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Taking Stock of Wholesale Power Markets in Developing Countries

A Literature Review

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Abstract

Although many developing countries have yet to meet the considerable prerequisites for establishing wholesale power markets, a significant minority of larger middle-income countries have introduced diverse markets in the past 25 years. Cost-based pools proved particularly popular in Latin America and look to be a more straightforward starting point than the bid-based pools adopted in some other jurisdictions. Successful design of power markets involves paying careful attention to four guiding principles. First, trading arrangements must ensure efficient and reliable operation of the market, efficiently employing available resources not only to balance aggregate supply and demand, but also to allow congestion management and supply ancillary services. Second, market design should ensure strong participation of the demand side of the market, by allowing large customers to participate directly in the market, and medium ones to see spot market prices through time-of-use tariffs. Third, open access to the power grid should be guaranteed through industry restructuring, removal of barriers to entry of different players, and establishment of a neutral system operator. Fourth, a workable framework for supply adequacy is required to ensure capacity meets demand without imposing supply constraints. This may entail complementing efficient energy price signals with other mechanisms (such as auctions and capacity obligations) to provide adequate incentives for investment in new generation capacity. Experience demonstrates that the early stages of establishing power markets can be challenging and necessitate the creation of regulatory mechanisms for market monitoring that can identify and address emerging design flaws, particularly for abuses of market power. Countries not yet ready to introduce wholesale power markets may still benefit from several emerging regional power markets. Looking ahead, the design of power markets is becoming increasingly complex due to the challenges posed by disruptive technologies such as variable renewable energy, large-scale storage, and increasingly sophisticated demand-side participation.

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Taking Stock of Wholesale Power Markets in Developing Countries: A Literature Review[1]

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1. Introduction

Standard prescriptions for power sector reform envisioned a rather linear path leading towards a fully unbundled and privatized sector organized into a competitive wholesale electricity market. In practice, a variety of power market models have been adopted across developing countries, reflecting local conditions (J. E. Besant-Jones, 2006; Gratwick & Eberhard, 2008). These have followed diverse paths towards the envisioned power market, ranging, for example, from sophisticated markets with brokers, retailers, demand aggregators, and multiple financial instruments (e.g. PJM in the United States); to cost-based pools with long-term supply auctions (e.g. Brazil). In many countries, hybrid markets have been established with continued strong state presence (e.g. Republic of South Africa and the South African Regional Pool; and Norway). Alternative trajectories can also be identified from the experience of reforming countries, including both gradual and abrupt reform efforts. Most strikingly, while some developed countries are moving back towards increased central planning, several developing countries continue to progress with market liberalization (Sen, 2014).

In reality, diverse power market structures and submarkets have emerged since the liberalization of the power sector in developing countries. Comprehensive typologies of market structures are missing in the surveyed literature. Nevertheless, a few important distinctions regarding power market structures are identified as a broad introduction to the wide variety of power markets adopted in different countries and regions. Further details are available from a variety of sources in the literature (Hunt, 2002; KEMA International B.V., 2007; Pérez-Arriaga, 2013; Stoft, 2002).

Wholesale power markets balance supply and demand for power by means of several submarkets in different timescales, ranging from intra-hour balancing operations to long-term contracts. Spot markets for electricity are commonly understood to operate on an hourly basis, often by means of centralized economic dispatch, or self-dispatching by producers complemented by balancing operations coordinated by the operator. Day-ahead and even week-ahead markets complement spot markets in mature wholesale markets, while weekly and daily unit-commitment is a centralized solution to the short-term coordination needed for reliable operation of the system.[3] Various contracts can be employed by market participants on timescales ranging from days and months (e.g. for options and other futures), a few years (medium term) or even one or two decades (long term).

A range of submarkets for products other than energy have been developed, including markets for reserves, capacity, ancillary services, CO_2 emissions and transmission rights. Analyzing wholesale power markets necessarily requires addressing each of the existing and potentially relevant submarkets, as well as the overall structure of the market and the interaction between submarkets. Multiple trading arrangements apply to different submarkets, ranging from bilateral to centralized markets. Some of the main designs that can be identified are: bilateral markets complemented by balancing markets or mechanisms (e.g. EU, UK); bid-based markets driven by market clearing and security-constrained economic dispatch (e.g. PJM, New Zealand, Australian

[3] Among others, operating reserves need to be determined before actual operation to allow the system operator to balance supply and demand respecting technical constraints.

NEM, Ontario, Singapore, Ireland); and mandatory cost-based power pools (e.g. South America, the Republic of Korea). Furthermore, bilateral or centralized arrangements can be adopted for both scheduling (e.g. day-ahead or unit-commitment) and dispatch decisions.

Trading arrangements also vary regarding risk-hedging and contracting instruments available to market participants. EU allows futures to be traded through power-exchanges, which extend throughout several countries, a design which should increase liquidity and encourage competition. In contrast, South American power pools often rely on long-term contracts between generators and distributors or large consumers, thus providing bankability for new investments. Hence, wholesale markets, contracts and bilateral transactions have different roles in different market designs. For example, while US ISO's approach to supply adequacy relies on capacity markets tightly coupled to short-term energy markets, South American pools often rely on competition for long-term contracts as the primary source of investment.

Wholesale power markets have been successfully established in countries with favorable conditions (mostly developed countries), while experience with wholesale competition in developing countries is rather scarce. A large body of literature discusses wholesale market reforms in developed countries (Joskow, 2008b; F. P. Sioshansi, 2008; F. P. Sioshansi & Pfaffenberger, 2006). Lessons from reform in developed countries are considered in this review when relevant, particularly those emanating from the California electricity crisis in early reform stages (J. E. Besant-Jones, 2006, p. 121; J. Besant-Jones & Tenenbaum, 2001). Experience with wholesale power markets in developing countries is relatively scarcer or less documented. Many countries that have undertaken reform efforts to their power sector have not implemented competitive wholesale markets, let alone retail competition (J. E. Besant-Jones, 2006; F. P. Sioshansi, 2013, pt. III; Vagliasindi & Besant-Jones, 2013; Victor & Heller, 2007).

The adoption of wholesale power markets in developing countries has been relatively limited to date and unevenly spread geographically (Table 1). The countries that have progressed the most, in terms of developing competitive electricity markets, are in Latin America and the Caribbean (LAC) and in Europe and Central Asia. In Africa, the Middle East, and South Asia, progress to date is generally limited to long-term contracts by independent power producers (IPPs) to supply incumbent utilities. Some countries in East Asia, for example, have made tentative steps to further their reforms (Vagliasindi & Besant-Jones, 2013).

Table 1 Overview of existing wholesale power markets in developing countries

Country	Year of market establishment	Type of market design established	Market size at establishment (yearly energy demand in TWh)
Nicaragua	1998	Cost-based	2.0
Bolivia	1992	Cost-based	2.3
Guatemala	1998	Cost based	4.3
Ecuador	1996	Cost based	9.1
Dominican Republic	2001	Cost based	9.7
Chile	1982	Cost-based	11.9
Peru	1993	Cost-based	14.5
Colombia	1994	Centralized bid-based	40.8
Philippines	2001	Centralized bid-based	45.2
Romania	2000	Centralized bid-based	49.6
Argentina	1992	Cost-based	53.4
Czech Republic	2001	Centralized bid-based	69.9
Poland	1999	Cost based	130.0
Turkey	2013	Centralized bid-based	228.3
Brazil	1998	Bid-based power pool centralized	317.0
India	2003	Partially centralized bid based	614.4
Russian Federation	2011	Bid-based	996.8

Table 2 Overview of developing countries currently in transition towards a wholesale power market

Country	Target year for full market operation	Transitional arrangement	Target Type of market
Vietnam	2024	Single-buyer by 2014, wholesale market by 2021	Wholesale (bid-based) and retail competition
Bangladesh	-	-	-
Pakistan	2020	Single-buyer plus	-
Kazakhstan	-	-	-
Egypt, Arab Rep.	2023	Three years for restructuring the single-buyer to create TSO	Wholesale and retail competition
Nigeria	-	Single buyer currently to be followed by bilateral contracts	Bilateral contracts plus spot market balancing mechanism
Mexico	2018	Cost-based pool until 2018	Centralized multi-settlement bid-based, and retail competition
Ukraine	2019	-	Bilateral with day-ahead, intraday and balancing markets

In many other countries hybrid approaches have been taken to incorporate some degree of market forces in centralized markets that continue to be dominated by state actors. Competitive supply auctions allow competition for the market where wholesale competition is limited, for example in single-buyer markets and in hybrid South American markets. Meanwhile, market forces can be incorporated in competitive tendering of new investments in generation plants and transmission networks, despite the persisting need for central planning and regulatory cost allocation procedures instead of relying on markets to drive new investments.

This literature review aims at summarizing the current thinking and recent experience on wholesale power market reforms in developing countries. Hence, the focus is specifically on those aspects of wholesale market design that are most relevant to current practice in developing countries,[4] leading to lesser emphasis on some more complex topics such as retail competition and smart grids. However, it is important to acknowledge that the power markets literature specific to developing country experiences is relatively sparse, particularly since 2006.[5]

This paper is organized as follows. The discussion first turns to identifying the considerable number of preconditions that a developing country needs to have in place before it is even relevant to consider the establishment of a wholesale power market (Section 2). For some developing countries that lack these preconditions, participating in a larger regional power market may be a good alternative (Section 3). For countries with the potential to develop their own wholesale power market in the future, the Single Buyer Model has often been put forward as an intermediate stage bringing certain challenges of its own (Section 4). For countries that are ready, the design of a wholesale power market presents a range of issues and a number of different alternatives that are covered in Section 5. The transition will need to be managed (Section 6), and, with the advent of technological disruption in the form of variable renewable energy, storage, and enhanced demand participation, the wholesale power markets of the future will face additional design challenges (Section 6). The main findings of the review are summarized in the concluding Section 7.

[4] Extensive treatment of the experience of developed countries with wholesale power markets can be found in (F. P. Sioshansi, 2008, 2013; F. P. Sioshansi & Pfaffenberger, 2006).
[5] The pre-2006 experience is comprehensively analyzed in Besant-Jones (2006). Recent electricity reform experiences in developing countries have been analyzed in (Vagliasindi & Besant-Jones, 2013), although with little emphasis on wholesale competition.

2. What Are the Preconditions for Wholesale Power Markets?

The introduction of wholesale competition is a relatively complex measure intended to further improve efficiency in a sector that is already functioning relatively well. Wholesale competition may induce efficiency gains in a restructured power industry, and may also help in passing these gains to final customers. However, in many developing countries the problems faced by the power sector may be much more fundamental, including underpricing of electricity, operational inefficiencies of the utilities, and lack of a stable regulatory environment to promote investment. The introduction of a wholesale power market will not contribute to addressing any of these basic problems, and should be deferred until other measures have been taken to improve the situation in distressed power systems. For example, integrating Independent Power Producers might be a better alternative to alleviate serious capacity shortages, while reforms to the distribution sector might be more effective in improving the quality of electric service and the financial sustainability of the power industry.

The majority of developing countries does not present the full range of preconditions for a wholesale power market, and can only make limited use of market forces. The list of prerequisites for a wholesale power market to be established and function effectively is quite lengthy, and is only met by a relatively small proportion of developing countries. These conditions may be grouped into a number of categories including the financial sustainability of the power sector so that entities are sufficiently creditworthy to provide payment security, the scale and structure of the generation segment and its ability to support competition, the quality of institutions available to oversee and regulate the functioning of a complex market, as well as the broader economic, political and social conditions of the country.

