School of Information Technology and Engineering at the ADA University

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# Comparative Analysis of International Experience and Outcome Indicators in the Application of the Liberal Market Model in Electricity

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THESIS ACCEPTANCE

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## Abstract

In recent decades, there has been a significant change in the global energy sector, as more and more nations are choosing to liberalize their power markets. This master thesis conducts a thorough comparative examination of global practices in adopting the liberal market model in the electrical sector, with a particular emphasis on the situation in Azerbaijan. This research examines the reasons, difficulties, and results linked to the process of liberalization, with the goal of obtaining valuable information that may guide policy choices and strategic development for the energy sector in Azerbaijan.

The research is motivated by the acknowledgement that energy market liberalization is a widespread global phenomenon, influenced by the need for economic effectiveness, heightened competition, and the incorporation of renewable energy sources. Azerbaijan, blessed with substantial energy resources, has initiated a process to deregulate its electricity market in order to improve operational effectiveness, attract capital investments, and guarantee a viable energy future. The aims of this thesis are to examine global instances of electricity market liberalization, discern recurring trends, and evaluate the particular difficulties and results witnessed in the Azerbaijani setting.

Review of the existing literature:

The literature study presents a thorough examination of worldwide patterns in the liberalization of energy markets, including detailed analysis of specific cases from various areas such as the European Union, the United States, China, and selected Post-Soviet nations. The study delves into several important topics such as the rules and regulations that govern the industry, the organization and functioning of the market, the involvement of different parties, and the consequences of opening up the market for investment, competition, and the well-being of consumers. The amalgamation of global literature forms the basis for the comparative examination and aids in the recognition of exemplary methodologies and possible challenges.

The study technique utilizes a mixed-methods approach, integrating qualitative and quantitative studies. Qualitative techniques entail a thorough analysis of legal and regulatory frameworks, policy documents, and stakeholder viewpoints, which enables a nuanced comprehension of the liberalization process. Quantitative techniques involve examining outcome indicators, such as fluctuations in power costs, patterns in investment, levels of market competitiveness, and the incorporation of renewable energy sources. The comparative study is organized to establish connections between worldwide experiences and the specific circumstances in Azerbaijan, enabling a detailed comprehension of the elements that impact the success or difficulties of the liberalization process.

The case study on Azerbaijan explores the context of the country's endeavors to overhaul its electrical industry. The text explores the legal and regulatory modifications, market frameworks, and the functions performed by bodies such as the State Agency for Alternative and Renewable Energy and the Azerbaijan Energy Regulatory Agency. The report examines the effects of market liberalization on energy security, sustainability, and the appeal of foreign investments in the electrical market of Azerbaijan.

The primary objective of this master thesis is to provide significant insights to the academic debate and policymakers in the energy industry. The research seeks to offer practical suggestions to policymakers, industry players, and regulatory authorities involved in the continuing liberalization of the energy market in Azerbaijan by incorporating worldwide experiences and adapting them to the Azerbaijani situation. The comparative analysis is expected to provide insights on transferable exemplary methods, potential obstacles, and the course of the liberalization process, eventually helping to the sustainable growth of Azerbaijan's energy industry on a worldwide scale.

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# LIST OF ABBREVIATIONS

| Abbreviation | Explanation |
|---|---|
| TSO | Transmission System Operator |
| DSO | Distribution System Operators |
| BRP | Balance Responsible Parties |
| BSP | Balance Service Providers |
| CSP | Congestion Service Provider |
| ISO | Independent System Operators |
| RTO | Regional Transmission Organizations |
| EU | European Union |
| US | United States |
| DER | Distributed Energy Resources |
| DA | Day-Ahead |
| LMP | Linear motor propulsion |
| MW | Megawatt |
| AI | Artificial Intelligence |
| ERCOT | Electric Reliability Council of Texas |
| LOESS | Locally Estimated Scatterplot Smoothing |
| CC | Combined Cycle |
| REI | Renewable Energy Infrastructure |
| EMO | Energy Market Operators |
| UK | United Kingdom |
| MMS | Market Management Systems |
| API | Application Programming Interface |
| COTS | Commercial Off-the-Shelf |
| CDO | Central Dispatching Office |
| NREL | National Renewable Energy Laboratory |
| NEM | National Electricity Market |
| FERC | Federal Energy Regulatory Commission |

# CHAPTER ONE:

## 1.1 Introduction

In an era marked by rapid technological advancements and global economic integration, the electrical energy industry stands as a critical nexus for sustaining modern societies. The liberal market model, with its emphasis on deregulation, competition, and efficiency, has emerged as a prominent paradigm in shaping the trajectory of this industry worldwide. As nations grapple with the complexities of meeting escalating energy demands and addressing environmental concerns, a comprehensive evaluation of the international experience becomes imperative. This master thesis embarks on a nuanced exploration, conducting a comparative analysis of international practices and outcome indicators in the application of the liberal market model within the electrical energy sector. Through this study, we endeavor to unravel the intricacies, assess the effectiveness, and derive valuable insights that contribute to the ongoing discourse on the evolution of energy markets globally.

## 1.2 The interplay between efficiency and innovation

The liberalization of the energy market fosters both efficiency and innovation. The inclusion of the private sector frequently offers state-of-the-art technology, management strategies, and business models, therefore augmenting the total efficacy of energy production, distribution, and consumption.

## 1.3 Main actors of market model

The electricity system and its markets are characterized by various actors with specific roles and responsibilities, outlined by law and regulation. While each role can be fulfilled by a separate player, companies often perform multiple roles simultaneously. The figure below illustrates the most important categories of actors and their relationships. The electricity system is divided into three domains: physical, administrative, and market. Physical domains involve production, transport, consumption, and security. Administrative domains involve managing customer relationships with grid operators, monitoring consumption and production, and arranging invoicing. Market domains list necessary market platforms for transactions. These roles are crucial for maintaining the stability and security of the electricity system.

**Figure 1.1** displays the essential tasks and outcomes. **Figure 1.2** illustrates the value network, where activities are allocated to existing market actors to enhance the understanding of their respective responsibilities in value creation. [16]

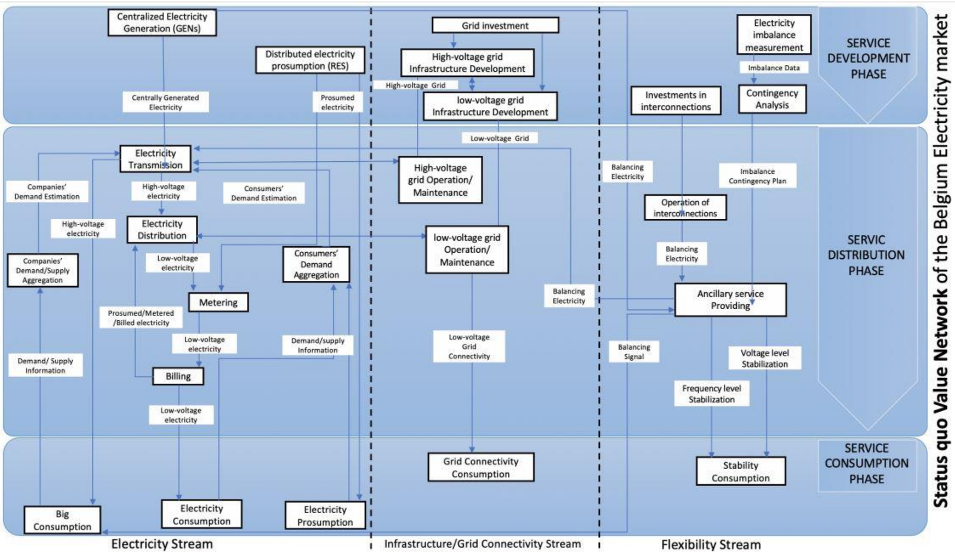



**Fig. 1.1.** Service streams, critical activities and deliverables in the current electricity market [16]

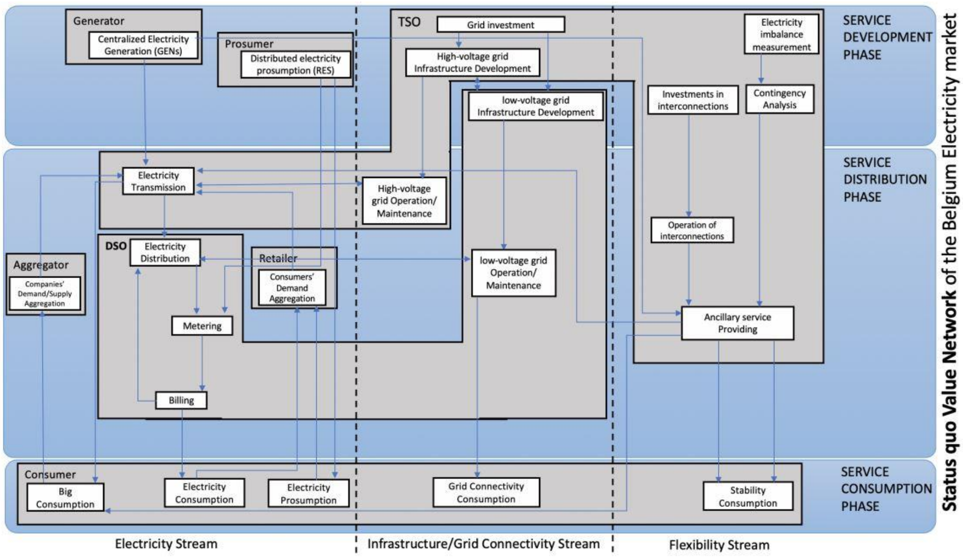



**Fig. 1.2.** Roles in the current electricity market [16]

### 1.3.1 Physical domain

#### *1.3.1.1 Electricity producers & consumers (connected party)*

Electricity producers, ranging from large to small, generate electricity from various resources like wind, solar, hydro, natural gas, and coal. They connect to the grid, become Balance Responsible Parties, and offer their production capacity to balance or congestion service providers.

