to existing fossil fuel subsidies) increases fiscal and economic pressures, especially at times of low oil prices (Poudineh et al., 2018).

Electricity markets are effectively in transition around the world, with considerable uncertainty around the development of future markets and business models that will reconcile the goals of market liberalization and renewables integration. Multiple options are available, whether for market structure, utility business model, or consumer engagement with electricity, with each model having its own advantages and disadvantages (Robinson and Keay, 2017). Approaches based on centralized coordination are effective for security of supply and risk mitigation, but not effective at coping with inefficiencies and information asymmetry when compared to markets; they are also susceptible to political pressures (Robinson and Keay, 2017). In contrast, systems with decentralized coordination are effective at addressing informational asymmetry and promoting efficiency, but not in dealing with risks and uncertainties. This implies that MENA countries need to design their own model of power sector reform on the basis of their energy system objectives, the energy transition, and their distinct

[4] As opposed to capacity or services.

[5] Storage could resolve intermittency issues, but has yet to achieve commerciality.

contexts. In this paper, we propose a *transition model of electricity markets* for the MENA region. Such a model needs to:

- combine the effective features of various successful designs;
- balance the roles of the market versus the government;
- be compatible with the current technology mix and institutions in the region;
- allow for the further development of renewables;
- be flexible enough to adapt to future developments in the electricity sector;
- encourage efficiency and security of supply; and
- promote consumer preference.

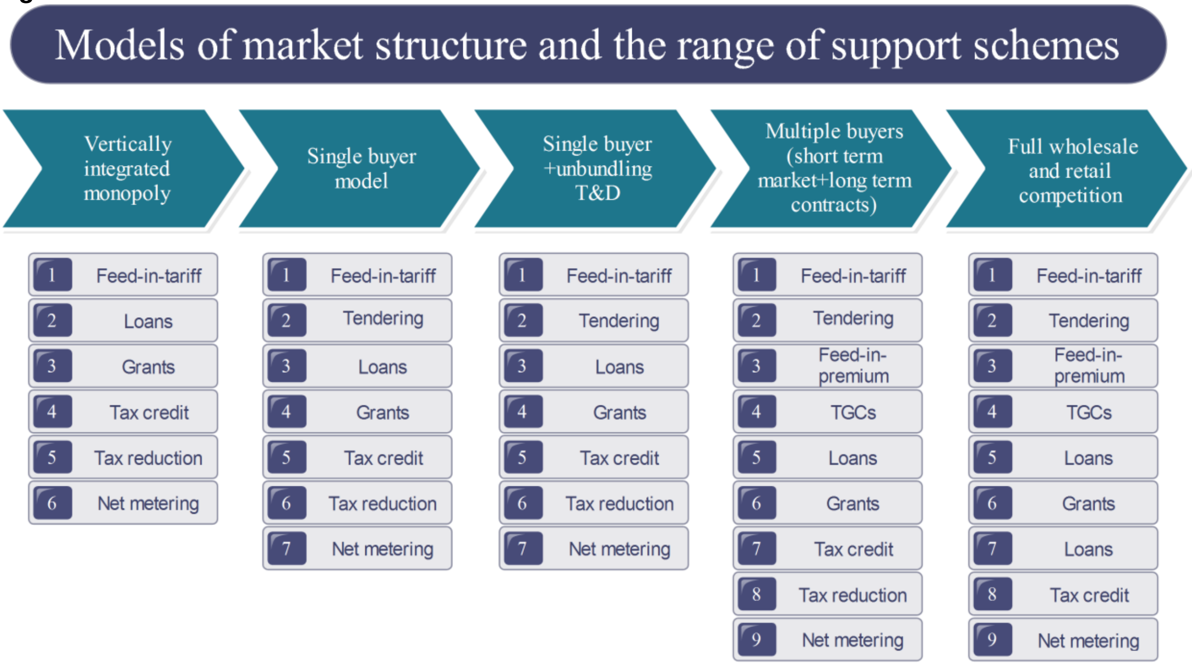
Section 2 describes how a transition model would look. Section 3 discusses how the transition model can be adapted to possible scenarios for future evolution of electricity markets, and Section 4 concludes.

2. A transition model for the resource-rich MENA countries

Various possible models of power sector structure are evident, progressively evolving from a *vertically integrated monopoly* (VIM), which owns and operates generation, transmission, distribution, and retail supply, to full wholesale and retail competition (see Figure 1). Each model resolves different issues in the functioning of the sector.[6] The first step from a VIM is a *bundled single-buyer model*, which allows for competition (private companies) in generation, but transforms the VIM into a monopsony—creating perverse incentives for the latter to prioritize its own generation assets in the dispatch. The *unbundled single-buyer model* corrects for this distortion, through the unbundling (accounting and/or ownership separation) of generation from transmission and distribution. However the single buyer (undertaking transmission and possibly distribution, if integrated with transmission) may decide not to offtake power from generators, or may default on its payments. Hence, the *multiple-buyer model* allows more than one offtaker (for example large electricity consumers, regional transmission companies, and distribution or retail companies) with grid operation carried out by an independent system operator, or by the largest transmission system operator. This model creates a wholesale electricity market for dispatch which is complemented with a market for long term contracts. The fifth model allows for *full wholesale and retail competition* with markets organized around day-ahead transactions, bilateral contracts and balancing. Poudineh et al. (2018) review the compatibility of renewables support mechanisms with each model, showing that tendering is compatible with all structures that have moved away from a VIM (see Figure 1).

