Prospects for power supply infrastructure enhancement

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Abstract. Traditional retail electricity market models transform under the condition of new technologies development and institutional changes in countries and worldwide. New models of the retail electricity market need to be adopted to recent requirements made by different stakeholders. The purpose of this study is to advance the understanding of transformation of the electricity retail market in different countries through introducing a uniform framework for comparison. The findings provide insights for experts and authorities on how the changes in the dynamic environment led to the emergence of new market models in six surveyed countries. Specific features of different models are highlighted to ensure optimal working conditions and incorporation with managerial practices in the industry as well as to help policy makers to understand what additional measures may boost the competition in retail electricity markets.

1. Introduction
The challenges of increasing the energy infrastructure efficiency, fighting energy poverty and transitioning to low carbon energy systems are tightly coupled with energy policies on national levels. There is evidence that polycentric governance and decentralization of energy solutions allow one to reach higher levels of experimentation and innovation required for providing reliable electricity supply [1]. Liberalization of retail electricity markets has a potential to produce benefits for different stakeholders, i.e. consumers, who can gain economically from switching service providers. Competition may also boost the enhancement of different electric services as well as accelerate the employment of distributed generation capacities and renewables, developing smart solutions and, thus, contribute to the decarbonization of the energy system. At the same time the reformation and liberalization of existing market models imply establishing an open access to technologies and information that would allow one to maximize efficiency of the energy system, while information security and privacy issues have to be addressed [2]. This paper will provide an overview of the retail electricity market models applied in different countries. Furthermore, beside the differentiation between countries, different electricity market models might appear within the same country. It may happen due to historical, geographic and some economic prerequisites. For example, in Russia, USA, China liberalization activity is complicated due to some factors. It is worth adding that the particular attention to the liberalization aspect, as an explicit indicator of the flexibility of the external environment and environment readiness for incorporating new technologies and practices, need to be observed. The authors will propose a unified
framework for the comparison of different retail electricity markets in order to assess the level of their liberalization and subsequent readiness for the described changes. Three main models of retail electricity market will be considered: monopoly, competition, single buyer.

2. Methodology and approach
The level and speed of the dissemination of new market models vary from country to country; thus, the presented paper is based on a descriptive case study consisting of multiple holistic cases in order to establish sequences of events during the period of liberalization and unravel underlying mechanisms.

2.1. Proposition of research
There is a noticeable transition towards more liberalized electricity markets with a broader set of actors and various methods of collaboration among them. This requires a corresponding environment – more flexible and ready for this type of changes. Regarding this, the central research question is:

RQ. Is the competitive model currently dominating in retail electricity markets?
From this research question, the following central propositions are derived:

P1. The higher generation capacity concentration within the generating segment the less competitive would be the retail electricity market.

P2. The higher generation capacity concentration within the sales segment, the less competitive would be the retail electricity market.

2.2. Countries for the analysis
There is a noticeable transition towards more liberalized electricity markets with a broader set of actors and various methods of collaboration among them. This requires a corresponding environment – more flexible and ready for this type of changes. The authors will pay particular attention to the retail markets of the following countries, as those being examples of similar processes ongoing in both developed and transition economies (Table 1) [3].

| Country       | Reason for inclusion into analysis                                                                                                                                 |
|---------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| USA           | • A bright example of the initially non-united energy sector with a considerably high level of decentralization of electricity value-chain elements  
                • Highly distributed governance of the sector (determined by the federal and regional structure)  
                • High interdependence of 2 major commodities: natural gas and electricity  
                • Innovative development of the electric power sector |
| China         | • A high level of state control and intervention in the electric power sector coupled with the strong trend towards the liberalization and renewables development  
                • Fast development of new trends in the electric power sector |
| Singapore     | • An interesting example of extraordinary influence of the government coupled with the extremely high level of market activity |
| Germany       | • Direction towards the development to a low carbon energy system  
                • A high level of electricity consumers’ fragmentation |
| Russian Federation | • One of the most representative cases of the development and transformation of the electricity power sector under the condition of post-soviet and transition economics  
                             • A strong trend towards competition within a highly regulated environment in the energy sector  
                             • Existence of zones with different conditions for the organization of the retail electricity market due to the features of the territory  
                             • Domestic carbon fuel and low carbon resources for electricity production  
                             • Significant concentration of production in all energy industries and high interconnection among them |
2.3. Research design
All the six cases were thoroughly studied through content and narrative analyses. Particular attention was paid to the examination of differences and similarities of the liberalization processes as well as to the underlying triggers of this transition.