#### *1.3.1.2 Transmission System Operators (TSO) & Distribution System Operators (DSO)*

TSOs manage the high voltage electricity grid, monitoring supply-demand balance and planning expansion. They collaborate to facilitate a single European market. DSOs operate the regional distribution grid, planning, construction, maintenance, and data exchange. Both aim to avoid grid congestion.

### 1.3.2 Administrative domain

#### *1.3.2.1 Balance Responsible Parties (BRP)*

A Balance Responsible Party (BRP) balances off-take and feed-in for imbalance settlement periods, transmitting customer forecasts to grid operator. BRPs apply, complete prequalification, and trade on market platforms.

#### *1.3.2.2. Electricity Suppliers*

Electricity suppliers contract with consumers, purchase power on the wholesale market, and some are BRPs, financially responsible for customer consumption and production. They forecast consumption and report on behalf of their customers.

#### *1.3.2.3 Balance Service Providers (BSP)*

Grid operator procures balancing capacity from Balancing Service Providers (BSPs) to address grid imbalances, requiring BSPs to prequalify at the company for market access.

#### *1.3.2.4 Congestion Service Provider (CSP)*

Congestion service providers (CSPs) offer location-bound, location-bound congestion management services to TSOs, enabling them to feed or take off power in high-pressure grid areas.

#### *1.3.2.5 Aggregator*

Aggregators combine flexibility from small consumers and producers, offering combined capacity in wholesale, balancing, or congestion markets. They may also become congestion service providers in the future. [10]

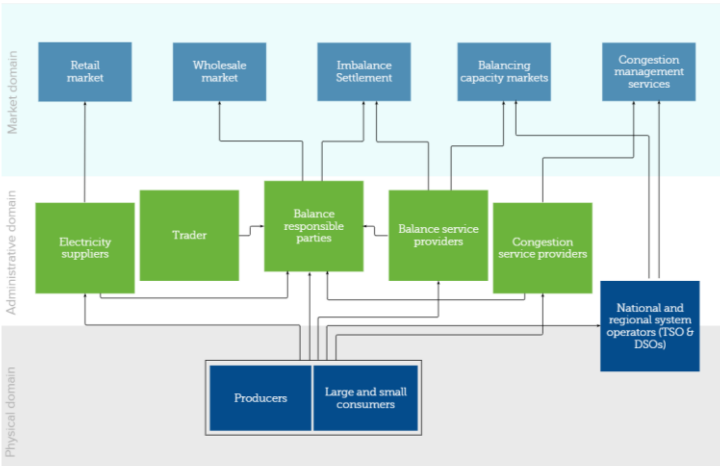



**Fig. 1.3.** Roles and actors on the electricity market and their connection to different sub-markets. [10]

## Literature Review

Over the last several decades, there has been a significant change in the global energy industry, characterized by the broad implementation of energy market liberalization. This literature study offers an extensive examination of various foreign experiences, illuminating the reasons, difficulties, and results linked to the liberalization of energy markets. The primary objective is to identify applicable knowledge for the particular situation in Azerbaijan.

1. Worldwide Patterns in the Deregulation of Energy Markets:

A comprehensive examination of energy market liberalization efforts on many continents demonstrates a consistent objective: to achieve economic efficiency, foster more competition, and facilitate the incorporation of renewable energy sources. Case studies conducted in the European Union, the United States, China, and some Post-Soviet states are used as reference points, providing significant knowledge on regulatory frameworks, market structures, and results.

2. Regulatory frameworks and industry dynamics are crucial factors in determining the outcome of energy market liberalization. Studying worldwide patterns reveals various regulatory methods that control the entrance into markets, pricing processes, and the responsibilities of important participants. Comprehending the complex interaction between rules and industry dynamics is essential for successfully implementing liberalization initiatives.

3. Market Organization and Stakeholder Involvement: Scholarly works from many locations highlight the importance of market organization and the proactive participation of stakeholders in influencing deregulated energy markets. An examination of organizational structures, the functions of market operators, and methods for stakeholder involvement enhances our comprehension of how these factors contribute to the competitiveness and effectiveness of the market.

4. Energy market liberalization has significant effects on investment, competition, and consumer welfare. It provides valuable insights into how investment patterns are influenced, how market competitiveness is affected, and how consumers' well-being is impacted. Examining variations in electricity expenses, trends in financial allocation, and customer feedback in deregulated economies yields a comprehensive comprehension of the intricate consequences linked to the procedure.

5. Integration of Renewable Energy Sources: The literature emphasizes the crucial significance of energy market liberalization in promoting the incorporation of renewable energy sources. Gaining knowledge about worldwide plans, motivations, and difficulties associated with the integration of renewable energy helps in developing policies that are in line with the global transition towards sustainable and varied energy portfolios.

6. Methodological Approaches in Comparative Studies: The literature on energy market liberalization is characterized by a wide range of methodological approaches. An integration of qualitative and quantitative methodologies, as shown in research investigating legislative and

regulatory frameworks, policy documents, and result indicators, is crucial for obtaining a comprehensive comprehension of the liberalization process.

This literature study provides a basis for comparing and analyzing the liberalization of the energy sector in Azerbaijan. It draws on worldwide experiences to understand the unique problems and possibilities involved. This study seeks to provide significant views on energy market liberalization in Azerbaijan by combining lessons from various international settings.

# CHAPTER TWO: Zonal and Nodal Energy Market Models

Power networks in European and American countries were traditionally controlled by state-owned monopolies, managing centralized nuclear facilities or conventional fossil fuel-based utilities. These monopolies controlled all components of the international connectivity system, limiting consumer access. This structure has several drawbacks, including impeding scientific and technical advancements, compromising product quality, and exerting unilateral control over pricing. The influence of state monopolies can determine sales, energy pricing, distribution fees, transitional fees, renewable energy costs, and surcharges for electromobility advancement. Social well-being is the most widely applicable economic criterion for assessing organizational performance in the energy market. The negative impact of monopoly can be seen on a price-quantity graph, illustrating a decrease in efficiency and social welfare.

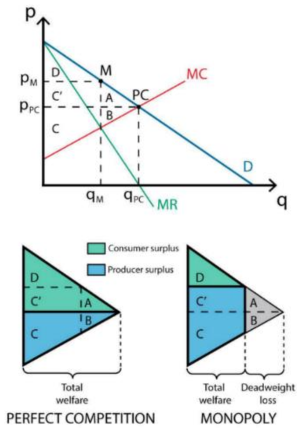



**Fig. 2.1.** The decline in economic well-being resulting from the monopoly Source [5]

Customers desire competition, but Figure 2.1 demonstrates how monopolies hurt prosperity. Market price is pPC, production is qPC, consumer surplus is D + C' + A, and producer surplus is C + B in perfect competition. Monopolies hurt customers. Production will drop to qM and price climb to pM. Consumer excess in Field D. Monopolists have producer surplus in Field C. Perfect competition lowers Field A consumer surplus and wellbeing. In Field B, producers lose. A + B fields reflect market monopolization economic well-being loss. Nodal models increase short-term energy market rivalry. The nodal approach resolves short-term energy and transmission markets with one auction. Transmission restrictions and physical laws limit network energy flow, therefore the auctioneer picks the lowest-cost bids that balance node energy supply and demand. Market clearing price equals node energy marginal cost. Customers obtain the greatest energy price with this cleaning procedure. Market actors mistrusted new enterprises, impeding state monopolies' collapse and competitive transition. Market-passive energy customers purchased electricity at regulated prices regardless of market circumstances. One-way energy flows with passive consumers and poor price elasticity. Future energy users should own the whole market share equally with all market players. Retailers and corporations require energy management. Flexible energy consumption is feasible for families. Slow washers and cleaners should know this. Energy-intensive customers may switch to cheaper electricity without disturbance. Strategy for the energy sector: demand response/management. Energy users go from high-cost to low-cost day/night tariffs via continuous optimization. Some users can't modify their power use. Consumer knowledge, technical, economic, organizational, and social developments are driving energy market customer engagement (Figure 2.2).