[6] Poudineh et al. (2018) provide a taxonomy.

Figure 1: Models of market structure



Notes: ISO = independent system operator; TGC = tradable green certificates.
Source: Reproduced from Poudineh et al. (2018, 147).

2.1 MENA electricity sector structures: basic features

Given their high levels of solar irradiation, MENA countries' renewable fleets are likely to be more heavily biased towards solar energy than, for instance, wind. Therefore, in theory, the intermittency of renewables should be much more predictable in MENA than in other places, such as OECD Europe, and also better correlated with peak demand for cooling, allowing more opportunities for innovation—for example through more decentralized and localized solar solutions rather than the traditional 'top-down' approach. In reality however, the extent to which these favourable features can be harnessed to enable renewables penetration is constrained by the characteristics of MENA countries' electricity sectors, and by the contexts within which they operate (for example underdeveloped institutions and rigid governance structures relative to OECD Europe). Their main characteristics are described below.

- **A tradition of monopolies**. Historically, MENA electricity sectors have been organized around vertically integrated, state-owned utilities endowed with a statutory or *de facto* monopoly over generation, transmission and distribution (Dyllick-Brenzinger and Finger, 2013). For instance, in Kuwait the monopoly is the Ministry of Electricity and Water, in Saudi Arabia it is the Saudi Electricity Company, and in Iran it is Tavanir, the holding company for generation, transmission and distribution. These state monopolies historically owned and operated all assets and infrastructure in the electricity sector.
- **Power sector reform**. Electricity reform legislation has been introduced in many MENA countries to reform the sector structure, but implementation has remained slow. The reform laws of Iran (1999), Saudi Arabia (2005), and Algeria (2002) envisage wholesale markets; the Abu Dhabi (United Arab Emirates) reform legislation (1998) envisages disaggregated single buyers with bilateral trading and third-party access, and the reform laws of Kuwait (2008; 2010) and Qatar limit changes to allowing independent power producers (IPPs) in generation, alongside unbundling (for Qatar) (Dyllick-Brenzinger and Finger, 2013).

- **Private-sector participation**. MENA electricity markets are all currently variants of the single-buyer model (refer to Table 1), with differences in the levels at which competition plays out. Private investment in generation is mainly facilitated through auctioning tenders for IPPs and IWPPs (integrated water and power producers) based on long-term contracts. Iran is the only MENA country where competition is introduced through bid-based auctions in the day-ahead and/or spot market for generation, with the price of electricity for the single buyer in the pool determined by the interaction of competing generators (Poudineh et al., 2018).

- **Renewables activity**. Most MENA countries have introduced long-term targets for renewable energy, some of which are highly ambitious. For instance, Kuwait is targeting 15 per cent of electricity demand to be met by renewables by 2030 and the United Arab Emirates' target is 24 per cent clean energy (including nuclear) in the energy mix by 2021. Saudi Arabia is targeting 9.5 gigawatts (GW) of solar capacity by 2023, while Iran is pursuing 5 GW of solar and wind capacity by 2020. Prominent projects that are active or in the pipeline include: Abu Dhabi's 100 megawatt (MW) Shams concentrating solar power (CSP) plant (operational since 2014); Dubai's Mohammed bin Rashid Al Maktoum Solar Park (photovoltaic [PV]), of which Phase 1 (13 MW) was completed in 2013, Phase 2 (200 MW) was completed in 2017 and Phase 3 (800 MW) is due for completion in 2020; Morocco's Noor 1 solar PV plant (350 MW); Kuwait's Shagaya solar thermal project (50 MW); and Saudi Arabia's Al-Aflaj 50 MW solar PV plant.

- **Renewables auctions**. MENA countries intend to meet their renewable energy targets through the use of auctions, some of which have yielded the world's lowest prices for solar energy. Examples include Phase 2 of Mohammed bin Rashid Al Maktoum Solar Park at 5.85 US cents per kilowatt hour (kWh), and the Dubai Electricity and Water Authority reportedly receiving five bids from international firms to build the third phase of the park in 2016, the lowest of which was 2.99 US cents/kWh. In February 2018, ACWA Power was awarded the rights to develop the 300 MW Skaka IPP solar PV project in Saudi Arabia at a record low tariff of 8.782 halala/kWh, or around 2.34 US cents/kWh.[7]

- **Tariff subsidies**. Another prominent feature of MENA countries' electricity sectors is highly subsidized electricity tariffs, which in many cases do not even reflect the production cost. Dyllick-Brenzinger and Finger (2013) estimated that in the high-income Gulf Cooperation Council (GCC) countries and also in Iran, residential tariffs ranged between less than 1 and 2 US cents/kWh, compared with between 6 and 18 US cents/kWh in the OECD countries. The global oil price downturn prompted several MENA countries, including Kuwait and Saudi Arabia, to raise retail electricity prices in order to shift their economies onto a fiscally sustainable path, but thus far with mixed success. For example Kuwait, which was the last GCC country to move on electricity reforms, proposed to more than triple its retail electricity price for certain consumers, but the proposal faced resistance in the country's parliament.

- **Revenue deficits**. As a consequence of subsidized tariffs, revenues collected by utilities are insufficient, requiring them to fall back on national government budgets for their investment requirements. Subsequently, MENA countries have tended to pursue the cheapest (in terms of capital cost) and quickest options for investment in generation, such as oil-fired boiler plants or open-cycle gas turbines, which are also technologies with low conversion efficiencies and thus high running costs (Poudineh et al., 2018).