At the first stage of the research, through the literature review, the authors achieved two major outcomes. They found that retail electricity markets may be assessed by the level of their liberalization (through a set of measurable parameters). The stage also allowed one to outline models for the classification of retail electricity markets with the corresponding set of indicators. It is worth noting that during the research, the authors paid specific attention to the market share attributed to a particular model within a given country (based upon a premise that several models may be functioning on one market at the same time).

Stages of the research determine the structure of the paper:
• comparative model for research of retail electricity markets in different countries is presented;
• comparative characteristics of retail electricity markets in different countries on the base of the comparative model will be provided.

This study concludes about the discussion of implications and directions for future research.

2.4. Comparative model
There is a noticeable transition towards more liberalized electricity markets with a broader set of actors and various methods of collaboration among them. This requires a corresponding environment – more flexible and ready for this type of changes.

As for the creation of the comparative model, the conducted cross-case synthesis allowed us to uncover a set of indicators that reflect the liberalization processes within the studied countries:
• Mechanism of the price regulation at the retail market (whether it is formed by market laws or regulated by the government. In the former case it may be more beneficial for the producers, but the latter protects consumers as the most vulnerable actor in the electricity market).
• Level of the concentration within the generation segment – will be measured with the generation capacity, Concentration Ratio index, CR5, which estimates a market share of the 5 largest companies in a certain market in 2017. (This allows one to assess the influence of the companies).
• Market share of power supply companies will be assessed through the calculation of a market share of a given company, MSi. (This helps to assess the level of market power of a given company).
• Degree of the value chain integration (this demonstrates which of the major stages are integrated: generation; transmission; distribution; sales. It indicates the level of liberalization of a given retail electricity market).
• Choice of the power supply company by consumers (whether it is possible to make a switch: yes / no).

2.5. Classification framework
The framework can be applicable to various cases. It should incorporate indicators which are (1) unified across the examining countries, (2) can be calculated in a representative way and (3) reflect the transition towards more liberalized electricity markets.

Considering indicators, provided in section 2.4 of the paper, only two of them may correspond to the stated above guidelines: “Value chain integration” (might be called a “Liberalization level”) and “Choice of power supplier”, i.e. choice available for the consumers on a given market (Figure 1).

To author’s mind, the examined countries could be classified by the given indicators into six quadrants of the matrix, depending on the level of their value chain integration and availability of choice for consumers. The formulated framework might help us to answer the research question as it will visualize positions of the surveyed countries on the liberalization scale.
In order to support the propositions of the study and to reveal the possible link between the scale of the competitive model adoption and concentration within generation and sales segments, respectively (P1 and P2), the authors of the paper will apply the following matrix (Figure 2).

![Figure 1. Classification framework [1]](image)

![Figure 2. Classification framework [2, 3]](image)

The matrices mentioned above are similar except from the value of OY. The Y-axis exhibits the concentration ratio in the generation segment for supporting P1 and exhibits the market share of a single power supply company for supporting P2.

3. Results

The conducted case study could bring us to the following results. We can see that among the countries surveyed, the competitive model in the retail electricity market is most widely used (5 out of 6 surveyed countries have adopted this model). This fact might be considered as a positive answer to the research question. However, there are cases when a single country adopts few models at the same time: Russia (single buyer and competitive models); Singapore (single buyer and competitive models), USA (monopoly and competition). It is worth mentioning that surveyed countries vary by the level of liberalization and availability of the choice of the power supplier – two major factors that all these countries have promoted during the development of their power sectors. Considering these indicators, we conclude that the observed electricity markets’ model might be plausibly grouped upon these indicators (Figure 3).
Figure 3. Classification of currently used retail electricity markets’ models [4–9]a

Note 1: USA 1 – VIC; USA 2 – Retail choice; USA 3 – Bilateral contracts; Singapore 1 – when power supply companies are market participants; Singapore 2 – when power supply companies are not market participants; Russia 1 – when electricity is acquired from guaranteeing supplier; Russia 2 – when the electricity is bought from independent power supply company

Note 2: the size of the flag represents the share, occupied by the model within the retail market of a given country (this share is also doubled in the circle in the upper right corner of the flag).