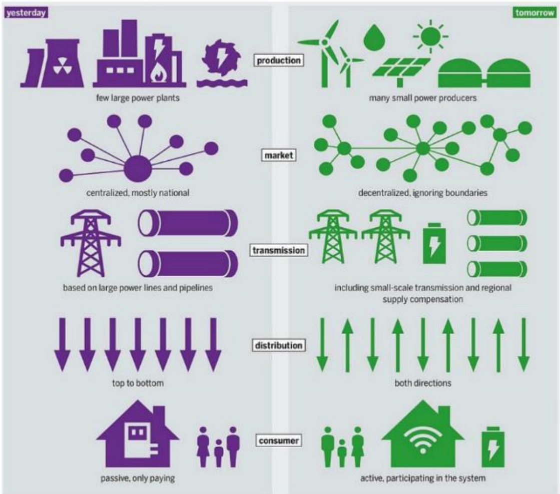



**Fig. 2.2.** Future of the energy sector. [5]

Figure 2.2 illustrates prosumers may join two-way electricity marketplaces. Grid power may be sold or generated by consumers. On-grid consumption follows off-grid. Installing solar panels on rooftops or around residences makes consumers prosumers. Advanced energy storage technologies like batteries will be employed. Governments must encourage active consumption with legal and financial incentives. Decentralisation and boundarylessness will allow market liberalization, price formulation, and energy transfer between zones under the new paradigm (Figure 5). A flexible energy demand and storage market will incorporate renewable energy into the electricity grid. The digitizing technology must be creative. Electrochemical, chemical, hydrogen, batteries, thermal, thermochemical, compressed air, flywheel, pumped, and magnetic storage may interrupt current for seconds to months. Storage is needed for renewable energy. If weather allows, wind, water, and sun may create unexpected power. Effective energy storage requires these sources. A system must coordinate and synchronize energy supply and demand across numerous complementary energy systems to handle various and unpredictable energy sources. Early energy sector digitization leaves energy infrastructure undigitized. A severely regulated energy industry makes it challenging to bring new ideas and technologies. Power sector dynamics and needs alter with distribution network digitization, automation, and renewable DER grid inclusion. Flexible loads and smart meters are emphasized to increase system dependability since DER energy production is unpredictable. The impact of digitization on energy. The energy sector will be automated and digitalized. Science buzzwords include big data, innovative machine learning, AI, IoT, and DLT blockchain. Making new distributed ledgers is tricky. In energy, DLT may allow peer-to-peer trade, microgrids, and local demand response.

**Table 2.1.** High-level comparison of the nodal U.S. style and zonal-EU style day-ahead market [11]

| Characteristic | Nodal (U.S. RTO/ISO style) | Zonal (EU style) |
|---|---|---|
| *Dispatch decisions* | Mostly central dispatch, self-scheduling of some assets | Self or central dispatch |
| *DA market operator* | ISO | Power exchange |
| *Bid design* | Multi-part bids | Mostly simple and block, possibly multi-part bids |
| *Market clearing rule* | Linear pricing | Strictly linear pricing |
| *Balancing responsibility* | Unit-based | Portfolio or unit-based |
| *Reserve procurement* | Co-optimized | Sequential |

## 2.1 Zonal Model

A zonal market framework, energy security, global competitiveness, and climate policy underpin the European energy plan. Zones are the main congestion-reduction approach. Several assumptions simplify the nodal market in this model. It distorts the complex physics-influenced market. Direct market participants avoid transmission network limits in energy transactions. Technical issues and transmission system operators can cause this. Politicians typically support this methodology for impartially handling energy merchants. A intentional political decision to use a zonal market model instead of a nodal one shapes EU zoning regulations. Most European nations use market zones. The EU energy market unification involves 28 countries and 500 million electricity users. Due to vast price zones, EU energy markets provide considerable trading options. Trading is limited solely by transmission bandwidth. European market model has three main components:

(1) Zones represent an integrated energy system that merges national markets into a pan-European market under the European market model. Europe legally integrates energy networks using the zonal market paradigm. European nations have similar characteristics in a zonal power market. Many nations use the zonal model. A zonal electrical market model divides the market into zones with consistent power pricing. A zone usually covers a large part of a country or the whole thing. Delays along boundary lines usually decide the result. Signal transmission is unrestricted in the defined region. Restricting long-distance connections will affect regional pricing. This model assumes there are no restrictions on transmitting power and doing business in pricing zones or market regions with the same price. This is the "copper plate" assumption. The "Copper plate" idea states that energy may be freely exchanged. This copper plate does not exist, but the electrical sector market is built on the notion that it exists. The transmission network and products manufacturing and distribution are restricted. Transportation costs for product delivery vary by location. Copper plate theory ignores energy transfer losses. Use the equation to get the physics-based loss ratio (index).

$$\Delta E_{\%} = \frac{\Delta E}{EI} \times 100 \qquad \text{(equation 2.1)}$$

- ΔE— Network losses and imbalances at a specific voltage level,
- EI— Electricity is supplied to the network at a specific voltage level.

The "copper plate" idea discourages expensive expenditures, causing problems for the transmission system operator. All sites get power from the TSO, which raises expenses. European zones were mostly defined by administrative demarcations, although they sometimes matched with state borders. The analysis did not evaluate transmission capacity in these zones. Interconnectors link zones, and their transmission capacity impacts transaction volume. European law allows dynamic zone changes, strengthening the zonal market. Thus, zone borders are easily changed. Political constraints hamper this mechanism's practicality or accomplishment.

(2) Capacity measures may temporarily help a commodities market by assuring adequate generation. Single-commodity markets focus on energy products by amount, time, and delivery zone, unlike two-commodity markets. Megawatt hours of energy usage determine charges. The Transmission System Operator (TSO) in an area provides essential services to keep the electrical system running smoothly. The manufacturer with the greatest merit order cost sets wholesale prices. Thus, prices reflect the generating unit's immediate variable cost or operating costs. The EU uses strategic reserve and capacity markets to improve the single-goods market and ensure medium-term power generating stability. These procedures are accepted because they are understood to be transitory government help.

(3) Markets help European industries integrate. The regulatory advantages of long-distance exchanges over zone-based ones. European law like the Clean Energy for All Europeans Package (CEP) prioritizes energy exchange inside zones over across zones. This method improves global market integration. Its use seems to threaten European consumers' supply. Transmission capacity assumptions ignore system technology and operational restrictions. Prices will converge and European manufacturing facilities will be more efficient. Price signals created under these conditions are mostly unrelated to system needs. Due to its simplicity, corrective steps were needed, resulting in a huge cross-border re-dispatching market. This market prices assets differently than wholesale. The energy exchange between surrounding system operators corrects market actors' trade-related physical flows. Inter-operator communication keeps electricity

networks independent and integrated in accordance with security requirements. Thus, preventive steps ensure energy reliability for end-users. Several experts believe electrical market changes may lower consumer power costs.

### *2.1.1 Drawbacks of the Zonal Model*

The EU's zonal market model fails to account for transmission network limitations and intricacies, lacks market price signals for manufacturing investors, and lacks a capacity market to guarantee electricity supply. The zonal market model's lack of site-specific energy values hinders new energy source installation and generating source sustainability.

The EU is adding tools like the capacity market to address these issues. This market encourages investments in upgraded and new power production facilities, energy management, and power demand flexibility. The move from an electricity-only market to one that includes capacity reduces market disruptions and improves energy market technical and economic efficiency without burdening producers and consumers.

The zonal market model is efficient yet full, requiring optimization of all activities to handle distant sources. The zonal market model ignores physical factors that significantly affect energy delivery costs. As the energy revolution continues, market power and system capacity diverge. An gradual adjustment will improve energy market technical and economic efficiency without overburdening producers and consumers.

Each area may be considered as separate energy subsystem in a multi-regional energy system market model to investigate zonal energy market model linkages. Each area is an autonomous energy subsystem in this market optimisation and network theory model of a multi-regional energy market. The suggested model helps energy policymakers understand how renewable energy affects the global energy market and may be improved to create a coherent power market.

European legislators advocate localization because it can solve the EU's zonal market model's problems and create a more efficient and ecologically friendly energy market.

## 2.2 Localization Model (Nodal)

The Operator oversees restricted trade and transactions in the localized (nodal) energy market, which operates like an auction. This approach lets suppliers submit bids that include current pricing, future investment costs, and energy supply and consumption nodal costs. Nodal markets in the US, Australia, and New Zealand provide opportunities to overcome market challenges and integrate intermittent renewable energy technology.