- **Distortion of consumption**. Despite the compatibility, in theory, between MENA countries' electricity load profiles and the pattern of solar irradiation in the region, in reality there is a mismatch created by inefficiencies in consumption. For instance in Kuwait, despite the temperature drop in the evenings, the electrical load remains relatively unchanged through the day due to inefficient buildings consumption (and distorted electricity prices)—primarily to meet demand for air conditioning.

[7] There are 100 halala in 1 riyal (SAR 1).

- **State dominance of the power sector**. Finally, the state has a very strong presence in the electricity sector in the MENA region, which cannot be easily or quickly circumvented in favour of more decentralized institutions, limiting the potential for radical innovation in the foreseeable future. MENA countries have struggled to establish independent regulatory and other institutions. For instance, Abu Dhabi's Regulation and Supervision Bureau, its notional electricity regulator, sets bulk supply tariffs and applies incentive regulation (for example RPI-X)[8] to networks, but still has direct government representation (Dyllick-Brenzinger and Finger, 2013). Studies suggest that the MENA countries' institutional feasibility should include the existence of renewable energy ministries and regulators, and definition of their resources, competencies, laws, existing strategies and activities in renewable energy (DIE, 2012). However, the current institutional frameworks for energy in the MENA countries are largely dominated by the oil and gas sector, and renewables have yet to be integrated within them (Poudineh et al., 2018).

Any structural design for the electricity sector in the region needs to consider the above context. At the moment, most resource-rich MENA countries are at an early stage of electricity sector reform (that is, vertically integrated or single-buyer structures), implying that they can exercise this as an advantage when designing their own reform packages to fit with their unique circumstances, whilst avoiding mistakes made in OECD countries. The transition model proposed in the section below is supported by this premise.

2.2 Components of the transition model

The objectives of decarbonization and renewables integration are catalysing a shift in the technological fundamentals of the electricity system, opening up possibilities for new commercial and business models around which markets need to reorganize. The uncertainty over the end-point of this shift implies that the 'ultimate' model is as yet unknown. MENA countries can adopt a transition model, which deals with the problem of attracting investment in renewables and, in doing so, balances the competitive functioning of electricity markets with investment incentives. This model would be more adaptable to the eventual outcome of the electricity transition in these countries. We describe its main features below.[9]

2.2.1 Unbundling

Unbundling of the sector into its functional components (generation, transmission, distribution, and retail supply) is a basic structural measure which needs to be implemented to address various perverse incentives that encourage anti-competitive behaviour by integrated monopolies. The aim is to make the network a separate unit and a neutral facilitator of the market, in which generators compete on a level playing field. In such a system, access to the grid is regulated and not negotiated. There are various models that can be adopted here. One is the independent transmission system operator (TSO), which is fully unbundled from the rest of the system (the previous model in the United Kingdom). The second is a legally unbundled TSO, such as that of RTE in France, in which the TSO operates separately to the rest of the system, but transmission assets remain under the ownership and control of the partially public-owned French utility company Électricité de France (EdF). The third model is the ISO, which does not own any transmission assets. MENA countries can start with legal or ownership unbundling and at some point move towards establishment of an ISO.

With regard to the distribution network, in theory the same unbundling rule would apply as for the transmission grid. However, the remit of distribution network operators (DNOs), which was previously restricted to network operations, would require expanding in a system with decentralized renewables into areas such as demand response and storage, smart grids and metering, and customer data

[8] A price-capping formula, RPI-X stands for Retail Prices Index less expected efficiency savings of X.

[9] We only focus on the design of wholesale and retail markets and network regulation, but it goes without saying that there is a need for an independent regulatory body to regulate networks and monitor competition in the market.

management. This would effectively transform DNOs into distribution system operators (DSOs), which share some of the traditional responsibilities of TSOs, but at a distribution level.[10]

2.2.2 Innovation-oriented network regulation

Prior to decarbonization, the function of the grid network—a natural monopoly—was limited to delivering electricity, with the distribution (and demand) side playing a passive role. However, the variability of supply introduced by renewables, along with the need for integration of demand-side resources, requires transmission and distribution networks to evolve into a new paradigm through innovation[11] in technologies, processes (management and operations), and business models. In transmission, this involves grid modernization, new technologies for long-distance, flexible transmission systems, and the use of advanced real-time telecommunications infrastructure (for example the supergrid). In distribution, significant disruption occurring at the grid edge will require networks to innovate to facilitate markets for distributed resources,[12] service-oriented business models, and integrated grid management. New markets for electricity—for example transport and heating—entail closer demand-side interaction than ever before (as in smart grids). In this new paradigm, performance-based network regulation[13] will need to be enhanced in order also to incentivize innovation, as opposed to solely focusing on cost efficiency gains and reliability standards.

Network companies have been slow to innovate in the absence of competition.[14] Although innovation is implicitly treated as part of cost efficiency in the traditional regulatory model of network companies, it needs to be separately incentivized (Poudineh et al., 2017). This is because innovation is riskier than business-as-usual activities: the outcome involves a higher level of risk and uncertainty that is distinct from cost efficiency outcomes; and even unsuccessful outcomes advance the industry 'learning rate' in the long run.