First, the financial health of the power industry is an absolute pre-requisite for the introduction of competition. Distribution utilities, which are the main buyers in the market, need to be creditworthy and financially sustainable, otherwise there will be no payment security and confidence in market transactions will break down. In many developing countries, end-user tariffs are far from being cost reflective, and this combined with serious operational inefficiencies, leaves many utilities in a financially precarious condition (Huenteler, Dobozi, Balabanyan, & Banerjee, 2017). It is virtually impossible to undertake any serious power sector reform – particularly the creation of a wholesale power market – unless a government is politically committed to closing the revenue-cost gap as its first priority (J. Besant-Jones & Tenenbaum, 2001; Jamasb, Nepal, & Timilsina, 2015).

Payment integrity is needed along the entire electric supply chain for unbundled power sectors, entailing strong payment enforcement between distributors and generators. Again, this remains a challenge in many developing countries with distribution utilities facing arrears from their own customers and getting into arrears with their payments to generators. The circular debt crisis in the unbundled power sector in Pakistan provides a clear illustration of these problems (Kessides, 2013). The situation can be further exacerbated where generators are IPPs with Power Purchase Agreements denominated in foreign currency, where a devaluation of the exchange rate can overnight render electricity purchases unaffordable for distributors whose tariffs are denominated in local currency.

Without these conditions in place, wholesale competition will not be fully effective, and can even contribute to the further deterioration of the power sector rather than its improvement. Opening wholesale competition under serious non-payment problems proved to be a poor reform strategy in Ukraine and other countries in Eastern Europe and the Former Soviet Union during the 1990s (V. Krishnaswamy, 1999; Venkataraman Krishnaswamy & Stuggins, 2003). In Ukraine, poor enforcement of payments led to a crisis where suppliers received little cash, and delinquent distributors withheld from the wholesale market the little cash they did receive. Even the little cash allocated by the Ministry to the distributors did not cover the costs of their distribution networks and customer services (J. E. Besant-Jones, 2006, p. 62).

Reforms to the distribution segment should be prioritized over introduction of wholesale power markets prior to the achievement of cost recovery (Victor & Heller, 2007, p. 297). Financially sustainable and creditworthy electric utilities facilitate private financing for the operations, maintenance, rehabilitation, and urgently needed expansions of the electricity sector (USAID, 2004, p. 32). Commercially viable distributors whose commitments to buy energy would entice more investors into the generation sector are clearly important for wholesale competition, especially in developing countries with limited capacity, excess demand and rapid projected growth in demand (Bacon & Besant-Jones, 2002, p. 15; Brown, 2002, p. 23; Kessides, 2004, p. 164).[6]

Second, a generation sector that provides scope for genuine competition among suppliers is another fundamental precondition for wholesale power markets. The scope for competition in the generation segment depends on several factors, including the size of the power system, the market structure in the power generation segment, an adequate demand-supply margin, the competitiveness of upstream fuel markets, and the absence of transmission bottlenecks. Each of these is described in further detail below.

The power system needs to be large enough to accommodate many buyers and sellers. A power system size of 1,000 MW is currently accepted as a valid threshold below which unbundling may not be advisable, let alone wholesale competition (J. E. Besant-Jones, 2006; Vagliasindi & Besant-Jones, 2013).[7] However, the minimum size threshold for wholesale power markets may be larger and needs to consider additional factors. To begin with, the system must be large enough to accommodate a significant number of generation plants operating at minimum efficient scale or beyond. Furthermore, there are fixed costs associated with the establishment of a wholesale power market, including the development of associated institutions and technological platforms, while, all other things equal, the benefits of wholesale power trade in terms of enhanced efficiency are likely to be proportional to the size of the power market. It follows that the balance between costs and benefits will become more attractive at larger system sizes, potentially 3,000

[6] The lack of creditworthy buyers of electricity is one of the reasons for IPPs to require long-term PPAs with government backed guarantees in order to finance new investments in many developing countries; and for establishing a single-buyer market or compulsory pool that relieves non-payment risks from generators (Arizu et al., 2006; J. E. Besant-Jones, 2006, p. 74)).

[7] Country income is the other major factor that has shaped reforms in developing countries. However, income has a relatively stronger influence than power system size on the roles of the public and private sectors and on access and affordability to electricity services; while power system size has a relatively stronger influence on market structure (J. E. Besant-Jones, 2006). Therefore, power system size is more relevant for the power markets theme.

MW and beyond. In practice, only around 10 percent of countries with small power systems (under 5,000 MW) have introduced wholesale markets, compared with over three-quarters of countries with power systems above 20,000 MW. Furthermore, “the experience of Ukraine suggests that, rather than market size, the main constraint on the feasibility of wholesale markets to operate is the ability of new generation companies to enter the market, access transmission resources on a non- discriminatory basis and enter into enforceable contracts with new or existing buyers” (Maurer, Bogetic, & Kessides, 2007).

In addition, the underlying structure of generation needs to provide adequate competition at the margin of supply. The condition of four or more generating companies competing at the margin of supply during valley, shoulder and peak hours, seems to be accepted as a general requirement for wholesale competition to be effective (J. E. Besant-Jones, 2006, p. 77; D. Newbery, 2002, p. 6).[8] The potential competition in generation is closely related to the resource mix and the share of inflexible baseload generation plants of the given country (e.g. nuclear and coal-fired power plants), since under such circumstances it is more likely that only a few firms with flexible gas or oil generation plants (more flexible to respond to price signals) compete in the margin of supply, setting the price. These structural problems should be dealt with before introducing wholesale competition; for example, by means of effective horizontal separation of generation assets.

Moreover, an adequate margin between supply and demand for power generation capacity is needed to make competition meaningful. There must be sufficient firms with spare capacity to compete by increasing output (Diaconu, Oprescu, & Pittman, 2009; S. Littlechild, 2000, p. 19; Pittman, 2014, pp. 161–163). If the electricity market is tight, it follows that almost all available capacity will always be needed, reducing any scope for competition among suppliers. According to the literature, a reserve margin that falls below 10 percent, could be expected to lead to volatile wholesale markets and high prices even if the actual market structure is fairly competitive (D. Newbery, 2002, p. 6). Therefore, countries facing serious supply adequacy problems – which again accounts for many in the developing world – should address the lack of investment in new generation capacity before considering the introduction of wholesale competition.

Competitive power markets need to be underpinned by competitive fuel markets in countries reliant on thermal power generation. Liberalization of fuel markets is an essential requirement for the development of competition among power generators.[9] In many developing countries, fuel markets are tightly controlled under state-owned monopolies that usually produce a limited range of fuel products under rigidly controlled prices, and struggle to meet even existing levels of domestic demand. Competition may be limited by concerns regarding discriminatory behavior from fuel suppliers related to electricity generators, particularly between state-owned fuel suppliers and state-owned generators.[10] Fuel availability at competitive prices, together with

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[8] There are problems in using standard tests for market concentration, such as the HHI for either capacity or output, for what matters is the extent of competition between generators with bids near the market clearing price (D. Newbery, 2002).

[9] Fuel costs amount to at least 60 percent of the total costs of thermal power generation. Also, the greater the options for fuel choice, the greater the potential for competition among investors in the power generation market.

[10] For example, if a generator is owned by or affiliated with a company that provides natural gas transportation to competing generators, this corporate relationship could be used to put its competitors at a competitive disadvantage (J. Besant-Jones & Tenenbaum, 2001, p. 14).

diversity in fuel supply sources, are required for enhancing wholesale competition and facilitating entry of new competitors with efficient generating plants (J. E. Besant-Jones, 2006, p. 77; J. Besant-Jones & Tenenbaum, 2001).

Transmission bottlenecks can create market power in generation even in large power systems with apparently competitive market structures. Countries must ensure that a well-functioning transmission grid is in place at the time of reform. Considering the small share of transmission in total system costs, it is important to ensure that the grid supports the reform through its initial years. Network congestion, barriers to access and vertical integration can lead to market power and limit competition and new entry (Jamasb, 2006, p. 25). Serious transmission bottlenecks need to be alleviated before establishing wholesale competition. Transmission capacity enhances efficiency and reliability of the electricity supply by allowing a better utilization of resources, and also limits the extent of local market power abuse by generators shielded from the rest of the market by transmission constraints (at least in some hours). The impact of transmission bottlenecks in markets opened to wholesale competition has proven to be significant both in developed and developing countries (Hugh Rudnick, Araneda, & Mocarquer, 2009; Ryan, 2014; Wolak, 2003a).

Third, country institutions and governance constitute another important precondition playing an important role in the success of electricity reforms and wholesale power markets[11] (Jamasb, Mota, Newbery, & Pollitt, 2005). The investment climate of the country is heavily influenced by the institutional environment. In many developing countries, electricity reforms take place within institutional settings that are characterized by unstable political systems, interventionist governments, unclear legislation on property rights, lack of judicial independence and credibility, and corruption. Emerging empirical evidence supports the importance of establishing appropriate institutional and regulatory framework in line with the institutional endowment of the country (Jamasb, 2006, p. 23). Nonetheless, careful design and implementation of reforms is needed even under favorable institutional conditions, as shown by the California electricity crisis.[12]

Power markets require the legal infrastructure for dispute resolution in a rapid, fair, and competent manner. This means that there should be mechanisms to enforce court decisions and property rights through courts and arbitration (J. E. Besant-Jones, 2006, p. 77). Establishment of credible dispute resolution and appeal procedures can reduce the risk of regulatory taking[13] and compensate for the lack of an independent judiciary. For example, in Bolivia and Chile, a new authority was established to resolve the disputes between regulators and companies (Jamasb, 2006).

A sound regulatory framework will help to reduce risk perceptions, attract investment and keep financing costs down. Domestic capital markets are too undeveloped to replace foreign finance or to provide a market assessment of performance by power suppliers and regulators. Hence,

[11] Institutional factors refer to sector-level legal and regulatory frameworks that influence and support the continuity of the reform process (Jamasb et al., 2005).

[12] The California electricity crisis occurred because of poor market design, among other issues, despite strong institutional endowments (in California, the state and national regulators have existed for more than 60 years and have established a good track record of honoring their commitments) (J. Besant-Jones & Tenenbaum, 2001). FERC's management of the crisis has also been heavily criticized (Wolak, 2003b).

[13] Regulatory takings are loss of value following a change in regulatory policy (Brennan & Boyd, 1997).

developing countries should avoid giving perceptions of excessive risk in their power sectors to foreign investors in the global competition for finance. For example, protection against major uncertainty in the regulation of tariffs and licensing is needed to attract private investors during the period following reforms until a good record has been established by the government and the new regulator. This requires that regulatory powers over electricity prices, for example, be limited to applying rules and regulations laid down in secondary legislation for a specific period following privatization of distribution and supply. This approach can be implemented without undermining the long-term regulatory framework by granting vesting contracts to the new distribution companies for a limited period (approximately 5 years), during which certain regulated variables are specified (Bacon & Besant-Jones, 2002, p. 14).

Finally, wholesale market reforms and their outcomes are shaped by the overall macroeconomic, political and social environment. Macroeconomic, political and social conditions cannot be separated from the analysis of the initial design of reform, its sustainability and subsequent adaptations or even reversions back from wholesale competition. The experience in most East European and Former Soviet Union countries clearly indicates that it is extremely difficult to carry out structural reforms of the sector and attract private investors during conditions of economic turmoil (Venkataraman Krishnaswamy & Stuggins, 2003, p. 7). In Ukraine, for instance, repeated attempts to breathe life into the spot generation market have failed since 1996, and most generation trades were arranged on an ad hoc bilateral basis among generators and distributors or final consumers by 2007 (Maurer et al., 2007, p. 69; Pittman, 2015[14]). The cases of Argentina (M. Pollitt, 2009) and Pakistan (Kessides, 2013) also illustrate the impact of the macroeconomic, political and social environment on the design, implementation and outcomes of electricity sector reforms. Nigeria has also recently embarked on the path towards a wholesale electricity market and certainly offers the requisite scale of power system. However, the country's power sector remains beset by many other fundamental problems, including capacity shortages, governance issues, payment security issues, and operational inefficiencies that will need to be addressed before an effective power market can be envisaged (Gatugel Usman, Abbasoglu, Tekbiyik Ersoy, & Fahrioglu, 2015).