New Zealand uses full nodal pricing, whereas Australia uses mixed. Distributed generation, which includes renewable energy, is rapidly changing distribution system operators' roles. This change is turning people from passive energy consumers into active energy producers who can give electricity to the power grid, relieving power infrastructure pressure.

Blockchain technology might improve energy system, market, and consumer transactions. Blockchain technology ensures transaction visibility, prevents tampering and speculation, and lets consumers, end-users, and small renewable energy producers participate in the energy market and easily sell their assets. Using a decentralized blockchain platform, carefully constructed smart contracts allow consumers and prosumers to directly swap energy without energy suppliers.

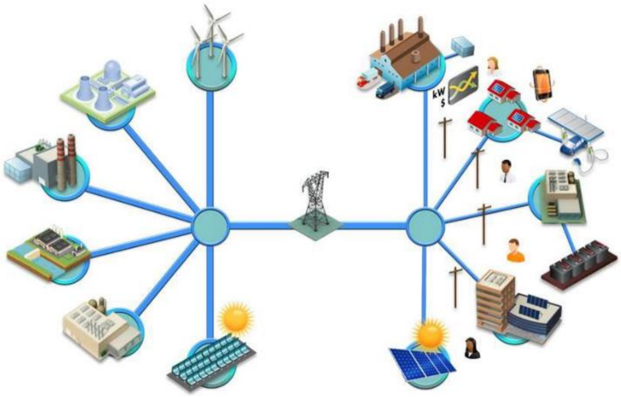


**Fig. 2.3.** Power system of the future. [5]

The Operator's strict control hinders market liberalization and complicates pricing. However, it grows safer with time. Some say dispatch-based location-based pricing would simplify things. Calculating marginal location costs for physical delivery is easy. Node market energy pricing depend on client location, electricity production, and infrastructural development. Market processes effectively distribute and alleviate traffic and price in nodal systems, increasing energy output and network resource allocation. All nodes, resources, and transmission limits must be considered to clear the nodal market. This market represents power system circumstances and reduces technical and market differences in energy transmission. Losses occur with electricity. Voltage transformation and wire energy transmission cause losses. Transformer core and coil losses are included. Figure 2.4 shows transmission network energy losses as technical and trade losses.

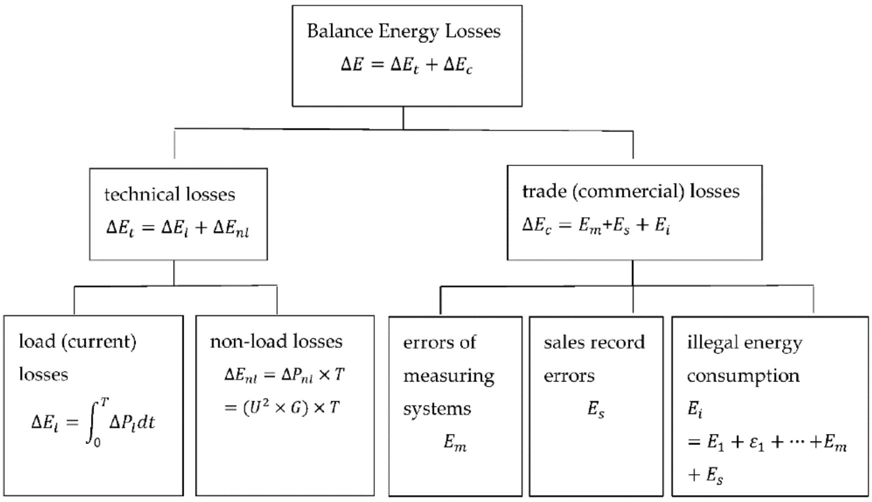



**Fig. 2.4.** Losses in energy sector.

$\Delta Pl$=power load losses, $\Delta Pnl$=power non–loaded losses, $U$=conducance of a network element, $G$=interfacial tension, $T$=time, $E1$=customer 1, $\varepsilon 1$=illegal consumption by customer 1 [5]

Average network transmission losses are 2–2.5%. Distribution network losses are 8–10%. The use of superconducting transmission lines may reduce these losses. Transportation losses should be included in energy supply costs. In most of the EU, customers and network users pay transmission rates for loss costs. Nodal price includes transmission loss expenses. Locations of suppliers and recipients affect energy pricing. System operators in power firms must calculate loss regularly. Costs of infrastructure construction determine long-distance transmission energy availability. The zonal market model accounts for this large loss in infrastructure and consumer spending. The node market sets energy prices using objective and transparent factors. The location model's energy pricing will depend on market variables, including producer, TSO, and DSO costs and demand. An optional cost. In moderate-energy locations, passive consumers might use mechanisms. Nodal pricing promotes end-user market involvement. Novel control features will enable two-way communication with moderate-sized demand management receivers. Parties may sign energy supply agreements according to their needs in a free-market system if they are ready to risk price swings and energy transmission costs. Multiple nodes are possible in the present price zone.

The nodal model is most efficient using an optimization technique that includes all expenses, including the locational marginal price. Linear motor propulsion (LMP) gives buyers and sellers exact price signals. LMPs tell investors where fresh energy is needed. Labor market reforms boost investment. The marginal location price at node k includes energy, congestion, and losses.

$$LMPk = LMP\frac{E}{k} + LMP\frac{C}{k} + LMP\frac{L}{k} \quad \text{(equation 2.2)}$$

The LMP model is "ecological" since it maximizes emission source efficiency, favoring low-emission sources. LMP works like taxis, where payment depends on journey length and distance. Driving expenses rise dramatically during peak demand and lengthy distances. Cost is much lower when demand is low and distances are short. The zonal method requires equal contributions from everyone.

The minimized objective function shows the cost of balancing the system with a one-unit demand increase. An incremental technique assumes a 1 MW demand increase at the receiving node to compute network losses. Applying the general equation for a network operating point generates network loss coefficients. Formulation of the equation:

$$\sum_{k=1}^{n} \boldsymbol{NLFk} \times \boldsymbol{\Delta Pk} \qquad \text{(equation 2.3)}$$

NLFk—network loss factor for node k;

$\Delta Pk$—increase of power in the node “k” assuming that the power flowing from the node has a positive sign, and the stream flowing into the node has a negative sign;

N—number of nodes.

The solution must follow restrictions, like any optimization problem. To meet demand, the location model requires equality restrictions for all network nodes. System components' technology causes uneven limits. Shadow, marginal, calculation, clearing, and concealed pricing imply limits. The shadow price of energy, a difficult calculation, should match its market price to appropriately reflect resource economic opportunity costs.

Identifying the nodal price components is necessary to understand and evaluate the Locational Marginal Price (LMP) mechanism. Power generating should prioritize low marginal costs. This lets system models specify nodal pricing variables. The nodal price includes energy, loss, and system limitation costs. All elements are numerical. Energy supply costs include transmission services, equipment depreciation, maintenance and repair, and transmission rights fees. This ensures price transparency. Based on the data, it is crucial to understand and analyze the contributions of European countries that will use the LMP approach to set nodal energy pricing in their power systems.

### 2.3 Pros and Cons of Zonal and Nodal Models of Energy Market

Comparing both energy market models shows that the zonal model has excessive simplifications and various shortcomings that need additional processes to minimize. This policy fails to encourage innovation and investment. The proposed nodal model is more realistic, fitted to market challenges, and allows for a modern energy market. Table 2.2 lists the pros and cons of both approach.

**Table 2.2.** An analysis of two market models.

| | Advantages | Disadvantages |
|---|---|---|
| **zonal market** | • theoretically unlimited commercial opportunities<br>• structure easy to implement<br>• electricity price set at a higher level of generality<br>• quick benefits for market integration<br>• no price signals on the market for potential investors in the manufacturing sector | • inability to increase exchange capacity between zones<br>• non-schedule flows<br>• inability to initiate investments in generation capacity based on market conditions<br>• the model does not correctly take into account physical phenomena that significantly affect the cost of providing energy to the end user<br>• requires implementation of additional security mechanisms, e.g., capacity market |
| **nodal market** | • not only the cost of production, but also the cost of energy transmission is included<br>• better use of the network by reducing security margins<br>• transparent and understandable prices for market participants<br>• model conducive to business innovation | • the nodal price system is more complex and more computationally demanding than the zonal price system |

Customers may actively participate in the nodal model by using the nodal price as a stimulus signal to shift their power demand to a cheaper time. Node models effectively show network circumstances and allow price element evaluation. It also helps analyze geographical data to add energy sources. The nodal market gives investors more incentives, but market effectiveness relies on location price signal validity and accuracy. Nodes have far more market power than zones. The suggested nodal model incorporates production and transportation costs to improve energy price. This technique promotes network localization and energy business investment. This paradigm fosters liquid short-term markets for equitable stakeholder involvement. Energy costs will match consumer value. The function of the final receiver will change as civic energy (prosumers and energy clusters) and electromobility expand. Digitizing the sector will boost power grid efficiency and resource use. Prosumers will create and trade energy. Big data, machine learning, and AI will impact the energy business. This will need new methods for evaluating and presenting data, combining fragmented information, and learning new skills to use energy system data for national and commercial competitive advantage. The nodal model incorporates production and transportation costs to improve energy pricing mechanisms, supporting network localization and energy industry investment. This paradigm fosters liquid short-term markets for equitable stakeholder involvement. Energy costs will match consumer value. The function of the final receiver will change as civic energy (prosumers and energy clusters) and electromobility expand. Digitizing the sector will improve power grid operations and resource use. Prosumers will create and trade energy. Big data, machine learning, and AI will impact the energy business. This will need new data analysis and visualization methods, integration of fragmented data, and new capabilities to use energy system data for national and commercial competitive advantage.