Incentivizing innovation requires the design of a compensation plan that remunerates network firms for their cost of efficient innovation, while sharing the risks between firms and their customers in an efficient manner (Poudineh et al., 2017). Regulators can adopt a combination of an *input-based approach*, which includes the costs of innovation in regulatory expenses,[15] *output-based regulation*, which allows firms to benefit from the full value of successful innovation outcomes (for example by allowing for additional revenues or extending the regulatory period), and tendering in order to regulate innovation and business-as-usual expenses of the firms. Regulators should be clear about the desired nature of innovation, as each of these schemes has its own characteristics in respect of risk implications and outcome. Input-based regulation can lead to overcapitalization, whereas output-based regulation faces problems with measurability of outcomes. Tendering, on other hand, exposes firms to the risk of losing upfront capital in case of competition loss (Poudineh et al., 2017).

Resource-rich MENA countries can adapt the regulatory model for innovation based on the innovation stage of projects. For risky R&D projects and those innovations that are at demonstration stage, an input-based approach would be more effective. However, for less risky projects and roll-out of established technologies, they can adopt an output-based incentive mechanism. For large projects and allocation of large innovation funds, MENA countries can adopt a tendering approach. However, in order to address the risk of upfront capital used for preparing bids, separate funds need to be

[10] See Poudineh et al. (2017).

[11] The creation or adoption of new or alternative methods to provide improved outcomes (UKRN, 2015).

[12] Renewables are conducive to distributed generation/microgrids located close to the electricity load, which can operate in islanding mode or be plugged into the main grid.

[13] Incentive regulation (price or revenue cap).

[14] Jamasb and Pollitt (2008) argue that research and development (R&D) expenditure in electricity has declined with incentive regulation.

[15] Subjecting them to the same regulatory restrictions as other costs. Alternatively, the regulator can treat these costs differently by passing them on to consumers, or including them in the regulatory asset base and entitling the firm to a minimum rate of return.

allocated for smaller projects through an input-based regulation whose techno-economic results can be utilized in bids for large innovation funds.

MENA countries also need to consider the issue of cost recovery from users and tariff design for networks. Networks costs are usually recovered from users through a one-off connection charge and another component known as 'use of system' charges. They should use these two components not only to recover the network costs, but also to incentivize efficient siting of distributed resources in order to optimize overall system costs. Furthermore, shallow connection charges for renewables need to be balanced against the risk of increased electricity prices for other users (and consequently the risk of load and grid defection).

2.2.3 Retail market: competition for large consumers, regulation for small consumers

In contrast to the original liberalization model in which retail supply was proposed to be fully competitive for all consumers, in a transition model retail competition may be useful only for large consumers, with regulation applied for smaller consumers. Competitive retail markets can fail to produce efficient outcomes for all users. The experience of OECD economies shows that consumers typically do not engage as envisaged in the original design of retail markets. This creates an opportunity for suppliers to exploit small consumers. The lack of engagement by small users is caused by inertia, transaction costs, lack of information, and negligible gain from change of supplier. Frequent switching, on the other hand, creates another problem. Most suppliers in liberalized markets are unwilling to enter into long-term contracts with generators in order to hedge against the volatility of wholesale market prices.[16] This is because they cannot rely on a consumer base who can easily switch suppliers. This absence of a forward market is one of the reasons that short-term energy-only wholesale markets do not provide sufficient incentives for investment.

A regulated retail market for small consumers means that the government sets the retail price as the combination of generation costs, network fees, and a fixed margin for suppliers. The government might also want to hold yearly auctions in order to identify least-cost suppliers for serving small electricity customers.

A regulated retail market, however, must not lead to governments distorting retail electricity prices through heavy subsidies or taxes. In essence, the final price of electricity needs to reflect the efficient costs of consumption. The experience of OECD countries shows that distorting the retail price signal has several side effects. For example, in EU countries the cost of renewable support schemes is recovered through a levy on electricity consumption, resulting in high retail prices even as the intermittency of renewables leads to depressed wholesale electricity prices (Robinson et al., 2017). The higher retail prices incentivize paying consumers to invest in distributed technologies (for example solar PVs), as this decreases their electricity bills (through lower consumption) and increases the cost to other users in places where the fixed costs of the power system are recovered through the energy component. Furthermore, with the increase in uptake of distributed electricity, government support scheme payments (the 'government wedge')[17] push up retail prices further (Poudineh et al., 2017), which can lead to further grid defection. There is also the problem of equity, as those who invest in self-generation are usually the better-off parts of society, whose generation facilities are subsidized through a surcharge on grid electricity paid by less well-off users.

In resource-rich MENA countries, the current retail price subsidies have similar distortionary effects. When consumers can have electricity from the grid for a trivial price, there is little incentive for them to invest in solar PV, energy efficiency, demand response or storage. This will make the uptake of distributed energy resources very difficult in such a system, given the extent of support that would be required from governments to make them attractive.

[16] They thus remain unhedged or use alternative methods such as acquiring generation facilities (an internal hedge through vertical integration; in fact the big six in the United Kingdom are vertically integrated, meaning that they own both generation and retail supply).

[17] Part of the retail price reflecting the cost of policy support schemes (Robinson and Keay, 2017).