[14] Russell Pittman, 2015, "Restructuring Ukraine's Electricity Sector: What Are We Trying to Accomplish?" http://voxukraine.org/2015/02/07/restructuring-ukraines-electricity-sector-what-are-we-trying-to-accomplish/#_edn3. Retrieved May 4th, 2016.

3. What Is the Role of Regional Power Markets?

Regional integration of electricity markets is a growing trend among developing countries with large potential benefits. Such markets are being developed in Southern and West Africa, Central America and the South Asia region.[15] Regional markets are at varying stages of development, but typically evolve from bilateral contracts (such as the West Africa Power Pool - WAPP) towards organized power pools (such as the Central American Power Market – SIEPAC)[16] (Table 3). Economic studies suggest that the benefits of cross-border power exchanges can be substantial, including arbitrage between high and low-cost sources of electricity in neighboring countries, optimizing the use of existing resources, and improving supply adequacy, among others (Raineri et al., 2013).

Regional power markets may provide an opportunity for smaller countries to enjoy some of the benefits of power trade, as long as other conditions are met. For countries whose power systems are too small to meet the necessary structural preconditions for a domestic wholesale power market in the foreseeable future, participating in a regional market can bring a number of similar benefits, including competitive price signals, and sharing of reserve margins. In South Asia, for instance, Nepal is increasingly involved in trading power into the Indian wholesale power market. In West Africa, a number of smaller economies benefit from importing power from larger neighboring systems. Nevertheless, to participate effectively in a regional power market, it is still relevant to ensure that the power sector is financially solid and creditworthy to undertake cross-border trading transactions.

Several institutional and market design challenges need to be addressed in order to exploit the benefits of regional integration in developing countries. Challenges and lessons related to wholesale power markets design and implementation are discussed next, drawing heavily from (Oseni & Pollitt, 2016). Issues related to regulation and political economy are not developed in depth here.[17]

First, a broader pre-commitment to free trade is an essential prerequisite for regional integration of electricity markets to be successful (Oseni & Pollitt, 2016, pp. 633–4). It is not clear that electricity can be traded easily without a prior commitment to the creation of a free trade area, notwithstanding the additional parallel trading arrangements needed to support electricity trade.

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[15] Regional integration of markets is considered to be a recently growing trend because Besant-Jones only briefly comments on the benefits of integration for smaller countries; while literature references on regional integration of electricity markets in developing countries tend to be more recent.

[16] An integrated market may encompass various markets (e.g. spot and day-ahead) with differing trading arrangements (e.g. bilateral trading, and power pools), just as any power market.

[17] For further details on subjects not directly related to power markets (such as the broader free-trade arrangements; and negotiation issues between multiple countries), refer to (Oseni & Pollitt, 2016) and the other references cited above.

Table 3 Summary of regional integration of power markets in selected regions.

Region	Current State of Regional Electricity Markets Integration
South Africa	South Africa Power Pool (SAPP) has been established for over 20 years with relative success, driven by surplus power from South Africa (despite domestic load shedding in 2014 by South Africa's Eskom). Large traded volumes (6 MW in average, comparable to 13 MW in average in NordPool, during 2012) from South Africa to its neighbors, albeit mostly via bilateral contracts. Short-term markets are in place since 2001 but amount for little trading overall (Oseni & Pollitt, 2014).
West Africa	West African Power Pool (WAPP) yet to resume market operation at pool level. Current power exchanges are based on bilateral contracts not guided by WAPP. Slow evolution of regional trading due to lack of transmission links and shortage of generation (Oseni & Pollitt, 2014).
Central America	Central American Power Market (MER) with spot market since 2002, although limited volumes are currently traded across borders. Eventual building of 1200km SIEPAC transmission line with 300 MW capacity (Oseni & Pollitt, 2014).
South America	19 operating bilateral interconnections, including three binational power plants. Initiatives are underway to integrate Andean Markets (Bolivia, Colombia, Ecuador, Peru and Chile). However, distrust between neighboring states obstructs the evolution of electric integration (Raineri et al., 2013).
South Asia	Currently lacking long-term commitments despite large potential benefits of regional integration, particularly for a joint Bangladesh, Bhutan, Nepal and India market, aimed at exploiting the considerable and under-utilized hydro potential of Bhutan and Nepal; the export of gas based generation from Bangladesh (Oseni & Pollitt, 2016). Policy, institutional, and political barriers impede a SAR integrated electricity market, for example: lack of confidence and trust, trade-restrictive policies, and challenges in creating effective regional bodies for cross-border coordination (Singh, Jamasb, Nepal, & Toman, 2015). Developing domestic power markets (most of which are single-buyer structures) and harmonizing grid codes and regulations among countries has been suggested for further integration in the region (IEA, 2015; Wu, 2013).
East Asia	Ongoing integration effort underway in the Greater Mekong Subregion, comprising Cambodia, the Lao People's Democratic Republic (Lao PDR), Myanmar, Thailand, Viet Nam, and the Guangxi Zhuang Autonomous Region and Yunnan Province of the People's Republic of China (PRC). Trade is envisioned to evolve gradually from PPAs to an integrated power market (Andrews-Speed, 2016).
EU / US	The EU and particularly Nord Pool are currently in advanced stages of integration, featuring regional power exchanges and energy prices. Mature regional markets also exist in the US (e.g. PJM), although further regional integration and more transmission interconnection capacity is needed.

Source: own, drawing upon references cited in the table.

Second, adequate transmission capacity is required, capacity enabled by international agreements for expanding transmission. For example, WAPP has not evolved from bilateral trading to an organized power pool, while SAPP and MER's lack of transmission capacity has limited the significance of the corresponding power pools. Note that adequate transmission capacity is required in interconnections and also within the power system of each country.[18]

Third, feasible technical and economic benefits must obviously exist for trade to occur. Clearly, there must be a price differential between the potential parties to the trade.[19] Other considerations, such as the alteration of electricity prices (which may increase for the exporter while decreasing for the importer), as well as the adjustment of factors of production, determine the potential benefits of international trade.[20] Thus, the viability (or otherwise) of an international power pool should be assessed in advance by a careful cost-benefit analysis.

Fourth, strong, efficient and independent institutions are needed to ensure effective functioning of electricity markets, although these are not strictly required for international trade. Both a cross border regulatory agency and an efficient operator responsible for administration of an integrated power pool improve the functioning of regional markets (Oseni & Pollitt, 2016, p. 635). An integrated power pool is required for organizing trading needs as well as an efficient market operator who can oversee and sanction the activities of market participants in order to prevent predatory pricing, non-disclosure of capacity, and other forms of unruly behavior. Moreover, external regulatory oversight is beneficial. For example, institutions of competition policy enforcement across a free trade area are not necessary but do act as regulator of mergers and market power in cross jurisdictional power pools. As in any other electricity market, institutional arrangements and market design issues need attention in regional electricity markets.

Finally, regional electricity markets should progress from a small number of countries towards increasingly competitive wholesale arrangements, guided by a clear timebound roadmap (Oseni & Pollitt, 2016, p. 636). The most integrated markets are those that have grown organically rather than those that deliberately started with a large number of jurisdictions. Starting small means that large gains from trading can be demonstrated and that new parties willingly opt in to an existing working arrangement. This would seem to offer more chance of steady deep progress, rather than prolonged initial development periods and thin trading. Organic and rapid growth of the market requires that participants develop and keep a timetable with clear objectives and details of the procedures or processes required. In terms of market design, the regional electricity market should evolve towards the use of day-ahead markets and / or real-time markets, which facilitates more trade and greater market efficiency.

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[18] Loop flows in the electricity system mean that the ability to export / import electricity across one transmission link is dependent on the absence of congestion on other transmission lines, which may be internal to each country.

[19] In many countries of WAPP this is not the case, in the sense that the price an importing country (e.g. Ghana) would be willing to pay for a kWh is less than the willingness to pay of demand for a kWh within the potential exporting country (e.g. Nigeria). In theory this country should be exporting only after satisfying its latent domestic demand. This fact may explain the slowness of the development of international interconnection from countries with favorable export potential (Oseni & Pollitt, 2016, p. 634).

[20] Refer to (Oseni & Pollitt, 2016, p. 629) for a theoretical discussion of the factors that affect benefits of international electricity trade.

4. What Are the Intermediate Stages on the Path to Wholesale Power Markets?

Given the demanding prerequisites for wholesale power markets, many developing countries find themselves at the intermediate stage with the Single Buyer Model. In a pure single-buyer model only the existing integrated monopoly in any area is permitted to buy power from a number of competing generators and/or Independent Power Producers. IPPs may only sell at regulated prices to the existing utilities, which still have a complete monopoly over all final customers (Hunt, 2002).[21] In developing countries, IPPs have generally sold their output to the state-owned single buyer on the basis of a long-term PPA with a state-backed guarantee for the off-taking utility's performance. Under this market structure, competition may take place for the market through tendering of IPPs, and within the market as different generators compete to sell to the single buyer.

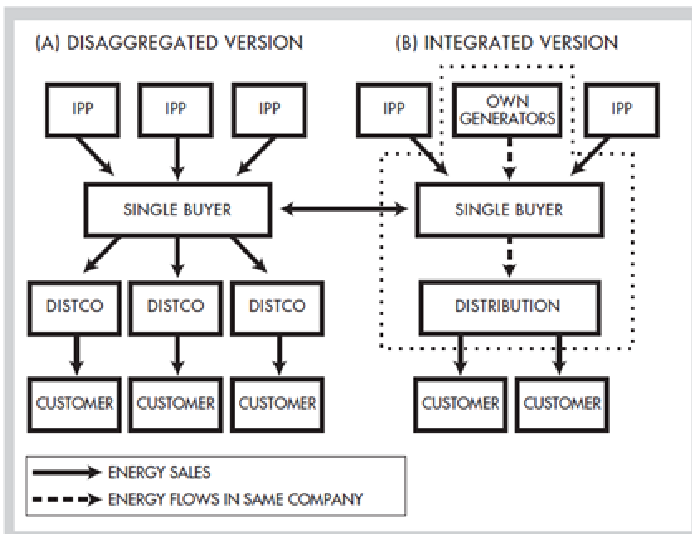

Figure 1 Single Buyer Model. Source: (Hunt, 2002)

The Single-Buyer Model is considered by some to be a second best to comprehensive restructuring, which allows for gradual transition towards fully wholesale competitive markets (Vagliasindi & Besant-Jones, 2013). The Single Buyer Model,[22] the argument goes, is a relatively easy to implement interim market structure between vertically integrated monopoly and wholesale competition. In a transition strategy from monopoly to wholesale competition the Single Buyer Model could help launch the reform process by showing the benefits of private investment and

[21] There are many variants to the single-buyer model, all with a central entity aggregating the load, playing some role in the procuring of energy to serve that load, and allocating this energy among different consumers or distribution companies. The term "centralized purchasing agency" has been proposed since it is more general and comprehends markets where the agency did not buy at all (Arizu et al., 2006). However, we adopt the simpler and more commonly known term "single-buyer" since (Arizu et al., 2006) cites the experience of developed countries to argue for a more general term.

[22] Independent Power Producers (IPPs) are implied when referring to the Single Buyer Model (but not the other way around), since the Single Buyer Model is a market model which comprises IPPs.

management. The most important of those benefits is the alleviation of supply shortages by means of introducing IPPs to an industry with limited financing capabilities. Turkey provides one example of a transition from single-buyer market to a wholesale competitive market (Vagliasindi & Besant-Jones, 2013, Chapter 11).