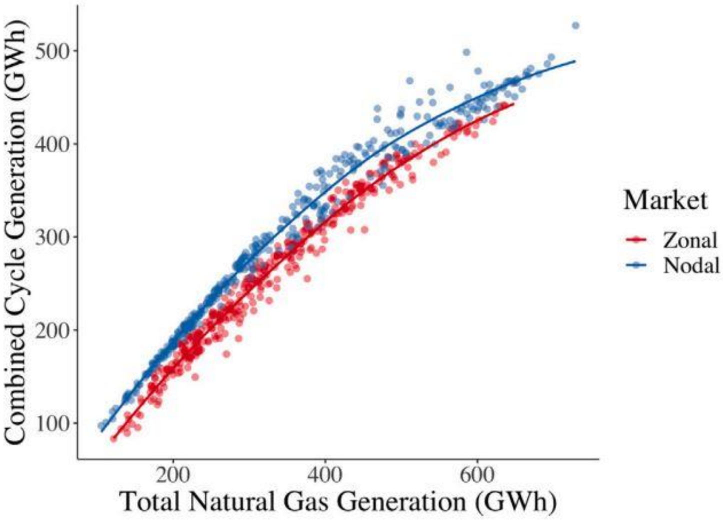



**Fig. 2.5.** Combined cycle generation vs. total natural gas generation (Daily) Data source: ERCOT. A local regression (LOESS) trendline is pictured. [17]

CC units generated 78.1% of total natural gas in the 12-month zonal period and 84.4% in the nodal period, according to ERCOT statistics. Fig. 2.5 compares daily CC and natural gas production. Given nodal market natural gas generation, CC generation is greater here.

### 2.4 Azerbaijan's Energy Market Liberalization

The liberalization of Azerbaijan's energy market is of utmost importance for the nation's future progress, economic diversification, and the adoption of sustainable energy practices. As Azerbaijan anticipates the complexities and prospects of the 21st century, the adoption of a liberalized energy market model emerges as a crucial strategic necessity.

The concept of economic diversification refers to the process of expanding and varying the range of industries and sectors within an economy.

The process of liberalizing the energy sector has the potential to stimulate economic diversification. By promoting competition and encouraging the involvement of private entities, the energy sector has the potential to emerge as a dynamic catalyst for economic expansion, extending beyond the conventional domains of the oil and gas sectors.

The process of liberalization has the ability to attract foreign direct investment. The liberalization of the energy market in Azerbaijan enhances its appeal as a favorable location for global investors who are interested in engaging with a competitive and transparent energy industry. Consequently, this development contributes to the advancement of economic growth.

The concept of a diverse energy mix refers to the utilization of a variety of energy sources in order to meet the energy demands of a given system or society.

The liberalization of a market has the potential to facilitate the development of a more varied energy portfolio. By promoting investments in renewable energy sources, Azerbaijan has the potential to decrease its reliance on conventional fossil fuels, so making a significant contribution to environmental sustainability and the mitigation of climate change hazards.

### 2.4.1 The Impact of Consumer Decision-Making and Economic Accessibility

The process of liberalization provides consumers with the ability to exercise their freedom of choice. The presence of many competitors in the market fosters competition, which in turn leads to advantages for customers such as competitive pricing, enhanced service quality, and a wider range of energy choices. These factors all contribute to increased affordability and improved overall service standards.

### 2.4.2 The topic of discussion is the regulatory framework and transparency

The successful implementation of a liberalized energy market requires the establishment of a comprehensive regulatory framework. The implementation of clear and transparent rules and regulations plays a crucial role in cultivating trust among players in the market. This fosters an atmosphere of fair competition and facilitates the development of a business climate that is conducive to sustained growth in the long run.

### 2.4.3 The topic is the correlation between job creation and skills development

The process of liberalizing the energy industry has the potential to generate employment opportunities and foster the enhancement of skills. With the emergence of new enterprises and the influx of investments in the industry, there exists a prospect for an increase in job opportunities and the cultivation of a proficient labor force specializing in contemporary energy technology.

The concept of global competitiveness refers to the ability of nations, organizations, or individuals to effectively compete in the global marketplace. It encompasses

The adoption of energy market liberalization in Azerbaijan brings the country in line with prevailing global trends. The aforementioned initiative strategically situates the country as a formidable

articipant in the global energy market, promoting cooperation and alliances with other countries while actively contributing to the worldwide shift towards sustainable energy sources.

## CHAPTER THREE: Legal Framework Regulating Renewables and Incentivization

The existing legislative structure governing the energy market primarily emphasizes the government's position as the primary actor, particularly through public utilities, with hydrocarbon resources playing a secondary role. The following are the five fundamental laws that serve as the foundation for all initiatives and strategies implemented in the energy industry:

The following laws pertain to energy in the country:

- Law 541-IQ, 1998: The Law on Energy
- Law 459-IQ, 1998: The Law on Electrical Power
- Law 784-IQ, 1999: The Law on Electrical and Thermal Power Plants
- Law 339-VIQ, 2021: The Law on Utilization of Renewable Sources in the Electricity Production
- Law 359-VIQ, 2021: The Law on Efficient Use of Energy Resources and Effectiveness of Energy

The Law on Energy was enacted in 1998, with a specific emphasis on promoting the growth of renewable energy sources and reducing the environmental impact of energy production. Simultaneously, the government was designated as the exclusive authority responsible for granting specific authorizations and licenses to any entity seeking participation in the energy market (Law 541-IQ, 1998). The Law on the Electrical Power enacted in 1998 was the initial legislation to acknowledge private generators as participants in the energy market, and it even promoted the market's deregulation (Law 459-IQ, 1998). Law 459-IQ established the specific participants of the energy market:

- State utilities;

- Private generators—these actors have the right to sell generated power to the state utility or the supply firm (monopolized by public utilities). Excess power generated should be purchased by state utilities,
- Energy supply firms (only public utilities),
- End users.

Electricity and Thermal Power Plants Law 459-IQ allows private generators to compete in the market if they operate on their own property and sell energy to public utilities or use it privately (Law 784-IQ, 1998).

In 2021, two laws passed. REI growth depends on Law 339-VIQ, the Renewable Sources in Electricity Production Law. The first renewable-energy-only law. Law 339-VIQ outlines the government's and power generators' responsibilities, assistance, and REI regulation principles.

Laws 339-VIQ and 359-VIQ, on Energy Efficiency and Effectiveness, encouraged renewable energy use in the future. Legally, renewable energy is underemphasized. Only twice is "renewables" mentioned in general listings (Law 359-VIQ, 2021). The Law on the Utilization of Energy Resources (94-IQ) proposed a renewable energy fund, but Law 359-VIQ replaced it.

Overall, the energy market's legal framework recognizes renewables as an alternative to hydrocarbons, emphasizes their development, allows private entities to participate, and states the state's intention to improve all of the above. Small private energy companies are scarce, so these measures can be improved.

Two state initiatives supported renewable energy growth in addition to the law. Azerbaijan implemented the 2004 State Program on Alternative and Renewable Energy. This program assessed the country's renewable energy potential, integrated it into the energy system, legalized the industry, and accelerated the privatization of small-scale generation plants. The 2012–2020 State Strategy on Utilization of Alternative and Renewable Energy Sources in Azerbaijan was implemented in 2011 to promote renewable energy. The 2014:2015-2020 State Program for Industry Development in Azerbaijan emphasized REI's strategic importance.

REI didn't increase until the late 2010s and early 2020s in Azerbaijan. Many legal measures have emphasized renewable energy and a free energy market, but the situation remains unchanged for several reasons. Concerns about energy security, abundant fossil fuel reserves that attract substantial investment through long-term contracts for exploration, extraction, and use, limited market liberalization, unclear entry procedures, and a lack of accessible information about energy market requirements and permissions are among these reasons. The Ministry of Energy's 2020 advanced energy market model allowed private companies to supply energy to end-users. Table 3.1 shows data.