The given classification incorporates 6 categories of the models (quadrants of the matrix): (1) USA 2, Singapore 1 and Russia 2 – the most liberalized markets; (2) Russia 1 and Singapore 2 – these markets include activities decoupling, but consumers lack choice of a supplier; (3/5) Germany – a hybrid of 3 and 5 categories as generation, distribution and sales are integrated, and transmission is decoupled; (4) China – average level of activities decoupling and lack of consumers’ choice; (6) USA 1 and USA 3 – the least liberalized retail electricity markets.

After study and assessment of the parameters, indicated in the comparative model (see paragraph 2.4 for details), we might conclude that the levels of concentration in both generation and sales segment significantly vary (Table 2).

As can be seen in some countries (USA, Russia) there are two models of the retail electricity market. This is due to the complex structure of the market itself. Large territories of these countries are characterized by heterogeneous density - in places of high population density there is an opportunity to create a certain unified energy system, in places of low population density there are isolated territories, energy supply of which is particularly difficult.

The brightest example in this case is Russia. The Russian electric power market is a mosaic one in terms of distribution and sales of electricity. Pricing depends on the entry of a region into a particular zone: there are price zones, non-price zones and isolated areas. In last ones, power is usually supplied by local heat and electricity systems. Consequently, in isolated areas power services and production are expensive due to significant transportation costs for fuel and equipment. And what is more, tariffs for generators are set by regional authorities based on their actual cost. Such conditions make it almost
impossible to organize market relations in the energy systems of these areas. This feature of the Russian market structure leads to the formation of completely different models of the retail power market. A main model for the most part of the territory will not be relevant for isolated areas. But at the same time, taking into account the development of technological base and distributed generation [10], available low carbon (nuclear and local RES) energy sources, it is possible to assume the appearance of hybrid models with wide implementation of integrated intellectual energy solutions and innovative energy ecosystems which are different from the existing ones in such areas. Study of these transformations and their phenomenon may become one of the further directions of research.

Table 2. Comparative analysis of market models of surveyed countries

| Country     | Degree of concentration within generation segment (concentration ratio)\(^a\) | Degree of concentration within sales segment (market share)\(^b\) | Current market model | Market share of the model\(^c\) |
|-------------|---------------------------------------------------------------------------------|---------------------------------------------------------------|----------------------|-------------------------------|
| USA         | CR\(_3\) = \(.22\)                                                              | 5 major power supply companies occupy 56% of the market MS\(_i\)~19.9\% | Monopoly\(^d\)       | 32%                           |
|             |                                                                                 |                                                               | Competition          | 41%                           |
|             |                                                                                 |                                                               | Monopoly\(^e\)       | 27%                           |
| China       | CR\(_3\) = 1.00                                                                  | 5 (affiliated with generators) + 300 local (function nominally) power supply companies MS\(_i\)~20\% | Single buyer         | 100%                          |
| Singapore   | CR\(_3\) = .78                                                                  | 26 power supply companies MS\(_i\)=3.8\%                      | Competition          | 70%                           |
|             |                                                                                 |                                                               | Single buyer         | 30%                           |
| Germany     | CR\(_3\) = .49                                                                  | 900 power supply companies MS\(_i\)=1\%                       | Competition          | 100%                          |
| Russia      | CR\(_3\) = .64                                                                  | Local power supplier at each territory (720 in total) MS\(_i\)=1\% | Single buyer         | 93%                           |
|             |                                                                                 |                                                               | Competition          | 7%                            |

\(^a\): CR – concentration ratio (calculated upon the share of generation by 5 biggest generating companies in the total volume of generation of a particular country – in 2017). Note: calculations include only that electricity generation, which was performed by a particular company on the territory of a particular country;  
\(^b\): MS\(_i\) – market share in generation capacity of a single power supply company in the total market;  
\(^c\): data for calculations is retrieved from previous sections of the paper and web-sites of Ministries of Energy of the given countries;  
\(^d\): in centralized market;  
\(^e\): in two-sided contract.

In order to support or reject the propositions, it is worth studying two next tables. There is no substantial connection between the degree of generation capacity concentration and predominance of a particular market model. For instance, in China, with the highest value of CR we may perceive an absolute dominance of the single buyer model; in USA, where CR has the lowest values, the monopoly model dominates; in Germany, where CR has average values, we can see the prevalence of the competitive market model (Figure 4).