However, experience of developing countries with the Single Buyer Model shows that design and implementation failures carry risks for power sector outcomes. It has been argued that the Single Buyer Model "has major disadvantages in developing countries: it invites corruption, weakens payment discipline, and imposes large contingent liabilities on the government" (Lovei, 2000). Furthermore, Single Buyer Model markets have often relied on long-term inflexible PPAs which deter the evolution of competition and lower the overall efficiency of the power generation sector. On the other hand, careful design has been said to mitigate problems such as inflexible contractual arrangements, transparency and corruption, in Single Buyer Model markets (Arizu, Gencer, & Maurer, 2006). Nevertheless, Single Buyer Model risks may not be avoidable by liberalizing electricity markets, as too many countries lack the necessary preconditions to make that a plausible solution (D. Newbery, 2002, p. 31).

Despite the on-going debate on the single buyer model, these hybrid or interim arrangements will remain widespread in developing countries at least for the foreseeable future. Based on the scarce available literature, disagreement seems to persist regarding the advantages and design elements for adopting the Single Buyer Model as a strategy for improving power sector performance. Nevertheless, the Single Buyer Model has been adopted in many developing countries, mostly in Asia (India, Pakistan, and Indonesia, among others) and Africa. Particularly in Africa, hybrid generation markets consisting of state-owned utilities and IPPs are expected to be around at least for the foreseeable future (Malgas & Eberhard, 2011). As of 2015, about 40 percent of developing countries had adopted some form of the Single Buyer Model. In about half of these cases, the incumbent utility remained vertically integrated with some interests in generation, while in the other half, the incumbent utility was fully divested from generation activities (Foster et al., 2017).

The Single Buyer Model relies on IPPs, which need to strike a delicate balance between reducing private investment risk, and transferring revenue risk from private investors to the single-buyer (often the state-owned utility). The Single Buyer Model requires long-term (life-of-plant) contracts to be signed between generators and the public utility, given the absence of a market and the significant governance risks associated with investing in developing countries (J. E. Besant-Jones, 2006; Hunt, 2002; D. Newbery, 2002). Long-term contracts allocate these risks between IPPs and the single-buyer (and/or government). Where IPPs sign long-term PPAs, they generally accept construction and operating risks. In many cases, they shared fuel availability risk with fuel suppliers. However, IPPs are generally insulated through take-or-pay provisions[23] against demand risk, dispatch risk, price risk, and exchange rate risk (Venkataraman Krishnaswamy & Stuggins, 2003, p. 19). The cumulative obligations to purchase power from IPPs exposes power utilities in many countries to serious financial risks, for example, Indonesia, Pakistan, and Philippines due to

[23] Under take-or-pay provisions the purchaser commits to purchasing a given level of output of the plant, independent of the demand level actually realized or the more general condition operations. Hence, the IPP will produce even if the variable cost of this power is higher than that of other plants on the system. Moreover, when retail sales fall below forecast levels, utilities are obliged to continue payments to IPPs for energy that they do not need (J. E. Besant-Jones, 2006).

the 1997 Asian financial crisis. Such problems ultimately led state-owned utilities to default payments to IPPs in Indonesia and Pakistan (J. E. Besant-Jones, 2006, p. 68,70; Gray & Irwin, 2003).

IPP contracts have often precluded the efficient use of plant output by means of take-or-pay provisions or by making the generators non-dispatchable. IPPs either fear that the system operator would discriminate against them (Hunt, 2002), or require revenue certainty to compensate for country-specific risks. Also, IPPs are usually not required by their contracts to provide ancillary services or to participate in congestion management measures (Halpern & Woolf, 2001, p. 5). In less developed countries where reliability of supply is a serious problem, paying generators to provide ancillary services represents a small price to pay for an enormous saving in the cost of attempting to maintain some measure of system security and continuity of supply through crisis management (Halpern & Woolf, 2001, p. 24).

A transparent process in the form of competitive bidding for selecting IPPs is critical to obtaining the potential benefits they offer. Competitive tendering can indeed considerably reduce the cost of generation, particularly compared to bilateral negotiations between the incumbent single-buyer and a selected generation company (D. Newbery, 2002). Contracts concluded under nontransparent processes attract allegations of corruption and expose these contracts to pressure for renegotiation (in Guatemala, Pakistan, Thailand), and even cancellation (in India, Indonesia and Tanzania). Much of this risk of renegotiation can be avoided by obliging IPPs to earn the right to enter into PPAs under a competitive bidding process (J. E. Besant-Jones, 2006).

Competitive tendering should compare PPAs that specify both the availability payment for capacity and an energy payment, linked to domestic prices and –ideally– indigenous fuels (D. Newbery, 2002, p. 27). Such two-part price structure provides bankability for financing IPPs while allowing efficient use of plant output by the power system operator. One part of the IPP price is a periodic availability charge that covers all the costs covered by the PPA (except for fuel and variable O&M costs) which provides bankability. The second part covers fuel and variable O&M costs based on a rate that is applied to the actual amount of energy that is provided under the PPA, which provides the system operator with the correct price signals for dispatching IPP plants efficiently (J. E. Besant-Jones, 2006, p. 70).[24] In Bangladesh, PPAs were signed with IPPs building high-efficiency CCGT burning low-cost indigenous gas. Some of the foreign exchange risk is hedged by indigenous fuel (D. Newbery, 2002, p. 32).

Nevertheless, take-or-pay provisions (either explicit or virtual) that limit efficient dispatch may still be required by investors. Although the two-part tariff (capacity and energy) should make IPPs indifferent to dispatch levels of their plants, it has often been the case that the energy charge reflected a significant profit for the IPP. Thus, IPPs were eager to ensure baseload dispatch for their power plants, despite the two-part tariff (Halpern & Woolf, 2001, p. 5). Otherwise, to hedge

[24] The economically efficient amount of output taken from an IPP's plant is that which enables the demand on the power system to be met at least cost from all the power plants on the power system. A take-or-pay structure distorts this incentive by effectively imposing zero short-term marginal cost on the system for the amount of power covered by the take-or-pay provision, even if the variable cost of this power is higher than that of other plants on the system (J. E. Besant-Jones, 2006, p. 70).

against dispatch risk investors might prefer to charge most of their expected margins to the capacity payment itself, while charging a very low energy price to ensure dispatch.[25]

Stranded costs or debts produced by high PPA prices (in local currency terms) under IPP contracts with take-or-pay provisions impede moves toward competitive power markets. Stranded costs can be defined as those costs that the utilities (or the IPPs) were permitted to recover through their rates (or PPAs, in the case of IPPs) but whose recovery may have been impeded or prevented by the advent of competition in the industry (Sidak & Baumol, 2001).[26] Under a take-or-pay PPA, the purchaser is obliged to pay for a contracted minimum output even if the amount that is actually used is less than this minimum level. Prices that emerge from a liberalized wholesale power market are likely to undercut these high PPA prices, and the difference between these prices become stranded costs that have to be absorbed under the restructuring of a power utility (J. E. Besant-Jones, 2006). Since most PPAs were for a long duration (15 to 20 years), it is difficult to accommodate them when the countries want to move towards competitive market models (Venkataraman Krishnaswamy & Stuggins, 2003, p. 19).

Design elements such as more flexible contractual arrangements and avoiding granting monopoly rights to the single-buyer, may help in enabling the future development of wholesale markets (Arizu et al., 2006, p. 32). However, under inflexible arrangements, integration measures may be required for wholesale markets to develop since IPPs may choose not to participate in the market, resting on the protections afforded to them by their PPAs and other agreements, as happened in Guatemala (Halpern & Woolf, 2001, p. 34). The same issue partially explains the lack of participation in the Philippines wholesale market, where only 9% of the energy is transacted, despite a decade of commercial operation of the wholesale market. Integration measures include forced contract integration; voluntary renegotiation; transitional adaptation of market rules to integrate existing IPPs; among others (Halpern & Woolf, 2001; D. Newbery, 2002, p. 36). However, the techniques to be used to integrate a PPA into the power market will vary depending on the nature of the contract, the specifics of the power sector or market design, and other important political considerations.

Transition from the Single Buyer Model towards wholesale electricity markets requires special provisions and cautions. The examples and experiences of a number of countries that have recently made or are making this transition are provided in Box 1 below.

[25] For an example of virtual hedging against dispatch risk, see the case of the PPA originally signed between the Cuiabá Power Plant (formerly developed and operated by Enron) and Eletronorte, a state owned company in Brazil (Arizu et al., 2006, p. 13).

[26] A larger body of literature discusses the rationale and mechanisms for recovery of stranded cost in the context of US electric utilities (Brennan & Boyd, 1997; Joskow, 1996; Sidak & Baumol, 2001; C. . Woo, Lloyd, Karimov, & Tishler, 2003; C. Woo, King, Tishler, & Chow, 2006), with limited applicability to developing countries.

Box 1 – Examples of Countries Transitioning from the Single Buyer Model to Wholesale Power Markets

Mexico provides a case where legacy IPPs may slow the transition to a competitive market. Mexico laid the legal foundation (which required amendments to the Constitution) for electricity sector reforms in 2013. Market rules were published during 2015 for a complete wholesale power market with day-ahead, hour-ahead, real-time, capacity, and ancillary markets; financial transmission rights; medium and long-term capacity auctions; and marketers (with no ownership of generation assets) engaging in virtual transactions.[27] The current design has been criticized for the partial vertical separation of generation, transmission and distribution – which raises concerns on discriminatory access procedures by the incumbent state-owned enterprise – among other reasons (Ibarra-Yunez, 2015). Given that nearly all the currently available capacity and electricity generation existed before the new rules were put in place, it has been suggested that there will likely not be any new participants from the supply side in the new wholesale market.[28]

Turkey recently replaced the Single-Buyer Model by a wholesale market (Vagliasindi & Besant-Jones, 2013, Chapter 11). Turkey's transition plan covered procedures for privatizing distribution and generation assets with the introduction of transitory vesting contracts through which generation, either from existing contracts or from public companies, will be allocated to distribution companies based on their weighted share in total demand to compensate for the demand of captive consumers. The main purpose of these contracts is to provide for a smooth transition by ensuring predictability of electricity prices and supply during the transition period and to cover stranded costs that are taken by a public specialized company (TETAS).

Vietnam has taken a phased approach towards competitive wholesale and retail electricity markets. The electricity Law enacted in 2005 established a single-buyer market starting in 2010. The single-buyer sells power to discos and large consumers at regulated prices. This market structure is planned to evolve into a pool with multiple buyers and sellers (Vagliasindi & Besant-Jones, 2013, Chapter 17). Currently, generation prices are the largest component of the retail tariff. At present, there is little possibility for reducing these through operational efficiency, as 90% of sales are covered by long-term financial PPA contracts, the prices of which are not transparent and have been negotiated between generators and the government. The PPA contracts range from 10 to 20 years for local IPPs and up to 25 years for a BOT. Special tariffs apply to renewable generation and small hydro plants, providing preferential pricing for renewable power (ADB, 2015, p. 54)

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[27] PWC, 2015, "Summary of the Power Market Rules draft", http://www.pwc.com/mx/es/industrias/energia/archivo/2015-04-power-market-rules.pdf

[28] Dwight Dyer, 2016, "A Short Primer of Mexico's Wholesale Electricity Market" http://www.eldailypost.com/opinion/2016/01/a-short-primer-of-mexicos-wholesale-electricity-market/ . See also Jim Heidell, 2018, https://www.paconsulting.com/insights/mexicos-new-wholesale-and-resale-electricity-markets/

5. What Are the Key Design Considerations for Wholesale Power Markets?

Wholesale power markets entail a fully competitive generating sector. Establishing wholesale competition entails establishing multiple sellers and buyers which interact in a marketplace in order to determine the equilibrium price and quantities. Generation is deregulated and sells into a competitive wholesale market; while distribution utilities and large customers purchase competitively in the wholesale market (Hunt, 2002, p. 46). Wholesale power markets encompass various markets (e.g. forward and spot, energy and ancillary) and have adopted a variety of structures (e.g. power exchange and pool; cost and bid-based).