**Table 3.1.** Target energy market model. [1]

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Generation | Public utilities | Transmission grid | A public utility in charge for:<br>1. Transmission<br>2. Dispatch<br>3. Market operating | Transmission grid operator | Public utility | Suppliers | Public utilities |
| | Private companies | | | | | | Private companies |

The primary distinction of the newly introduced model proposed by the Ministry of Energy, as opposed to the previously described legislative framework, is that private enterprises will now have the capability to market the produced power directly to customers.

The successful transition of countries to renewable energy sources highlights the need of implementing supportive policies to encourage private investment in the energy sector. Azerbaijan has previously lacked this component, however in the 1990s, there were discussions about establishing incentivized systems, as specified in regulations 94-IQ and 459-IQ. Curiously, the Ministry of Energy has issued two distinct documents outlining separate methods of supporting the growth of the energy market and renewable energy sources (refer to Table 3.2).

**Table 3.2.** Support mechanisms announced by the Ministry of Energy of Azerbaijan.

| Names of Documents | |
|---|---|
| **Energy Sector in Azerbaijan** | **Development of the Renewables in Azerbaijan** |
| Feed-in-Tariffs | Mechanism to offer high potential zones to private investors either directly or through a selection process |
| Special mechanisms to support active market actors | Feed-in-Tariffs |
| Provision of subsidized loans | Special tax and customs regimes |
| Research and development support | Net metering/net billing |
| | Other support mechanisms |

Feed-in-Tariffs (FITs) are the predominant kind of financial assistance employed in nations that have achieved significant progress in Renewable Energy Infrastructure (REI) development. The Council of European Energy Regulators (CEER) published its Status Review of Renewable Support Schemes in Europe for the years 2016 and 2017. The report identified the following policies as the most often implemented in European countries:

- Feed-in-Tariffs (FITs),
- Feed-in-premiums (FIPs),
- Tradeable green certificates,
- Investment grants.

Without a strong legal framework, the REI struggles to progress. Despite papers and legislation, renewables were not prioritized until recently. The implementation of recent regulatory measures, energy market frameworks, and complementary policies is uncertain. However, green energy is becoming more popular as efforts and resources are directed toward it. Later in 2019, the government announced increased collaboration with many firms to learn how to standardize renewable energy regulation. In order to gain expertise in three areas—attracting private investment in renewable energy, developing mechanisms to incentivize private actors, and increasing the proportion of renewable energy in electricity consumption—a contract was signed with Norwegian DNV Energy Advisory LTD. In addition, the Ministry of Energy announced efforts to develop bidding systems to attract private investors to the energy market.

Azerbaijan is a small energy market with about 6,000 MW of installed energy capacity and less than 2,000 MW of potential renewable energy installations, so it may not need complex legislation like that of larger countries with larger populations, economies, and more diverse energy sectors. We immediately think of two simple options for Azerbaijan. One way to ensure national energy security and industrial development is to design a contractual framework like the Contract of the Century for petrochemical sector reconstruction. A basic auction system like those used in many countries is another option. This system would make renewable energy affordable and enable project collaboration. Azerbaijan would benefit from a contractual approach, say the authors. Because of their Contract of the Century implementation success. Azerbaijan can align its economic interests with its project partners by simplifying the consortium and setting clear, mutually beneficial conditions. This project could be completed with Azerbaijan's leading energy company.

Legal framework for renewable energy implementation evidence is still developing. Its reliability and effectiveness are less certain than the diagnostic phase and Azerbaijan's renewable energy potential. The regulatory authorities may use this scenario's challenges and opportunities.

### 3.1 Law of the Republic of Azerbaijan on electric energy

Transition to liberal market relations against the background of the Law "On Electric Power" and the Decree of the President of the Republic of Azerbaijan dated May 19, 2023 on the implementation of the Law "On Electric Power".

Law No. 858-VIQ "On Electric Power" entered into force on April 11 of this year.

On May 19 of the current year, the President of the Republic of Azerbaijan signed a decree on the application of the relevant law.

In order to adapt the electric power subjects and consumers to the changes in the electric power market, including the introduction of free competition relations and the abolition of subsidization, the process of applying the elements of the electric power market is planned to be carried out in three stages and in the following periods:

1. the first stage lasts from the date of entry into force of this Law - from January 1, 2024 - to June 30, 2025;
2. the second stage lasts from July 1, 2025 to June 30, 2028;
3. the third stage starts from July 1, 2028

**The Law of the Republic of Azerbaijan** outlines the process for regulating electricity generation and transmission activities. **In the first stage,** measures are planned to separate these activities from a legal and administrative point of view. This includes obtaining permits from the relevant executive power body in accordance with the law.

The specialized department of the central operative-dispatching service of the transmission system operator will implement economic optimization of electricity production. Financial and functional separation of electricity distribution and supply activities will be established. Regulation of electricity transmission, wholesale and retail prices (tariffs) will be implemented by the body determined by the relevant executive power body.

**In the second stage,** a separate legal entity under the transmission system operator will be established to organize the operation of the electricity wholesale market. The market operator will purchase electricity from all producers, except those who sell electricity to a guaranteed buyer in accordance with the law. The market operator will also sell electricity to all suppliers.

The legal and administrative separation of electricity distribution and supply activities will be implemented by the market operator. The regulation fee will be determined by the body determined by the relevant executive authority in agreement with the authority. Separate elements of the balancing market and the auxiliary services market can be applied in the wholesale electricity market.

**In the third stage,** an independent market operator will be created. Market relations in the electric power sector will be regulated by the following rules approved by the regulator: wholesale market regulations, balancing rules, commercial accounting rules, retail market regulations, the procedure for determining normative indicators of electricity losses of transmission and distribution system operators for the reporting period, and an electricity market monitoring procedure.

# CHAPTER FOUR: Technological Framework: Software Solutions

## 4.1 Plexos:

### *4.1.1 How energy market prices are set*

Energy generators submit bids to the market that include the quantity of energy they can supply and the associated cost of supplying that energy. Simultaneously, consumers, including industrial consumers and energy retailers, determine their anticipated energy requirements and the amount they are prepared to pay for it. Energy Market Operators (EMOs) serve as the central entity responsible for coordinating the matching of bids for energy supply and demand, determining energy prices, and overseeing the functioning of the grid. Typically, Market Operators arrange the bids from energy generators and consumers in order to match the two sets of bids. The price of energy is determined by the intersection of consumer willingness to pay and the cost of the highest-priced units of electricity being consumed.

### *4.1.2 How PLEXOS models short- and long-term energy prices*

Energy Exemplar clients can invest and plan confidently with PLEXOS energy pricing forecasts from minutes to hours.

In the UK market, PLEXOS models each generator so that they recover their operating cost and then determines the minimum bid price of a generator asset by factoring in operating costs, electricity volume, and ramp flexibility. Unable to meet high demand in an hour, a coal power generator must stay online for a long time. This type of technical limitation helps determine a generator's energy output.

Energy Exemplar's simulation-ready datasets simplify PLEXOS setup. Datasets contain all "seed data" needed to model the power system, including technical and economic representations of every component, from transmission line capacity to generator characteristics.

Model each generator's cost per megawatt accurately. And other economic parameters like maintenance, emissions, and others to estimate generator bid prices. Minimum up time, minimum down time, and ramping capabilities can be used to model constraints on how each generation unit can operate and how much energy it can produce hourly and sub-hourly.

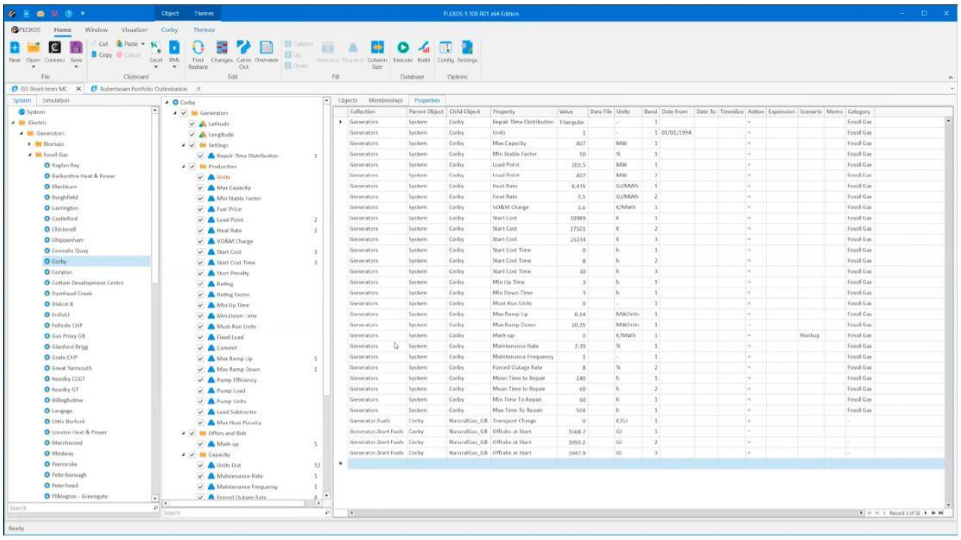


**Fig. 4.1.** Interface of the Day-ahead market page of Plexos software.

These details allow PLEXOS to generate bid prices to predict market bids.