2.2.4 Hybrid wholesale markets: short-term energy markets with long-term energy contracts

Given the issues associated with short-term wholesale markets providing sufficient incentives for investment—for example due to the absence of a forward market in which generators can hedge risks[18]— and the misalignment of incentives due to short-term consumer 'switching', we suggest a transition model of wholesale markets for MENA countries in the form of a hybrid structure that decouples long-term investment from short-term system optimization. This entails a combination of 'interventionist' and market mechanisms as follows:

- *A short-term energy market* for short-term coordination and optimization (dispatch) based on spot electricity prices.
- *Long-term contracts* to support long-term coordination, reduce risks for new entrants, facilitate project financing and ensure resource adequacy. Long-term contracts decouple investment decisions from price movements in the short-term energy market (Roques and Finon, 2017).

The operation of the short-term market is a very well-known process in the power industry, and MENA countries can easily accommodate this. However, the operation of a long-term market is less straightforward. Long-term energy contracts are usually allocated through auctions. Designing auctions that deliver the optimal outcome, considering the context and government objectives, is not a trivial task. It entails significant government coordination alongside dealing with associated risks and unintended outcomes (such as over- or under-procurement). However, useful lessons can be learnt from international experience of auction design.

The standard process of auctions for allocation of long-term contracts requires developers who meet predetermined financial and technical criteria to submit bids in order to develop their generation technology, with the power offtaker signing a contract with the lowest bidder. These auctions can be technology-specific (to scale up a specific technology), technology-neutral (where technologies compete on a level playing field), or multi-technology (competition among several technologies, with the proportion of energy contracted from each determined by the auction outcome). Long-term contracts can facilitate secure revenue streams for investors,[19] whilst competitive auctions ensure lower consumer prices for electricity. The product to be auctioned can be capacity (measured in megawatts, for example) or energy (megawatt hours). While conventional generation can be contracted through energy or capacity auctions, the variability of renewables and underdevelopment of storage technologies or other forms of flexibility services imply that renewables are more suited to energy auctions (they can be moved to capacity auctions once the market is established and participants have gained experience).

Auctions should be conducted at regular intervals to send firm market signals to investors, and non-fulfilment of contracts should result in penalties and ideally some market mechanism to mitigate the impact of non-delivery of contracted quantities.[20] Auctions also require decisions on volumes to be contracted and the method of price discovery.[21] The two primary methods are uniform pricing and a 'pay as bid' approach, which theoretically lead to revenue equivalence under certain assumptions regarding the bidders' risk attitude and informational setting, among others. Selection of a pricing rule in a multi-unit auction setting involves trade-offs and depends on auction environment parameters and the specific objectives of the auctioneer (Hochberg and Poudineh, 2018).

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[18] Exacerbated by caps on the wholesale price, for example due to political reasons, or concerns over market power during scarcity periods. Scarcity pricing helps generators recover fixed costs from the energy-only market and caps may prevent this.

[19] Partly depending on the organization of electricity markets.

[20] The short-term market should be capable of balancing the market in such a situation.

[21] First-price sealed-bid auctions are popular in the energy industry. However, Latin American countries have used a combination of auction types and more than one round of auctions.

Hybrid wholesale markets have been used in some Latin American countries. Brazil provides an example of this model where its wholesale market has three components, as follows (Hochberg and Poudineh, 2018):

- The Regulated Contracting Environment (ACR) hosts auctions for power purchases on behalf of regulated customers, for volumes determined by five-year forecasts submitted by distribution utilities. Auctions allow for contracting over different time periods, ranging from one year to 30-year forward contracts (for large hydro). Utility demand is aggregated and every generator contracts with a distribution utility, thereby spreading power offtaker and credit default risks.
- The Free Contracting Environment (ACL), operating alongside ACR, is where power consumers with demand over 3 MW, generators and power traders can negotiate bilateral contracts.
- Energy reserve auctions are convened as required by the market operator (CCEE), which is also the offtaker, paid for through an energy reserve charge applied to all grid-connected consumers.

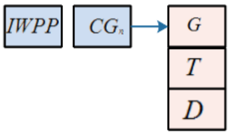
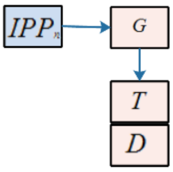
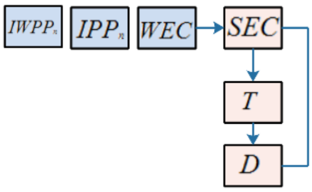
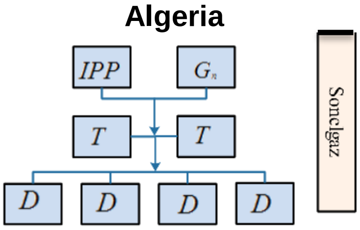
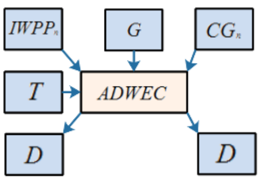
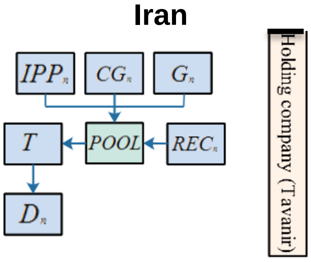
Since 2004, Brazil has contracted the equivalent of 80 GW of capacity through these auctions, comprising roughly 60 GW of clean energy, with prices for some technologies falling by over 50 per cent (Hochberg and Poudineh, 2018). Additionally, Brazil has a short-term balancing mechanism for ACR ('adjustment auctions') with contracts for 3–24 months. All contracts are backed by firm energy certificates (FECs) representing the maximum amount of energy that can be offered, issued by the Ministry of Energy and Mines to every grid-connected generator. The CCEE calculates distribution tariffs and administers the spot market, which accounts for differences between contracted and produced electricity. The National Agency of Electrical Energy (ANEEL), which administers the auctions, [22] uses these tariffs to determine final rates for regulated consumers (Hochberg and Poudineh, 2018).