Careful design of the reform is required for establishing wholesale power markets, even under very favorable conditions. The California electricity crisis demonstrates that designing and implementing successful electricity markets is a complex task even for developed countries with plenty of industry and institutional endowments (J. Besant-Jones & Tenenbaum, 2001). Relatively agreed upon design principles that have proven to be important for developing countries are briefly outlined next.[29] However, competitive market structure and more general favorable conditions are required for the reform to be successful in improving power sector outcomes, regardless of the market design implemented (Chao & Huntington, 1998, p. 180).

Despite their heterogeneous evolution, four fundamental principles should guide the design of wholesale electricity markets: short-term efficiency; demand side participation (at the very least for large consumers); open access; and a workable framework for supply adequacy. Market design, across a wide variety of contexts, can usefully draw upon the following four principles.

The first principle is that the market design must encourage wholesale competition while preserving system reliability. Trading arrangements must ensure efficient and reliable operation of the power system and market, efficiently employing available resources to balance supply and demand, congestion management, and ancillary services management. A transparent and efficient price formation process should ideally be in place, but regulated retail or even wholesale prices are common in developing countries. Efficient management of risk should be encouraged by providing means and incentive to hedge price volatility in forward markets, through intermediate and long-term contracts; and distributors could be obliged to purchase their power needs in advance.

The choice of market architecture for encouraging wholesale competition while preserving high standards of system reliability remains an open issue; particularly regarding the spectrum of market organization options ranging from bilateral to centralized markets. Centralized markets seem to be the standard close to or during real-time system operation, since the particular properties of electricity require coordination for supporting competition (Hogan, 2002). However, both centralized markets in the US, and bilateral markets in UK and EU, have been developed for scheduling decisions day-ahead of physical delivery. In theory, centralized markets achieve higher

[29] Extensive prescriptions for the design of wholesale power markets are outside the scope of this document, but can be found in textbooks such as (Chao & Huntington, 1998; Hunt, 2002; Stoft, 2002).

productive efficiency than bilateral markets due to tight integration of non-convex generator costs, and the interactions of energy, transmission and other services. However, centralized markets suffer from incentive issues since generators may find it profitable to misstate their parameters (R. Sioshansi, Oren, & O'Neill, 2008).

The complexity and transparency of the market and the price-formation process vary across bilateral markets, power exchanges and centralized pools. The price formation process is particularly important for providing signals to market participants regarding efficient system use and investment in new capacity (both in generation and transmission). However, regulated wholesale prices or regulated prices for small household customers are often established in developing countries (Williams & Ghanadan, 2006). The wholesale price formation process varies across bilateral arrangements, power exchanges and power pools. Bilateral exchanges, common in commodities markets, are characterized by continuous trading and prices unique to each transaction. On the other hand, centralized exchanges and pools establish a uniform clearing price for standardized contractual commitments. However, power exchanges often employ simple bids (e.g. price-quantity pairs) and zonal pricing, thereby simplifying the market clearing mechanism and forcing generators to internalize their operating constraint while minimizing production costs. Centralized pools often employ complex bids (e.g. including start-up costs and other technical parameters) and locational marginal pricing derived from complex optimization algorithms. The high resolution and theoretically superior signals for efficient system use and investment in new capacity provided by the nodal pricing system comes at the expense of increased complexity (Chao & Wilson, 1999; Stoft, 2002). The complexity of the scheduling process increases exponentially in hydrothermal systems with large cascaded hydro reservoirs (e.g. Chile, Brazil) due to the ability to store water in order to displace thermal production years ahead in the future, making the design of markets in hydro-dominated systems particularly complex (see Box 2).

Cost-based spot markets with capacity and ancillary services obligations (such as those developed in Latin America) offer a simpler and less risky alternative for introducing wholesale competition in developing countries that lack appropriate conditions for full bid-based competition (J. E. Besant-Jones, 2006, p. 78).[30] After several years of operational experience the cost-based spot market can evolve into a bid-based spot market (J. Besant-Jones & Tenenbaum, 2001, p. 7). It is argued that cost-based markets would provide the time necessary for the market to evolve until wholesale competition is viable. Cost-based pools have worked relatively well in Latin America, despite being an inferior form of competition compared to bid-based pools. Moreover, cost-based pools ensure efficient dispatch as long as generators tell the truth about their production costs, and make it difficult for generators to exercise market power[31] (J. Besant-Jones & Tenenbaum, 2001, p. 7).

[30] The cost-based bidding approach allows competition for market share based on auditable costs of generators that give incentives to producers to reduce their costs (J. E. Besant-Jones, 2006, p. 74). It represents a relatively natural extension from the traditional merit-order dispatch systems used in many pre-reform, vertically integrated power systems (J. Besant-Jones & Tenenbaum, 2001, p. 7). Cost-based power pools have been established in Chile, Argentina, Bolivia and Peru (Bacon & Besant-Jones, 2002, p. 14).
[31] Although suppliers are constrained to bid their regulated costs in a cost-based market, this does not eliminate the incentive or ability of privately owned suppliers to exercise market power. Specifically, suppliers can now be expected to attempt to raise their regulated costs of production that enter the dispatch process (Wolak, 2003a, p. 64).

However, cost-based markets do not remove the incentives to exercise market power, and increase the regulatory burden associated with setting a standard for prudently incurred input costs for each generation unit (Wolak, 2003a, p. 65). Generators can and do treat the scheduling and dispatch program as a device whose output can be manipulated by the inputs they provide in the form of purported cost functions, availabilities, etc. (Chao & Wilson, 1999).

Box 2: The challenges of designing power markets in hydro-dominated systems

Hydro systems pose significant challenges to coordination, pricing and reliability in centralized markets. The availability of hydro resources is highly uncertain. Scheduling and dispatch of large hydro reservoirs (i.e. with the ability to store energy on a seasonal or yearly basis) needs to simultaneously account for the value of water in displacing thermal generation in the future as well as its value in providing a reliable service.

California, Chile and Brazil experienced electricity crises due to a sharp reduction in available hydropower combined with poor market and institutional design. In California, regulatory response was slow and ineffective in alleviating the excessive prices due to market power exercise (Wolak, 2005a). Chile experienced random (rather than planned) blackouts during the late 1990s due to poor crisis management and incompatible incentives for market participants, in the face of a severe (but predictably extreme) drought (M. Pollitt, 2004). In Brazil, the 2001 electricity crisis was the result of government inefficiencies and misinformation, as well as the lack of appropriate incentives for investment in thermal power plants (Araújo, 2006).

On the other hand, Norway experienced and survived a severe hydro shortage during 2002-2003. Withheld capacity by generators in the face of low hydro inflows led to raising wholesale prices, which in turn fed through to retail prices. Significant demand response to hiking retail prices largely explains the ability of the market to withstand the serious supply shock with no intervention from authorities nor rationing (Amundsen, Bergman, & Fehr, 2006).

It is not clear whether a particular market architecture is most appropriate for hydro systems, based on the aforementioned experience. Norway coped with the shock in hydro availability by means of a competitive wholesale and retail market, tightly integrated with neighboring markets. Chile, Brazil and California were not as successful in coping with extreme hydro conditions. However, the highly centralized design of the Brazilian market has been justified because of the large economies of coordination both within a basin and among basins (Araújo, 2006).

Furthermore, cost-based pools and single-buyer markets may derail comprehensive reforms instead of providing the time for paced transition to competitive power markets. The Republic of Korea is currently stuck in what should have been a transitional arrangement for the three year-long phase I of power sector reform. The reform efforts were stopped before the initially planned development of wholesale and retail market due to strong opposition by stakeholders based on their own interest and the California power crisis of 2000/2001. The largely administratively managed single-buyer, cost-based mandatory power pool has been in place for over 15 years with no substantive changes (Kim, Kim, & Shin, 2013; Pittman, 2014). On the other hand, PJM adopted a cost-based power pool for the first year of market operation without derailing further reform attempts (Wolak, 2003a). No developing country experience with the transition from cost-based to bid-based pools (or other kind of advanced wholesale competition such as bilateral markets) has been found in the surveyed literature.

The international experience does not suggest a single market architecture to be superior in supporting competition and reliable electricity service. For example, England and Wales abolished the compulsory gross pool with capacity payments and instead developed a bilateral self-dispatched energy-only market (NETA, in 2001) (R. Green, 2005; David Newbery, 2013). More recently though, UK developed a competitive capacity market. On the other hand, centralized market structures have continued to work in US and Latin America.

The second principle is that liberalization of wholesale markets requires a comprehensive approach to both the supply and demand side of the market. Power markets suffer from severe demand side flaws. The lack of demand elasticity enables market power abuse during tight hours, and requires expensive peaking plants to be dispatched in order to clear the market (thus increasing wholesale prices) and operate the system reliably without recurring to costly load-shedding. Increasing demand participation in power markets through demand-response programs have drawn attention in US and the EU, and also in the academic literature surveyed. The benefits of demand participation are particularly relevant due to the increased need for flexibility resources in order to efficiently integrate VRE while preserving high system reliability standards.

Demand inelasticity and its impacts in power markets can and should be alleviated by integrating at least large customers into the wholesale market, while metering and billing on an hourly basis (MIT, 2011; Zarnikau, 2008). The California electricity crisis shows that a sound market design must assure that final customers (with the exception of small residential consumers) are not isolated from wholesale market prices (Hugh Rudnick & Montero, 2002). At least large customers should participate in the wholesale market, since power supply to large electricity users is an intrinsically competitive segment because the cost of competing for their business is small compared with the potential profits (J. E. Besant-Jones, 2006, p. 71). Direct contracting between large customers and generation companies is feasible even if supply of households and other small customers remains regulated, as demonstrated by the Chilean and Brazilian experience (Millán, 2007). Moreover, retail tariffs should be designed so that at least large and medium sized customers can “see” spot market prices on an hourly basis and can cut their consumption in response to high prices (i.e., demand can respond to high prices) (J. Besant-Jones & Tenenbaum, 2001, pp. 9–10). These measures to improve metering and exposing large customers to real-time pricing do not need to wait for supply liberalization (Hugh Rudnick & Montero, 2002).

Both buyers and sellers in a deregulated market should have the means and incentives to hedge price volatility in forward markets, for example through medium and long-term contracts. Market participants should not be forced to rely completely on mandatory, short-term bulk power markets. Forward obligations reduce the incentive for exercising market power (Allaz & Vila, 1993). Lack of vesting or other forward contracts was one of the enablers for the unprecedented exercise of market power in the California electricity market crisis during the early 2000s (Wolak, 2005a). Apart from vesting contracts, volatility in spot electricity prices can be hedged with a variety of other financial instruments such as futures contracts, options and derivatives. However, the markets for such instruments are not easy to create, can be manipulated if there is not enough volume and, more importantly, may divert attention from more critical “first order” tasks such as raising tariffs so that distribution entities can recover their total cost (J. Besant-Jones & Tenenbaum, 2001, pp. 9–10).

The third principle is that open (or third party) access to the power grid is an essential element of introducing competition to electricity markets and increasing their efficiency[32] (Ellery et al., 2013). The institutional arrangements for market operation —including grid codes, access rules, and commercial tools for the operation of the transmission system— should be established before competitive power trading arrangements are introduced (Arizu, Jr., & Tenenbaum, 2002). Third-party access would allow entry by new types of suppliers, including industries that own power generators to meet their own power needs and that can sell excess power from these plants, developers of small power plants ("distributed generators") fueled by both conventional and unconventional renewable energy forms, IPPs able to conclude sales agreements directly with industrial and other large power consumers, and small service providers in rural areas that sell to local grid-connected power markets (J. E. Besant-Jones, 2006, p. 78).