The demand side. End users can provide more granular information to account for extreme weather events, fluctuating fuel prices, or intermittent renewable generation, among other market conditions, after PLEXOS provides some regional demand scenarios.

After configuring your scenario, PLEXOS meets demand and reserve capacity at the lowest cost to emulate market principles. Configure and analyze any market time step from hourly to five-minute increments and any time horizon from very short to thirty years.

Price can be displayed in tables and charts to simplify stakeholder presentations. [23]

## 4.2 Software proposed by ABB

### *4.2.1 Overview of Market Management Systems*

The diagram below shows the MMS systems to be purchased, their components, interrelationships, and interactions with non-MMS systems, external systems, and stakeholders. The diagram shows MMS functionality and components at a high level. Suppliers must and should design their own solution architecture and explain how it meets RFP requirements in their responses. The MMS will have at least three architecture layers for presentation, logic, and data, as shown above.

The next section briefly describes MMS component high-level requirements. Detailed requirements follow.

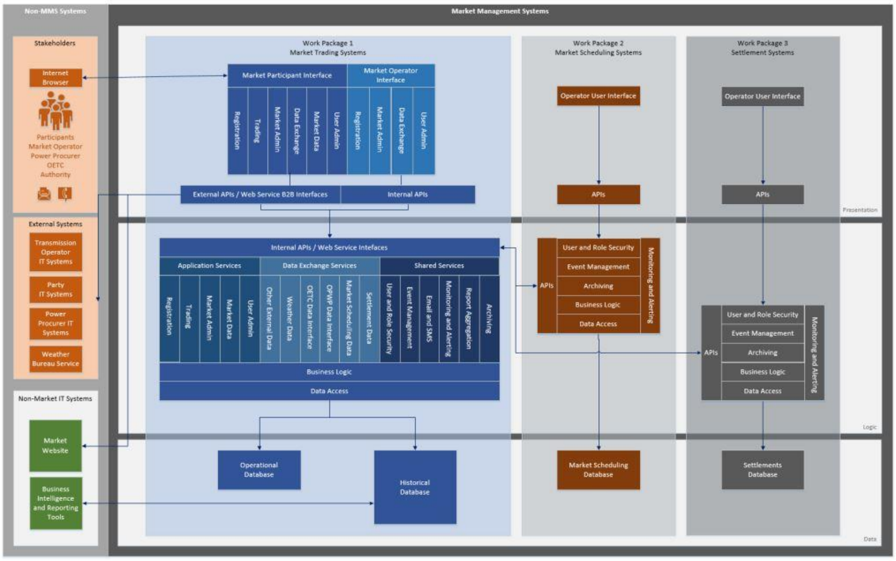



**Fig. 4.2.** Overview of MMS Systems

### *4.2.2 Market Scheduling*

The proposed Market Scheduling Systems will use proven software solutions used in other electricity markets worldwide. This software will be customized to meet market requirements. The Market Scheduling Systems will rely on the Market Scheduling, Pricing, and Mathematical Optimisation Engine for scheduling, credit, and price calculations in the Electricity Market. The Market Scheduling System will operate independently and interact with other MMS systems via APIs.

### *4.2.3 Market Scheduling Database*

The Market Scheduling database stores market information and supports the functionality of the systems. Most Market Scheduling System data will be imported from the operational database via APIs and converted into input case files for optimisation engine processing. The Market Scheduling Database will store the post-processing results in output case files alongside the input case files. The database will be small, with case files and other data regularly and aggressively archived to the historical database. High transactional use will be optimized.

### *4.2.4 Settlement Systems*

The Settlement Systems are expected to be Commercial Off-the-Shelf (COTS) software solutions, similar to those being used in other electricity markets around the globe. This software will be configured and customised in accordance with the Market Requirements. The Settlement Systems will undertake the import, validation, pre-processing, aggregation, processing and calculations required on Settlement and Meter Data in order to prepare and issue Settlement Statements and Settlement Invoices for the Electricity Market. The Settlement Systems will be architected and operated as a standalone system that interacts with other MMS systems via defined API's.

### *4.2.5 Settlements Database*

The Settlements database is used to store Market Information and support the functionality contained within the Settlement Systems. The majority of information required by the Settlement Systems will be imported from the historical database via APIs and converted into input case files for Settlements processing. Settlements post-processing results will be written to output case files and stored locally within the Settlements database along with the input case files.

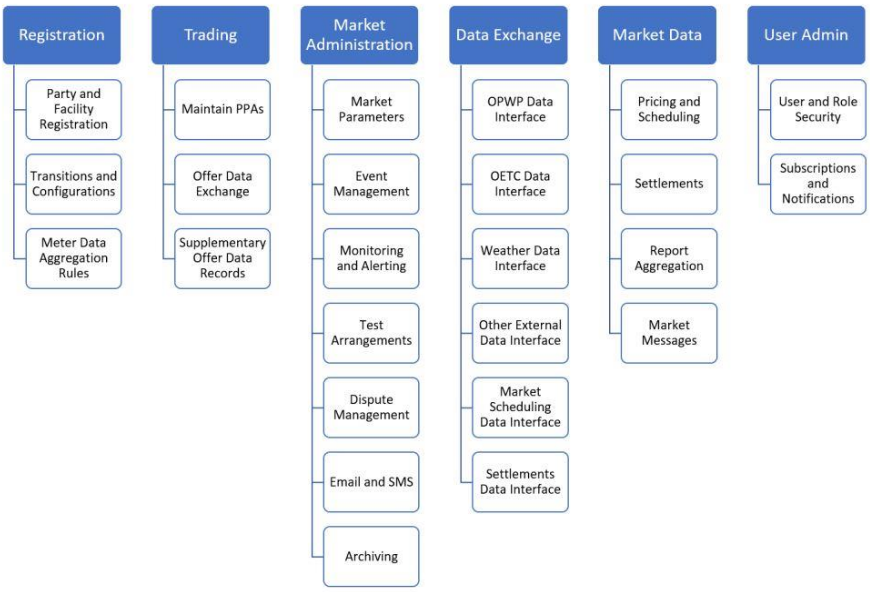



**Fig. 4.3.** Market Trading Systems - High-Level Functional Requirements

### 4.3. Software simulation by Azerenergy:

In December 2020 Market Operator was established within “Azerenergy” OJSC. The Market Operator has started to operate as a related body for the application of the liberal model in the test mode.

Currently, the Day-Ahead and Balancing Market in simulation mode is being tested by the Market Operator. For Day-Ahead Market, on a daily, basis, market participants (power plants) send their sales offers for the next day by using the software developed by "Azerenergy OJSC.

Bids are ranked from cheapest to most expensive, and the price of the last power plant meeting the demand is determined as the purchase and sales price for the corresponding hour. Then the unconstrained schedule is forwarded by the Market Operator to the Central Dispatching Office.

Taking into account the state and reliability of the energy system, Central Dispatching Office corrects the unconstrained load schedule and sends it again to both the power plants and the Market Operator through the software. Where the demand and supply of the Market Operator meet, the hourly price of Day-Ahead Market is determined and sent to the power plants.

After CDO adjustments, the load and price differences between constrained and unconstrained schedules are recorded and a cost analysis is carried out.