2.2.5 Future hybrid structure: short-term energy markets with long-term capacity contracts

While long-term energy contracts are currently an effective approach for attracting investment in generation technology, they are not free of distortions. This is specifically an issue in capacity-constrained power systems (Brazil, on the contrary, has an energy-constrained system due to the presence of hydro resources). The coexistence of long-term contracts and short-term energy-only markets risks pricing distortions—most transactions occur in the long-term market, undermining the relevance of the short-term market (market foreclosure) (Peng and Poudineh, 2017). As a result, generators may limit their participation in the short-term market, affecting competition in the short market, and hence prices.

[22] Brazil previously used a two-phase auction process. Under this approach, a descending-clock auction determines first-phase winners, and a sealed-bid auction determines the final winner. The two phases were swapped in 2017 for 'continuous reverse-trade' auctions to address problems with collusion.

Table 1: Steps towards a transition model for MENA countries

MENA model	Model description	Steps towards transition model
Kuwait 	Single-buyer	1. *Unbundle T&D from G* 2. *Innovation-oriented network regulation* 3. *Retail competition for large consumers, regulation for small consumers* 4. *Hybrid wholesale market: LT energy contracts + ST energy market* 5. *LT capacity market + ST energy market*
Qatar 	Single-buyer	1. *Unbundle T&D* 2. *Innovation-oriented network regulation* 3. *Retail competition for large consumers, regulation for small consumers* 4. *Hybrid wholesale market: LT energy contracts + ST energy market* 5. *LT capacity market + ST energy market*
Saudi Arabia 	Single-buyer + unbundled transmission	1. *Unbundle D* 2. *Innovation-oriented network regulation* 3. *Retail competition for large consumers, regulation for small consumers* 4. *Hybrid wholesale market: LT energy contracts + ST energy market* 5. *LT capacity market + ST energy market*
Algeria 	Single-buyer + unbundled transmission and distribution	1. *Innovation-oriented network regulation* 2. *Retail competition for large consumers, regulation for small consumers* 3. *Hybrid wholesale market: LT energy contracts + ST energy market* 4. *LT capacity market + ST energy market*
United Arab Emirates (Abu Dhabi) 	Single-buyer + unbundled transmission and distribution	1. *Innovation-oriented network regulation* 2. *Retail competition for large consumers, regulation for small consumers* 3. *Hybrid wholesale market: LT energy contracts + ST energy market* 4. *LT capacity market + ST energy market*
Iran 	Limited wholesale market	1. *Innovation-oriented network regulation* 2. *Retail competition for large consumers, regulation for small consumers* 3. *Hybrid wholesale market: LT energy contracts + ST energy market* 4. *LT capacity market + ST energy market*

Notes: G = generation; T = transmission; D = distribution; CG = captive generation; WEC = Saudi Water & Electricity Co.; SEC = Saudi Electricity Co.; Sonelgaz = Algerian electricity holding company; ADWEC = Abu Dhabi Water & Electricity Co.; POOL = Iranian mandatory power pool; REC = regional electricity company; Tavanir = Iranian electricity holding company; subscript *n* = multiple entities; LT = long-term; ST = short-term.
Source: Authors.

Even if generators are mandatorily required to participate in the short-term market, they are unlikely to bid rational prices as they may already hold a long-term contract. We therefore argue that, as the economics of renewables improve over time and a market for flexibility is developed, MENA countries can eventually transition from hybrid structures with a long-term energy market to a long-term capacity market for renewables alongside the short-term energy market.[23] This truly separates markets for investment from markets for energy and decisions related to long-term investment from operational decisions on short-term generation choices. This modified hybrid market structure is the next step of the transition model. Table 1 above shows the current structure of electricity markets in MENA countries, and the steps towards the transition model.

Renewables also need to be placed on a level playing field with other types of generators. As the share of renewables grows, operational flexibility becomes important. Yet, in general, renewable generators are not responsible for balancing deviations from their forecasted generation schedule—removing their incentive to improve the quality of their forecasts (Peng and Poudineh, 2017). Renewable generators are also protected from short-term coordination in the wholesale market through priority dispatch, leaving no incentive to curtail production even when this is the optimal option on a system-wide cost basis (Peng and Poudineh, 2017). Thus, at some point renewables need to become responsible for balancing, and priority dispatch for them needs to be removed.

3. Future evolution of MENA electricity markets

An 'ultimate' model of electricity market reform, which reconciles liberalization and renewables integration, is still evolving. The direction that this takes will broadly depend on three factors: development of technologies; development of institutions; and public acceptance and consumer preference. The transition model discussed in this paper is flexible to adapt to future scenarios in the power sector.