An independent and efficient system operator is one of the required conditions for establishing open access, together with a regulator with authority to enforce market rules (Arizu et al., 2002; Ellery et al., 2013; Hogan, 1998, p. 3). The experience of countries that have successfully introduced a minimal open access regime suggests an emphasis on the early introduction of institutional components, such as the independent regulator and system operator, which allows proceeding to the market design phase incorporating open access (Arizu et al., 2002; Ellery et al., 2013). Avoiding conflicts of interest— typically observable under vertically integrated electric utilities— and abuse of market power with respect to grid access, dispatch decisions, and grid expansion planning is of particular importance (Ellery et al., 2013; Hunt, 2002). Hence, restructuring to separate generation from transmission should take place as early as possible (D. Newbery, 2002, p. 38).[33] Moreover, the neutrality of a system operator toward all seller and buyer agents should ideally be established legislatively (Ellery et al., 2013).

The governance structure of the system operator should ensure the presence of all key stakeholders, while preserving transparency and effective independence from market participants (Ellery et al., 2013). Key stakeholders include generators, transmission entities, and consumers. Consumers were not represented in the original governance structure of the system operator in Peru and Chile, raising concerns regarding the independence of the operator from generators (Arizu et al., 2002, p. 5; Ellery et al., 2013, p. 26; M. Pollitt, 2004, p. 15). Self-governance should be encouraged if it can lead to faster decisions, at lower cost and does not open the door to monopoly abuse. However, self-governance should be combined with regulatory backstops in rule changes, dispute resolution and market surveillance (Barker, Tenenbaum, & Woolf, 1997, p. xiv). Moreover, it has been suggested that the regulator should be have the legal right to intervene if there is an appeal by a market participant or on the regulator's own initiative (Arizu et al., 2002, p.

[32] Open access refers to the possibility for any party selling or buying electricity, for a cost-reflective fee and subject to transparently defined system security constraints, to connect to and make use of transmission and distribution systems, regardless of who owns and operates the power grid (Ellery et al., 2013, p. 1).
[33] For example, Chile formed a regulated and independent transmission entity that is legally barred from cross-ownership with generators, over concerns about abuse of market power after initially keeping transmission bundled with generators (J. E. Besant-Jones, 2006).

5). Nevertheless, the scope and mechanisms for regulatory interventions should be well-defined before establishing the wholesale market (Wolak, 2003a, p. 28).

Responsibility for control of power system dispatch and administration of power trading arrangements could be given to the transmission company (J. E. Besant-Jones, 2006, p. 76). This arrangement is said to provide a practical solution in the weak institutional and financial environments found in many developing countries, particularly when the transmission company is state-owned and so not under the control of private traders in the market. However, care must be taken on how much political pressure could be exercised over a state-owned transmission company. For example, in India, state load dispatch centers (SLDCs) have resisted connection of open access customers, often citing technical constraints that are difficult to independently confirm. Furthermore, Indian states have often blocked a generator's request to sell power outside state boundaries, by invoking a provision in the electricity law which allows state intervention in the system operator under extraordinary circumstances (Ellery et al., 2013).

Recent experience in several countries highlights the importance of properly balancing competition with centrally directed transmission expansion. The example of Peru demonstrates that private-sector investors in both transmission and generation react positively to the transparency and predictability of a well-organized system-planning framework (Ellery et al., 2013, p. 28). Chile evolved from a transmission expansion framework based on bilateral contracts towards centralized transmission expansion planning, successfully addressing the problems of underinvestment and congestion produced by the market-based transmission expansion framework (Hugh Rudnick et al., 2009).

The fourth principle is that developing countries require a workable framework for supply adequacy, ensuring adequate capacity to meet demand without experiencing supply constraints (generation, transmission, fuel, etc.). First and foremost, competition requires that investors in new supply capacity face no major barriers to entry to the wholesale power market[34] (J. Besant-Jones & Tenenbaum, 2001, pp. 9–10; Hunt, 2002, p. 40,105). Furthermore, the market must provide signals and incentives for investment in new generating capacity when needed. These can be provided by various means, such as imposing a capacity obligation on distribution companies purchasing power in the market, setting up a parallel capacity market or capacity payments to the energy spot market, or developing a forward energy trading market whose prices signal expectations about future supply/demand balances (J. Besant-Jones & Tenenbaum, 2001, pp. 9–10).

Long-term contract auctions have proven to be a very effective mechanism for attracting new players; ensuring electricity procurement at the lowest possible price for consumers, when competition is feasible and desirable (Moreno, Barroso, Rudnick, Mocarquer, & Bezerra, 2010; H. Rudnick, Barroso, Skerk, & Blanco, 2005). International experience with electricity auctions with the objective of increasing generation capacity can be either with (1) multiple buyers, either through a centralized or distributed process, and multiple sellers, as in the cases of Brazil,

[34] Entry barriers to the generation segment of electricity markets include uncertainty and expense in facing delays to the permitting process, regulatory uncertainty about after-the-fact price reviews, and regulatory constraints on managing trading risks efficiently by means such as hedging instruments (J. Besant-Jones & Tenenbaum, 2001, pp. 9–10).

Colombia, Peru, Panama, and Chile; and (2) a single buyer and potentially multiple sellers, as in the cases of Mexico and Vietnam, where auctions have been used by state-owned companies to procure electricity from Independent Power Producers (Maurer & Barroso, 2011).[35] Further details on the Latin American experience with auctions both for long term power supply and transmission expansion are detailed in Box 3 below.

Box 3: Latin America's experience with auctions for power supply and transmission expansion

Brazil and Chile have successfully applied **long-term contract auctions** for the last ten years. They simultaneously implemented auction-based schemes to ensure generation adequacy, following the same conceptual basis but employing different procurement schemes. Peru, Colombia and Panama later implemented similar auction-based schemes. Auctions foster the participation of many participants, ensure competition and tend to allow efficient price discovery (given appropriate auction design). The product being auctioned – a supply contract – provides the revenue stability that is needed for financing and thus reduces risks for newcomers (Moreno et al., 2010). Overall, the new contract auctions in Brazil and Chile have been of great interest to international investors looking to South America's electricity market: candidate suppliers include a wide variety of technologies, comprising new hydro projects, gas, coal and oil-fired plants, sugarcane biomass, solar and wind renewables, and international inter-connections. Increasingly, the same auction mechanism has been successfully used to promote investment in new renewable sources of energy as part of the transmission to low carbon energy systems, particularly in Brazil, Uruguay, Chile and Peru (Barroso et al., 2014). The auction mechanism has incorporated a strong market signal to promote new investment. Nevertheless, the whole process must be well designed in order to get efficient prices, to achieve the entrance of new investors, and to develop competition and demand coverage.

A second advancement into incorporating more market-oriented regulation is the implementation of competition in Brazil, Chile and Colombia into **transmission expansion**. The reforms comprise centralized and determinative transmission expansion planning by national governmental institutions, combined with decentralized implementation and operation of transmission assets, by agents selected by means of auctions for transmission concessions. The auctions for transmission concessions, started in 2005, aim at establishing a level playing field for companies to compete for the mandate to provide transmission services, which involves both the obligation to implement a set of facilities and operate it for a pre-defined period, and the right to be remunerated for that. Within the auction, the companies compete with basis on the annual revenues they require to implement and operate under each concession. The success of this model in the region is evidenced by the notable attraction of private capital to electricity transmission (Ferreira, Rudnick, & Barroso, 2016). Similar competition schemes integrated into transmission expansions have developed in the US (Herling, Koza, & McGlynn, 2016).

Finally, full retail competition should only be considered as a final stage of market liberalization, and its desirability continues to be debated in developed countries. "Retail competition in

[35] It has been suggested that "capacity obligations can be useful in the interim *only* if hourly metering, hourly pricing, and demand response are woefully inadequate, the other interim alternative being some form of capacity payment" (Hunt, 2002, p. 132). However, confidence on energy-only markets to provide supply adequacy is declining among experts (C. Batlle & Rodilla, 2010). Relying on energy-only markets to provide adequate capacity requires instantaneous demand response when needed and ignores transmission failures (Cramton et al., 2013). Markets without a capacity mechanism are not able to provide adequate capacity since they are unable to optimize blackouts. Moreover, practical experiences with electricity auctions, capacity obligations and other mechanisms have proven to be a workable framework in developing countries.

electricity is the ability of a customer to choose a preferred retail supplier ... The supplier has the right of access to local distribution network to which the customer is connected. The supplier typically buys the electricity from a generator or trader or in an electricity pool, or in some cases might generate its own electricity. It pays the relevant transmission and distribution charges …", (S. C. Littlechild, 2003). Retail competition requires that wholesale markets are in fact competitive and working to keep costs and prices down (Hunt, 2002, p. 55). Hence, retail competition should be implemented after wholesale power markets are well functioning. Moreover, although the UK experience has shown that competitive retail markets are workable (M. G. Pollitt & Brophy Haney, 2014), the academic literature does not seem to have reached a consensus regarding the desirability of developing retail competition (Defeuilley, 2009; S. Littlechild, 2009).

Experience with retail competition in developing countries has been very limited to date. Moreover, the interaction between long-term contracting, vertical integration and retail competition has not been analyzed in developing countries. Developing countries have often employed long-term contracts and PPAs in order to attract much needed private investments. Such contracts limit the scope and potential benefits of retail competition, since most of the power sold to end customers is already procured by a price set in the contract. Furthermore, retail competition and the lack of vertical integration between generators and retailers may result in significantly higher electricity prices (J. B. Bushnell, Mansur, & Saravia, 2008; R. Green, 2003). Vesting contracts are thus needed in the transition towards power markets in order to avoid substantial increases in wholesale prices (Wolak, 2000). The Philippines has recently introduced retail competition after moving on from a single-buyer market to a wholesale market. However, the large volume of long term contracts signed before liberalizing the power market has limited wholesale competition, and the interactions with newly established retail competition are yet to be seen.

6. How Can the Transition to Wholesale Power Markets Be Managed?

The transition stage from the old power market to the new power market is a vulnerable period when derailment of the reform process is possible (J. E. Besant-Jones, 2006, p. 115). Implementation issues in opening wholesale competition include investment during the initial settling in of the market; mitigating abuse of market power; and dealing with market design flaws, among other issues. Some of these implementation issues might be alleviated by careful design of the reform (e.g. market design to reduce the scope for market power abuse). The nature of these challenges in the specific context of developing countries has not yet received much attention in the surveyed literature; however, a brief review of the available material is provided.

Competition should be introduced gradually to the wholesale power trade in developing countries, given the general absence of the necessary conditions for open competition in power markets. This could be done by the following means (J. E. Besant-Jones, 2006, p. 78). First, generation capacity is distributed among many owners. Second, regulated open access to transmission and distribution networks is provided to third parties; allowing multi-buyer trading on a bilateral basis between generators and distributors and other parties, instead of trading through a single buyer of wholesale power. Third, the system operator is restructured to represent the interests of all wholesale market participants without being under undue influence of any group of participants when dispatching system supply capacity. Last, but not least, distributors pay generators fully and promptly and, in turn, generators pay their fuel suppliers fully and promptly, preferably on liberalized fuel markets that enable generators to reduce their fuel costs.

Bilateral trading among multiple buyers and multiple sellers may be considered as a precursor to the establishment of gross power pools,[36] *but only once distributors are creditworthy purchasers.* Under bilateral contracts, generators are individually exposed to the risk of nonpayment by distributors, and so generators are concerned about the creditworthiness of the distributors that purchase their output. Gross power pools, on the other hand, relieve generators of this specific exposure by centralizing nonpayment risk, although this increases the incentive for payment delinquency by distributors ("free riding").

Thereafter, competitive trading arrangements in a wholesale power market should be introduced carefully to provide scope for dealing with design flaws as well as settling-in problems (Barker et al., 1997, p. xvii; J. Besant-Jones & Tenenbaum, 2001, pp. 9–10). An important lesson from developed countries around the world is that the initial market design will inevitably have flaws. This implies the need for ongoing market monitoring to correct these flaws before they develop into serious problems, entailing a credible regulatory process that (Wolak, 2003a, p. 28): sets well-defined boundaries on acceptable market outcomes; defines those outcomes that justify regulatory invention; clarifies in advance the form of any legitimate regulatory intervention; and

[36] In a gross power pool, generators have to sell all their electrical energy into an organized exchange (J. E. Besant-Jones, 2006, p. 74). For further details on gross pools, net pools, bilateral contracts and power exchange, see (KEMA International B.V., 2007; Shuttleworth & McKenzie, 2002, Chapter 3).

follows through with these pre-commitments should the standards for acceptable market outcomes be violated.