As for the link between the degree of the concentration of power supply companies and predominance of a particular model, there is a bidirectional linkage: there are cases when a high concentration is observed within the dominance of a monopoly model (USA) while there are also cases when such connection is less evident (China). Meanwhile, considering the case of Singapore, relatively a small number of power supply companies (12 and 26 respectively) exist within a competitive model (Figure 5).
Altogether, the facts mentioned above lead to a conclusion that more evidence is needed in order to support or discard the proposition of the existence of a link between the concentration within the sales segment and predominance of less competitive market models. We might sum up the results in the following table (Table 3).

**Table 3. Support of the proposition**

| Research question / Propositions | Result |
|----------------------------------|--------|
| RS                               | Yes. The competitive model is currently dominating (among the countries surveyed) |
| P1                               | Not supported |
| P2                               | Partially supported – more evidence is needed |
4. Conclusion

The conducted case study analysis allows one to draw some conclusions. As it was shown by means of the proposed framework for the comparison and retrospective timeline analysis, the energy policy in the examined countries pursues the establishment of open and competitive retail electricity markets. In this way, the results show that currently competitive models dominate among those that were analyzed, while in some countries the complete transition to purely competitive markets may take more time and efforts both from the government and the business. At the same time, levels of the concentration in certain segments (generation or sales) do not necessarily directly determine the level of liberalization on the market.

The energy policy and liberalization reforms differ from country to country in terms of institutional constraints, scope, geographic areas, number of players, consumer disparity, etc., while regulatory requirements tend to evolve over time in all discussed countries and this evolutionary process is continuous over time. The results of the study may be applicable to energy policy reformation processes taking place in developing countries, where liberalization in public utility sectors may be still at an incipient stage. Also, it seems to be useful for authorities in terms of developing additional regulatory rules or introducing subsidies that would provide incentives for market entry and boost competition, integration of markets and of distributed generation, etc.

Despite the evident trend towards retail electricity markets liberalization there are still certain obstacles slowing down this process. The liberalization of retail electricity markets might require a high switching rate between different suppliers among consumers as far as it is one of the main outcomes of the deregulatory reform. Yet consumer activism and initiative to create a competitive market seem to be considerably low when it comes to switching between electricity retailers [11]. This may be due to the long-term institutional constraint of default supply, thereby, the practice of switching between electricity retailers seems to be new or even unknown for the majority of consumers. Another source of low consumer involvement can be associated with the inertial decision-making or budget constraint. Consumer inertia arises both from the incurred costs of searching alternatives and the incumbent’s brand advantage [12].

Electricity is an instantaneous commodity and a virtually intangible product, both its production and consumption take place simultaneously; storage is still expensive, and the demand is very inelastic and follows certain seasonal patterns and fluctuations. Modern electric grids have to be balanced with certain technologies, such as high capacity storage systems, demand response programs, smart grid solutions and non-dispatchable renewable generation [13].

Considering all these barriers, more empiric evidence is needed in order to understand whether switching to purely competitive market models is the only alternative. On the one hand, deregulatory reforms are aimed at increasing economic efficiency and provide price reductions for end-users of electricity. On the other hand, it can be noted that there is no direct evidence in favor of a competitive electricity market instead of a regulated monopoly [11]. Also it should be noted that new ecology requests and development of intellectual integrated energy systems and innovative energy ecosystems may lead to next deep transform of retail energy markets, roles and strategies of their participants, price and capacity reserves mechanisms, regulation and policy of the energy sector and economy.

A noticeable limitation of this study is that its results are anchored to the cases of the 5 countries and their specific energy policy reforms. Hence, we cannot infer directly that the same conclusions would be representative for other cases.

Nevertheless, the proposed framework allows doing further comparative analysis and, thus, can be applied to other cases in future research in order to validate (or not) that certain patterns of deregulatory processes coincide in various retail electricity markets.

Further research may involve comparative analyses of liberalization processes in other utilities (landline telecom, rail, natural gas, etc.) under the creation of different intelligent power systems and change the consumer’ role. This could help to assess the effects of deregulatory reforms and technology development and improve our understanding of the consumer behavior as well as incumbent responses to liberalization and new entrants’ incentives to join the market.
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