3.1 Development of technologies

Technological advances—primarily relating to decentralization and digitalization—will shape the future of electricity markets. Advances on the distribution side include the 'smart grid': a modernized power network where the convergence of power system engineering and intelligent communication systems enables greater flexibility of business and system operations (Farhangi, 2010). Smart meters enable real-time load balancing, giving consumers the option to actively manage their consumption. Smart grids are a complement to microgrids, distributed generation systems capable of functioning as 'islands' or being plugged into the grid, enabling efficient operation.[24]

Another key technological innovation is *blockchain*: a cryptographically secure shared record of transactions updated by a network of computers instead of a central authority (Peng and Poudineh, 2017).[25] In combination with 'big data'[26] and the Internet of Things,[27] blockchain technology can act as the backbone of the industry's smart-grid management system, enabling the automatic diagnosis and reconfiguration of network problems; as traffic no longer goes through a central system, the impact of disruptions is minimized. The development of advanced distribution-side technologies could facilitate decentralized trading platforms (for example peer-to-peer markets)[28] and a diversity of market participants (Peng and Poudineh, 2017). Technological developments in the electricity sector present huge opportunities for MENA countries and are complementary to energy efficiency programmes

[23] We acknowledge that there is a trade-off here between market compatibility and investment incentive. Energy-based long-term contracts provide the strongest incentive for investment in generation capacity, but they can be incompatible with operation of the short-term market. Capacity-based long-term contracts are market compatible, but they may not sufficiently incentivize renewable generators to invest in new capacity.
[24] For instance, minimizing any disruption to the whole grid due to faults in one part.
[25] Blockchain technology is used for cryptocurrency transactions.
[26] Analytics of data with a significantly higher volume, velocity, and value (Poudineh et al., 2017).
[27] A worldwide network of interconnected objects, including 'smart' appliances (Peng and Poudineh, 2017).
[28] A mechanism for small-scale distributed generators to trade electricity.

across the region (for example Saudi Arabia, the United Arab Emirates, and Kuwait), which for instance target the use of more efficient appliances.

On the transmission side are supergrid technologies that aim to connect power systems, as well as integrate renewables from remote locations to the grid, through long-distance high-voltage direct current cables that overlay the existing grid (Peng and Poudineh, 2017). For example, attempts to connect Europe's grid with the MENA region are related to the development of a supergrid. These developments will change the configuration of national markets and necessitate new market design, new operating models and a revised view of the issue of security of supply as cyber security becomes the key in an interconnected power system.

3.2 Development of institutions

Future electricity markets will need entirely new supporting institutions that complement the characteristics of a sector predominantly based on renewable energy. 'Institutions' in this context refer not just to traditional top-down structures, but also to universally accepted interfaces, protocols, and standards to ensure a common communication vocabulary among system components within and between networks (Peng and Poudineh, 2017). Institutions also require a rethinking of the scope and purpose of regulation. For example, while one aspect is the treatment of innovation (as discussed earlier), another is the treatment of storage and demand response, which when commercialized at scale could fundamentally transform electricity sector operations. The current treatment of storage, for instance, regards it as a consumer when power is flowing in, and generator when power is flowing out, leading to the risk of duplicate payments for network use (Robinson and Keay, 2017). Furthermore, new actors may enter the system or existing actors may change their role, and this requires modification to the institutional setting of the power system. For example, as discussed earlier, DNOs may need to evolve their roles outside of the traditional network business into DSOs. A step ahead of this would be DSOs' evolution into distribution system platforms (DSPs): intermediaries that convert data to accessible information—aiding consumers and suppliers alike to make efficient consumption/production choices—connect participants, and reduce transaction costs (Poudineh et al., 2017).[29]

3.3 Public acceptance and consumer preference

Public acceptance and consumer preference will be critical to influencing the future shape of electricity markets. In the initial stages of renewables deployment, public acceptance is needed for support schemes (for example consumption-based levies). At later stages, the uptake of technologies such as smart grids implies that consumers willingly make proactive decisions in changing their consumption patterns (and possibly their daily routines). This, however, requires dealing with the issues such as privacy and customer data management in a proper manner. Similarly, the uptake of supergrids needs widespread political support and hence public backing, requiring their positive externalities to be highlighted (including energy security, complementarity with economic policy, job creation, and equitable distribution of benefits). Finally, with decentralization and the emergence of self-generators as competitors to traditional utilities, there are multiple paths to the liberalization of retail markets. A case in point is California, in which self-generation and the promotion of community choice aggregators have introduced fierce competition with traditional utility companies. Thus, the retail electricity market in California could be considered as liberalized, but in a different way from the traditional sense.

These technological advances, along with changes in consumer preference, as they become more active will shake up our traditional understanding of power sector liberalization. Indeed, peer-to-peer markets enabled by blockchain technology can become a competitor to the traditional vertical setting of electricity markets (wholesale-network-retail) as the known model of liberalization. Given the multiplicity of technologies, as well as their complementarity, future electricity markets could be some

[29] With business models similar to aggregation software services, DSPs could facilitate peer-to-peer markets.

combination of vertical and horizontal structures (prosumer-network-prosumer); which structure ultimately dominates will depend on which technology facilitates the lowest transaction costs and how consumers engage with these two different settings of the power system.

There are several examples of these structural changes in the power sector that have transformed the role of consumers. In the Netherlands, start-up company Vandebron provides an online peer-to-peer energy marketplace platform for renewable energy, through which local renewable electricity generators can sell their energy directly to households and businesses, with only a small flat subscription fee for both sides. As of February 2016, Vandebron hosted 50 producers and 30,000 households on its platform (Parag and Sovacool, 2016). New York State's Public Service Commission adopted a regulatory framework in 2015 allowing utilities to act as a market platform that enables third parties and customers to be active partners in the energy system (Parag and Sovacool, 2016). California's Self-Generation Incentive Program (SGIP) was launched in 2001 and later developed in response to peak load crises,[30] supporting a number of 'behind-the-meter' technologies for commercial and residential users, effectively enabling distributed generation and peer-to-peer trading. The SGIP was reweighted in favour of distributed storage technology in October 2013, when the California Public Utilities Commission adopted a 1,325 MW procurement mandate for electricity storage by 2020. The SGIP contains funding incentives for customer-sited storage, such as a $/kWh rebate for residential consumers based on the size of the battery, with the largest benefits going to early adopters.