Market monitoring and regulatory oversight are therefore important for successful power market reforms. Market monitoring is intended to detect and verify abuse of market power, correct design flaws and prevent further abuses. The role of the regulatory process is to ensure that the conditions necessary for vigorous competition exist and to limit the economic harm associated with the exercise of unilateral market power when they do not exist (Wolak, 2005b). However, devising theoretically sound and practically useful market monitoring procedures is a challenging task in electricity markets. For example, traditional market concentration measures such as Herfindahl-Hirschman Index fail to quantify the existence and exercise of market power in an electricity market, since even short periods of market power exercise due to transmission bottlenecks or during tight supply-demand conditions can be extremely costly, as proven by the California crisis of 2000/2001 (Adib & Hurlbut, 2008; J. Bushnell, 2005).

However, care must be taken to design regulatory mechanisms that do not further exacerbate market challenges. Moreover, the cure can be worse than the disease, since excessive regulatory mechanisms can introduce more economic harm than the market power they are attempting to prevent (Joskow, 2008b, p. 23; Wolak, 2005b). The regulator must design proactive protocols for rapid regulatory intervention to correct market design flaws as quickly as possible and order refunds as soon as unjust and unreasonable prices are found (Wolak, 2003b). It is prudent to use simple instruments (for example, limits on vertical integration or horizontal concentration) instead of theoretically more efficient rules when high powered incentive mechanisms can be manipulated and the regulator is weak (J. E. Besant-Jones, 2006, p. 78).

Credible regulatory institutions need to be established before undertaking reform. Investors and consumers need to trust regulatory and government institutions to honor commitments and treat them fairly for reform efforts to be successful. In many developing countries, the regulator is a new institution, its responsibilities vis-à-vis the government may not be clear, and previous governments may have a history of reneging on agreements (J. Besant-Jones & Tenenbaum, 2001, pp. 9–10). Establishing the legal basis for reform in an electricity law or act is an important step for signaling the country's commitment to reform, although it does not guarantee a correct implementation and success of the reform. Lack of clarity in property rights can also be addressed through appropriate legislation (Jamasb, 2006).

A key transitional issue is how to deal with existing IPPs whose power purchase agreements may not make them competitive in the emerging market (Halpern & Woolf, 2001, p. 24). Although IPP contracts may well provide a rapid solution to the problem of financing capacity expansion, the question is how these contracts should be structured in order to ease integration in the wholesale market. In the case of legacy contracts with high-price power purchase agreements, a "workout" of contracts or an explicit stranded-cost mechanism may be needed before the market becomes operational to ease their integration (see the example of the Philippines described in Box 4 below).

A wholesale market will generally not work unless these foundational measures are taken (J. Besant-Jones & Tenenbaum, 2001, pp. 9–10).[37]

Electricity markets are particularly vulnerable to the exercise of unilateral market power. This is due to the low price elasticity of electricity on both the demand and supply sides of the market; as well as the inability to store electricity economically (Borenstein, 2000). Local market power may also emerge because of limited transmission capacity (Ryan, 2014; Wolak, 2005b). Moreover, unlike other markets, firms need not collude to exercise economically harmful market power in electricity markets. The past two decades of international experience with wholesale electricity markets has demonstrated that significant consumer harm can result from firms simply engaging in unilateral profit-maximizing behavior given the actions of their competitors (Wolak, 2005b).

Market conduct regulation is unlikely to be effective at controlling anti-competitive behavior. No market design will work well if there are not an adequate number of competitive suppliers of generation service, adequate demand side responsiveness, or the market power of dominant firms has not been mitigated in some way (Joskow, 2008b, p. 22). When structure is not conducive to competition, the regulator and pool operator will find themselves unsuccessfully "chasing after conduct". The solution is not a better rule, but a change in structure (Barker et al., 1997, p. xviii).

The best solution to supplier market power in the energy markets is to have enough suppliers to begin with, to have a demand side that works, and to police subsequent mergers carefully (Hunt, 2002, p. 95). The general proposition holds that the more sellers, the better. Argentina sold each generating plant individually when it privatized, rendering 38 generators, all with market share below 14% (Bacon & Besant-Jones, 2002). The United Kingdom, by contrast, broke the existing national generator into only three companies resulting in two dominant firms in practice, and had endless problems with market power until the regulator forced them to divest some of the plants to other owners (R. J. Green & Newbery, 1992; Hunt, 2002, p. 95; Wolfram, 1999; David Newbery, 2006).[38] Market power can also arise through vertical reintegration of the power industry (between generation and distribution segments), as illustrated by the case of Georgia in Box 4.

It is also important to provide mechanisms for investors to manage their risks efficiently. Vesting contracts may be required as a transition mechanism to provide price certainty for distributors; revenue certainty for new generation owners; and reduce the scope of market power in the initial stages of wholesale competition. Although vesting contracts are one way to foster an active forward market during the initial stages of a restructuring process, they are not essential to success of a restructuring process. What is essential is that load-serving entities purchase a substantial fraction of their energy needs, certainly more than 80 percent, in the forward market

[37] Stranded costs of regulated utilities are not discussed here because they relate more to the *utility governance and restructuring* theme.

[38] There are problems in using standard tests for market concentration, such as the HHI for either capacity or output, for what matters is the extent of competition between generators with bids near the market clearing price (D. Newbery, 2002).

at least a year in advance of delivery[39,40] (J. Besant-Jones & Tenenbaum, 2001; Wolak, 2003a; J. E. Besant-Jones, 2006). However, in markets with retail competition investors may prefer physical rather than financial hedges, as was the case in Australia where vertical integration between generators and retailers took place instead of deeper developments of financial derivatives (Moran & Sood, 2013).

Box 4 – Challenges in the transition to a competitive power market

The **Philippines** successfully resolved the power crisis of 1990–1993 by liberalizing the market for independent power producers (IPPs). Philippines' partial electricity sector reform through IPPs was a good option available considering all the circumstances at that time, such as the power crisis and the limitation of institutional backgrounds, including the regulatory capabilities and the financial system. However, the legacy of the IPP solution of the power crisis put a heavy burden of electricity consumers to pay off the high IPP electricity supply price (Toba, 2007). In an effort to bring competitive pressures to bear in resolving this situation, a wholesale electricity spot market was launched in June 2006, without sufficient number of market participants to create a competitive environment (Toba, 2007). Despite comprehensive restructuring efforts, and the recent entry of new market participants along a dramatic reduction in market concentration, the Philippines continue to face power supply challenges, and Filipinos pay some of the highest electricity prices in Southeast Asia.[41]

In **Georgia**, the electricity sector's economic efficiency and viability has been successfully improved. However, the sector retains some noncompetitive structural features that can limit the potential benefits of competition (ADB, 2015). Transparency in pricing and independent regulatory competence are still lacking. Generation, transmission, and distribution companies often have the same owners, or form part of the same vertically integrated company. Because bilateral power purchase agreements are the main form of electricity trade, one would expect buyers to prefer to procure electricity from their own generation sources. Vertical reintegration can thus enhance corporate profitability, but may also nullify the competitive potential expected from the mainly horizontal break-up of the public sector utility. Thus, the need to unbundle the power industry and prevent subsequent mergers during the operation of the wholesale market is portrayed by the Georgian experience.

Finally, policy makers may have limited tolerance for the substantial price volatility that occurs with competition in the market (J. E. Besant-Jones, 2006, p. 77). There can often be a temptation for regulatory intervention to cap market prices during periods of spiking due to scarcity. While well-intentioned, this kind of market intervention blurs price signals and may dilute incentives to invest in needed new generation capacity. Transitional arrangements might alleviate this issue. For

[39] Competitive markets require a full set of forward and spot markets and risk-management tools that allow suppliers and buyers to hedge against price volatility (Hunt, 2002, p. 115). Moreover, long-term contracting mitigates the scope for market power since it reduces the amount of energy that would benefit from a price increase resulting from withholding part of the generator's output. However, shorter-term contracts are less effective since raising the short-term spot price may increase the contract price at the time of renewing the contract (Carlos Batlle, 2013, p. 391; Stoft, 2002, p. 349).
[40] The California electricity crisis illustrates the disastrous outcomes of forcing distributors to purchase almost all of their supply needs in the day-ahead and shorter-horizon spot markets (J. Besant-Jones & Tenenbaum, 2001; Wolak, 2003a).
[41] EIA, 2015, "Supply shortages lead to rolling power outages in the Philippines" http://www.eia.gov/todayinenergy/detail.cfm?id=20252

example, vesting contracts[42] may provide greater price certainty for distributors; revenue certainty for new generation owners; and reduce the scope of market power in the initial stages of wholesale competition. Such vesting contracts for smooth transition to wholesale markets and also to recover stranded costs were part of the reform strategy in Turkey (Vagliasindi & Besant-Jones, 2013, p. 237).

[42] Vesting contracts are forward contracts assigned as a precondition for the sale of state-owned generation assets (i.e. divestiture of state-owned generation). The vesting contract commits the new owner of the generation capacity to supply a substantial fraction of the expected output of the unit to load-serving entities at some pre-set price (Wolak, 2003a, p. 27).

7. What Are the Emerging Challenges for Power Market Design?

Modern power markets in the developed world are being heavily impacted by the clean energy transition as well as emerging disruptive technologies; including demand-response schemes, smart grids, storage and electric vehicles. This is particularly the case in Europe and North America, where aggressive actions have been taken to reduce the carbon footprint of fossil fuel generation technologies. While some of these developments have not reached power markets in developing countries, the effects of low cost renewable technologies are around the corner. To achieve the efficient and secure transition to sustainable energy systems, market design needs to enhance short-term market efficiency, incorporate mechanisms to ensure resource adequacy, and develop efficient support mechanisms to increase investment in renewable energy sources.

Low-carbon generators need to participate in electricity markets as they can and should earn a high fraction of revenues there. Such participation provides an important market feedback loop, revealing the value of different low-carbon technologies, in different locations. A market design with a high temporal and geographical resolution is therefore needed to cope with more volatile and uncertain production and power flow patterns due to increased share of wind and solar generation (IEA, 2016; Neuhoff et al., 2013). Moreover, exposing renewable generators to the cost of imbalances in the shorter term enhances their ability to properly estimate production (C. Batlle, Pérez-Arriaga, & Zambrano-Barragán, 2012).

Energy market revenues alone, however, may not be enough to attract low-carbon investment at the required scale; in a timely manner and at low cost, even with dramatic reductions of solar and wind levelized costs. Long-term arrangements backed by governments may still be necessary to attract a sufficient amount of new low-carbon power generation. A new consistent market framework is needed, which includes carbon pricing and support for low-carbon investments (IEA, 2016). A variety of policy support mechanisms for renewable energy sources have been undertaken worldwide. These support mechanisms may be either based on prices (e.g. feed-in tariffs or premiums) or quantity (e.g. renewable portfolio standards and auctions). The choice and performance of each support mechanisms depends on the maturity of the particular electricity market, and should differentiate between renewable resources that are dispatchable (e.g. biomass) and those that are non-dispatchable (e.g. wind and solar) (C. Batlle et al., 2012). It is worth noting that subsidies have become less relevant as wind and solar development cost fell over recent years. Hence, a policy shift from subsidies (e.g. feed-in-tariffs) to auctions has occurred in many markets.

Among integration mechanisms, auctions for renewable resources have proven to be relatively successful in providing increased renewables investment in an efficient manner; both in developed and developing countries (Barroso et al., 2014; Neuhoff et al., 2013). Auctions appear as an effective way to stimulate competition among investors, provide price disclosure while eliciting the right amount of investment, and offer revenue stability via long-term contracting. However, auctions are also complex compared to feed-in-tariffs. Moreover, the experience of Brazil, China and India illustrates that delays in construction and underperformance may result from overoptimistic bidding (Barroso et al., 2014).

Increasing penetration of wind and solar power increases the need for flexibility resources. The output of variable generation resources (primarily wind and solar generation) varies over time and cannot be predicted precisely. Thus, increasing share of variable generation requires more flexibility in the resource fleet so as to maintain system reliability.

Furthermore, high penetration of wind and solar power may depress overall market prices and increase price volatility weakening price signals for capital investment. This may call for the development of special mechanisms to ensure that both variable and capital cost of plant can be covered, and incentives for long-term system reliability are retained (Milligan et al., 2016). The concern regarding cost-recovery stems from wholesale price depression, the merit-order effect, and increased price volatility. First, zero-marginal cost plants (solar PV and wind farms) reduce the revenues of all generators by depressing wholesale energy prices. Moreover, sustained periods of negative prices may result due to production-based subsidies or priority dispatch rules (Brandstätt, Brunekreeft, & Jahnke, 2011; Nicolosi, 2010). Zero-marginal cost plants also reduce revenues of conventional mid-merit power plants by pushing them out of the market during hours of high Variable Renewable Energy (VRE) production (the so-called merit-order effect). Raising wholesale price volatility also increases risks and therefore financing costs for investments in new generation capacity.

Altogether, the penetration of variable renewable generation resources has given rise to an ongoing discussion on the provision of reliability by energy-only power markets, and the need of capacity markets. Some argue that energy-only markets are unlikely to deliver adequate investment to support system reliability in the long-run. The inability of energy-only markets to provide revenue sufficiency is largely caused by demand-side flaws and the lack of adequate scarcity pricing, besides the aforementioned merit-order effect, and lower and more volatile wholesale energy prices.[43] Although demand-side flaws and scarcity pricing have been long been an unsolved issue with wholesale power markets, the impacts on revenue sufficiency are augmented by the penetration of variable renewable energy resources.

Adequate scarcity pricing is needed in energy-only markets to achieve supply adequacy by allowing power plants to recover their fixed costs. Extended periods of tight supply when variable renewable energy production is unavailable (e.g. during the night when the sun is not shining) increase the need for peaking capacity (available to ramp-up output very quickly to meet demand when renewable generation falls). In turn, peaking capacity requires adequate scarcity pricing in energy-only markets, so that peaking power plants recover at least part of their fixed costs within the energy market. Regulatory price caps on the energy market as well as out-of-market procedures by the system operator may further distort revenues for peaking plants (Roques, 2008).

Nevertheless, price caps and other distortions to scarcity pricing may not be completely alleviated in developing countries due to the political cost of sustained periods with extremely high energy prices as well as the increased extent of market power abuse during hours of tight supply. Therefore, increasing demand-side responsiveness is even more important to help competitive

[43] There are examples of energy-only markets which have delivered timely investments in generation infrastructure, for example Australia's National Energy Market (Moran & Sood, 2013).

market-clearing during peak hours.[44] However, the extent of demand-response remains limited. Moreover, demand-response does not seem a priority for developing countries with limited access to electricity services and serious capacity shortages.

Therefore, price or quantity based mechanisms might be needed to complement energy-only markets, in order to incentivize the optimal level of supply adequacy (Milligan et al., 2016). The alternatives to provide long run reliability whilst boosting integration of renewable resources can be categorized in two groups (Sen, 2014): (i) greater use of markets to ensure investments in both renewable and conventional generation, by developing capacity and balancing markets; or, (ii) central planning or coordination solutions, such as a single-buyer agency to coordinate the integration of renewables into the electricity sector. Academic literature seems to be mostly concerned with the first option, focusing on the design of capacity markets to efficiently achieve supply adequacy (Cramton, Ockenfels, & Stoft, 2013; IEA, 2016; Joskow, 2008a; David Newbery, 2015). However, successful experiences in Brazil and Chile demonstrate that auctions can provide investment in renewable and conventional energy sources driven by market forces, while also ensuring supply adequacy. Currently it is not clear which approach is best suited to ensure supply adequacy under different country conditions and market designs.

[44] Although demand-response may help alleviate the missing-money problems, energy-only markets are simply unable to optimize blackouts. Therefore, energy-only markets will never, in strict theoretical terms, be able to provide optimal reliability levels (Cramton et al., 2013).

8. Conclusions

Wholesale power markets promise enhanced efficiency gains for well-functioning power systems that have already completed a comprehensive restructuring process. In that sense, wholesale power markets represent the end-point of power market reform, and presuppose numerous prior steps, including: the restructuring of the power industry to vertically separate generation, transmission and distribution segments; as well as the horizontal break-up of generation into multiple entities to dilute market power; the creation of a regulatory framework; and the introduction of strong commercial incentives in power utilities, often through private sector participation. The main benefit of wholesale competition is to induce additional efficiency gains in such a restructured power industry, both by requiring generators to compete for dispatch, and by allowing system-wide economies, such as the pooling of reserve margins across generators. With appropriate regulatory and tariff design, power markets may also contribute to passing such efficiency gains to final customers.

However, preconditions for the introduction of wholesale power markets are considerable and are often not met in developing countries, where power sector challenges may be more fundamental. First and foremost, financial sustainability and health of the power industry seems to be a pre-requisite for competition, entailing cost-reflective end-user tariffs, as well as payment integrity across the electric supply chain. Second, structural conditions in the generation segment need to be conducive to competition, including an adequate number of flexible and sizable generators able to compete at the margin of supply, an adequate system reserve margin to create space for competition, and an absence of transmission bottlenecks that create local market power. Third, broader conditions related to the institutional, economic, politic, and social environment, are also important in enabling wholesale competition. Many of these conditions fail to be met in many developing countries, either because sectors are highly subsidized and susceptible to liquidity problems, and/or because power systems are relatively small and would not support an adequate number of competing generators.

Regional power markets may offer an alternative route to competition, particularly for countries with relatively small but financially viable power systems. By joining a larger regional market, small countries can overcome the challenges of scale and experience competitive pressures through neighboring countries. Financial viability remains important, however, to provide payment security for cross-border exchanges. A number of regional power markets are emerging in the developing world, including in Central America, Southern Africa, West Africa and South Asia. In some cases, these are still limited to bilateral contracts (e.g. West Africa), while others have already established regional power exchanges (e.g. Central America, Southern Africa).

For countries that are not yet ready to implement wholesale power markets, the Single Buyer Model presents a valid intermediate step, and raises several challenges of its own. Many developing countries have adopted the Single Buyer Model entailing vertical separation of generation, transmission and distribution, often with the transmission entity acting as the single buyer of wholesale power for onward sale to the distribution segment. In some cases, this is intended to be an interim arrangement on the path to a wholesale competitive market. Reliance on IPPs as the primary method for expanding generation capacity in Single Buyer markets raises risks that a large share of energy needs will be covered by inflexible long term PPA contracts that subsequently limit the scope for participation in any future wholesale power market. If PPAs incorporate relatively high costs, for example due to a lack of competitive procurement, these may eventually represent stranded costs for the power system as a whole.

When it comes to market design, a significant distinction is between cost-based and bid-based pools. There is considerable variation in market design across the developing world. A key distinction is between cost-based pools (where dispatch is based on marginal cost information previously supplied to the regulator) and bid-based pools (where dispatch is based on price bids made by generators that do not need to be substantiated by cost information). Cost-based pools may be simpler to implement initially, and limit the scope for abuse of market power; while bid-based pools provide greater flexibility for revelation of preferences by market participants.

Despite widespread heterogeneity, four guiding principles remain broadly relevant when considering the design of markets. These are: promoting short-term efficiency; enabling demand-side participation; providing open access; and ensuring supply adequacy.

First, market design should encourage wholesale competition while preserving system reliability. Trading arrangements must ensure efficient and reliable operation of the power system and market, efficiently employing available resources not only to balance aggregate supply and demand, but also to allow congestion management and supply ancillary services. A transparent and efficient price formation process should ideally be in place. Efficient management of risk should be encouraged by providing means and incentive to hedge price volatility in forward markets, through intermediate and long-term contracts. Moreover, distributors could be encouraged to purchase a large portion of their power needs in advance.

Second, market design should ensure strong participation of the demand side of the market. At least large customers should participate in the wholesale market, since power supply to large electricity users is an intrinsically competitive segment because the cost of competing for their business is small compared with the potential profits. Direct contracting between large customers and generation companies is feasible, even if supply of households and other small customers remains regulated. Moreover, retail tariffs should be designed so that at least large and medium sized customers can "see" spot market prices on an hourly basis, through advanced metering combined with time of use tariffs, and thus face the incentive to adjust demand during periods of high prices. In fact, such measures to improve metering and expose large customers to real-time pricing need not wait for market liberalization. Furthermore, increased demand participation has positive effects in mitigating market power, and providing flexibility to the system for increased integration of variable renewable energy sources.

Third, open access to the power grid is an essential element of introducing competition to electricity markets and increasing their efficiency. Competition requires that investors in new supply capacity face no major barriers to entry to the wholesale power market. Ensuring open access suggests that restructuring to separate generation from transmission should take place at an early stage. Third-party access should allow entry by new types of suppliers, including industries that own power generators to meet their own power needs and that can sell excess power from these plants, developers of small power plants ("distributed generators") fueled by both conventional and unconventional renewable energy forms, and IPPs able to conclude sales agreements directly with industrial and other large power consumers, as well as small service providers in rural areas that sell to local grid-connected power markets. From an institutional perspective, open access calls for the establishment of an independent and efficient system operator neutral to all sellers and buyers. A possible alternative arrangement is to allocate the responsibility for dispatch and administration of power trading arrangements to the transmission company, especially when it is state-owned and so not under the control of private traders in the market. In either case, careful attention will need to be paid to corporate governance issues.

Fourth, developing countries require a workable framework for supply adequacy, ensuring adequate capacity to meet demand without experiencing supply constraints. The market must provide signals and incentives for investment in new generating capacity when needed. While peak-load and scarcity pricing could in theory provide the required signals and revenues for ensuring long-term balance between supply and demand, international experience suggests that additional mechanisms might be needed to encourage adequate investment. These can be provided by various means, such as imposing a capacity obligation on distribution companies' purchasing power in the market, setting up an explicit capacity market to operate in parallel to the energy spot market, or actively developing a forward energy market. In particular, long-term contract auctions have proven to be a very effective mechanism for attracting new competitors, ensuring electricity procurement at the lowest possible price for consumers, when competition is feasible and desirable.

The transition stage from the old power market to the new power market is a vulnerable period when derailment of the reform process is possible. Experience from developed countries suggests that it is impossible to perfectly anticipate all market design issues, and flaws will inevitably come to light during the early years of implementation. Therefore, it is important to put in place market monitoring arrangements that allow regulatory oversight of the nascent market, to detect and verify abuse of market power, correct design flaws and prevent further abuses. However, devising theoretically sound and practically useful market monitoring procedures is a challenging task in electricity markets. Abuse of market power may prove difficult to detect, and even harder to control through regulation of conduct. Ultimately, restructuring of the generation segment is key to achieving market competition, and is best undertaken prior to the introduction of the market.

Finally, the emergence of disruptive technologies in the electricity sector is creating new challenges for the design of wholesale markets. Critical technological disruptions include the expansion of variable renewable energy, as well as the advent of storage resources, and the growing sophistication of demand-side participation. The impact of variable renewable energy is to depress market prices (due to their zero-marginal cost) and introduce increased price volatility (due to sudden swings in production), making it increasingly challenging to recover investment costs associated with new power generation, and necessitating the design of parallel market mechanisms, such as markets for ancillary services.

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