3.4 Compatibility of the transition model with future scenarios

The transition model described above is largely compatible with potential outcomes in the future evolution of the electricity sector, which reduce to either greater centralization or more decentralization (or their combination), depending on the three factors identified above and their associated transaction costs.

In a *centralized* scenario, the power sector in the region moves towards large-scale renewable plants (desert-based CSP plants, utility-scale solar PV plants, and onshore and offshore wind farms) and battery storage technologies, with conventional generation technologies (oil and gas) becoming a minority in the system. As renewable technologies create zero marginal costs, a part of short-term market (that is, day ahead) loses its significance, while the long-term capacity component of the market, along with real-time energy and the ancillary service market, remain significant. The transition model is therefore easily adaptable to such a scenario and electricity markets do not have to be redesigned. Large-scale network technologies dominate in this scenario, with regional balancing through the supergrid (for example the GCC grid and the MENA interconnection with Europe). This scenario would require centralized coordinating institutions and widespread public backing for greater regional interconnection and trading among MENA countries. This would require a rethinking of the GCC interconnection from its present perception as a backup (limited to small-scale transfers during outages) to being seen as an opportunity for optimization of the electricity system.

In a *decentralized* scenario, consumers transform into prosumers, with smart-grid technologies and their integration with smarter appliances and devices (Internet of Things) resulting in consumers self-selecting their consumption, selling electricity to each other and to the grid. We argue that the transition model is easily adaptable to this scenario as well, as the capacity element can be introduced into the retail market; that is, consumers can subscribe to a capacity level that best suits them and communicate this to suppliers who can bid in the capacity market on their behalf. This capacity-based decentralized market structure also allows generators/investors to recover their fixed costs, as consumers need to pay the capacity charge regardless of whether they draw energy from the grid (in contrast to decentralized energy-only markets where consumers can 'opt out' of grid-

[30] California's solar PV generation has grown from just 3 gigawatt hours (GWh) in 2008 to 12,571 GWh in 2015, creating problems with variability and demand-supply balance at peak times. See www.energy.ca.gov/almanac/electricity_data/electric_generation_capacity.html.

connected supply, creating uncertainty over the recovery of fixed costs, especially for the network segment). This decentralized structure also opens up potential new markets, such as for flexibility services (Boscan and Poudineh, 2016). A potential concern over introducing capacity payments for retail consumers is equity: consumers who have a low level of consumption could end up paying disproportionately higher charges. However, this can be dealt with through *ex post* measures (for example discounts to low-income consumers).

A combination of the above two scenarios is also possible, but differences in transaction costs and consumer preference imply that one will eventually predominate, or outweigh the other.

4. Conclusion

The tension between liberalization and decarbonization in pioneering electricity markets, such as in the European Union, has arisen partly because renewables were imposed upon a market designed for conventional fossil fuel electricity. MENA countries, by contrast, have the opportunity to design their electricity markets around the incorporation of renewables at the outset and tap into years of international experience gained through trial and error. These countries can adopt market structures that avoid issues related to the perverse incentives of integrated monopolies and counterparty risk of single-buyer models, and also the risk of market breakdown under fully liberalized electricity systems with a high share of non-dispatchable resources.

In relation to the wholesale market design, we have argued that a hybrid structure of short-term coordination (through energy-only markets) combined with long-term contracts is proved to be the way forward for MENA countries during the transition period, particularly given the contexts within which they operate (for example rigid governance structures and underdeveloped institutions as compared with OECD Europe). In the long term, these countries could move towards long-term contracts for capacity, as the electricity sector evolves into one where fossil fuels gradually recede from the generation mix, zero marginal-cost renewables and storage technologies become commercialized and competitive, and participants in the market gain experience.

For the network segment, MENA countries can adopt an innovation-oriented regulatory model, as opposed to traditional incentive regulation with a focus on cost efficiency. The difference between these two approaches is in the incorporation of risk in the model for regulating network companies, given the high degree of uncertainty in the outcome of innovation activities. An input-based regulatory model is an effective approach for early-stage innovation activities such as R&D, whereas an output-oriented model is more suitable for deployment of established technologies. For the allocation of a large innovation fund, a two-stage competition is proved to be the way forward.

The retail market can be opened to competition for large consumers, but for small users it can be regulated without the government distorting retail prices through subsidies. The structure of final electricity prices must not lead to inequitable distribution of system fixed costs or encourage grid defection.

Finally, the advent of prosumers, along with fall in the cost of batteries and advances in information and communication technology, may open up a new path for consumer involvement in the electricity sector. It also may provide a new design for restructuring the power sector in the form of prosumer-network-prosumer as an alternative or complement to the traditional liberalization model of wholesale-network-retail.

A key argument in this paper is that there is no one path to market liberalization, as combinations of technological advances, consumer preference, and institutional changes can offer alternative or complementary approaches to the ‘classical’ model of power sector reform.

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