**Fig. 4.4.** Log-in panel, Energy market simulation software by Azerenergy

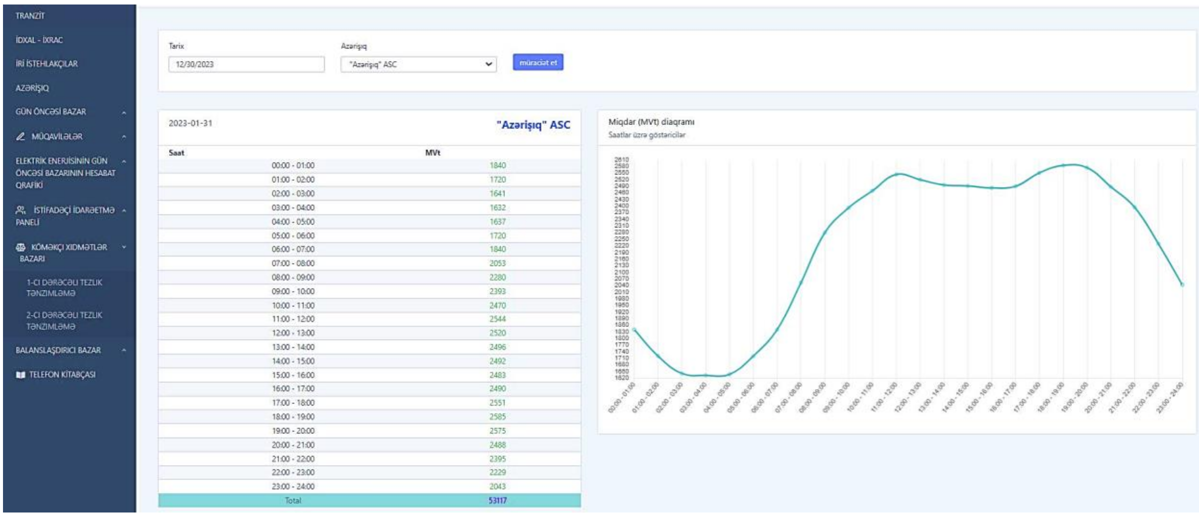



**Fig. 4.5.** The interface that «Azerishiq» OJSC use to send their day-ahead consumption to the Market Operator

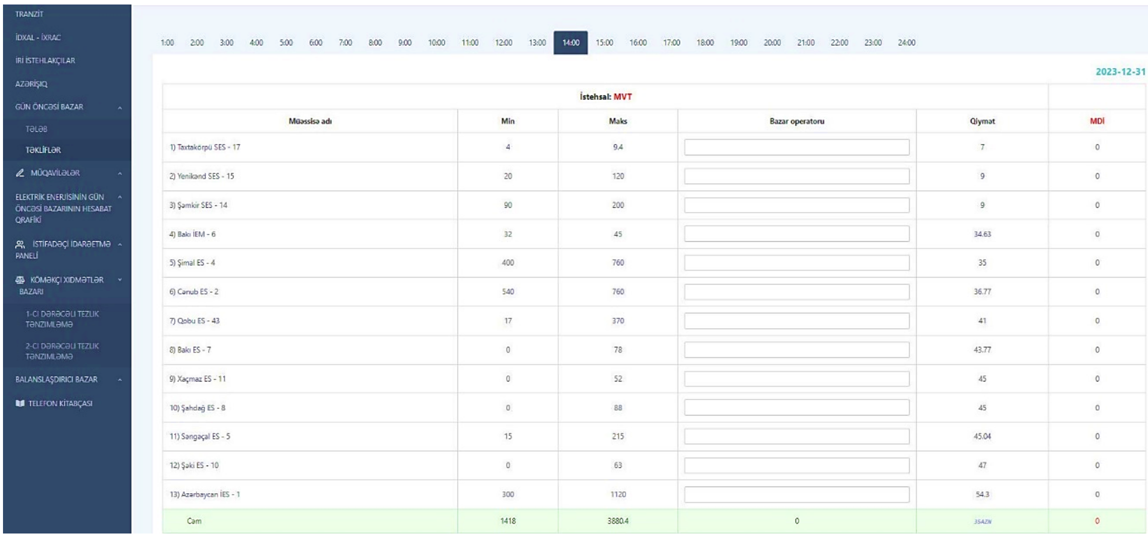



**Fig. 4.6.** Market Operator's interface when it ranks and chooses MW amount from the power plants

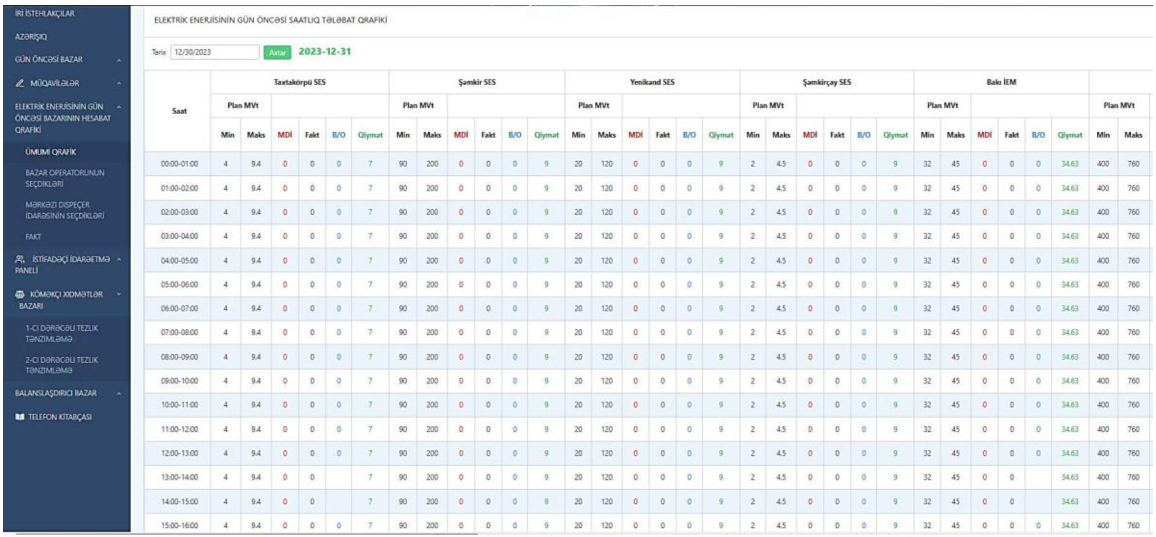



**Fig. 4.7.** Day-ahead demand calculation.

As it shown on the **Figure 4.5**, Azerenergy receives the demand list from the Azerishig OJSC and in accordance to this list, sets the generation requirements.

Upon receiving the demand sheet from Azerishig, the system will promptly provide the ultimate demand forecast for the next hour, day, and week. Subsequently, the market operator's and dispatch department initiates the process of selecting offers via an auction accordingly to the demand list from Azerishiq and own Day-Ahead demand calculations. **Figure 4.7.** The objective is to get the bids from the stations based on their maximum capacity. For instance, if the total electricity demand of the country on that particular day is 3000 Megawatts, the power stations provide their highest level of electricity output, which is 300 Megavolts, 500 Megavolts, 1000 Megavolts, 400 Megavolts, and 800 Megavolts. Upon observing the closure of consumption, the system operator procures electricity from the authorized power plants located beyond the point of intersection between supply and demand. Every station is compensated equally for each megawatt of electricity, regardless of their previous pricing offers. The facility consistently offers a price that is either lower or equal to the price supplied by the system operator. The system operator purchases energy from all stations at the price determined at the point of junction. **Figure 4.6.**

As an example, Gobu ES offers a megawatt for sale at a rate of 41 qepik. The junction point of supply and demand occurs in Shaki ES, where energy is available at a price of 47 qepik. Every station, including Gobu ES, is compensated with 47 qepik for every megawatt of electricity generated.

It is evident that the highest rows of the table are often filled by plants that generate electricity from renewable energy sources (RES). Based on the outcomes of a transparent competition, plants that have renewable energy sources (RES) are included in the list of plants that have bought energy. However, despite the pricing, the system operator chooses to buy energy from plants with RES because of their fluctuating nature, profitability, and low level of harmful emissions. The cheap pricing of renewable energy plants may be attributed to the low energy costs and little production expenditures associated with this kind of energy. However, renewable energy sources also possess some drawbacks, with their unpredictability being the foremost concern. Therefore, to ensure a consistent frequency and stability of the energy system, the system operator will procure electricity from power plants that play a crucial role in stabilizing Azerbaijan's energy system. Irrespective of costs, electricity will be procured from Mingachevir HES and Azerbaijan TPP, for instance.

#### *4.3.1 The introduction of a diverse array of price plans and services*

"Azerenerji" OJSC has prepared an instruction on Day-Ahead Market (DAM) organization to improve the Market Operator's activities and organization. Azerenergy simulates the price offer method of power plants for GOE based on the experiences of other countries with a liberal market model. Initial agreements with stations required participants to make a price offer with a 10% (formally) profit on variable costs.

Today, there are three main liberal electricity market models:

1. "North American" spot markets in North America offer prices by adding a profit to variable costs.

2. European "European-style" spot markets, where sellers can bid anything.

3. In cost-based spot markets, which began in Chile and spread to other Latin American countries, the price offer equals variable costs without profit.

Due to its price, the European model requires strong competition. Sellers can offer any price here. Example: Turkey's liberal electricity market. The variable-cost price offer mechanism works in the other two models. These mechanisms help select the most efficient stations selling their products in the market, make "economic dispatch" and increase economic efficiency.

In countries transitioning to a liberal market, experts recommend stations make an initial price offer based on variable costs. As a Market Operator, we apply this mechanism based on current conditions.

Thus, natural gas-powered power plants submit sales proposals to the Market Operator with a 10% profit on variable costs based on load-efficiency, temperature-efficiency, and natural gas prices.

**Table. 4.1.** Table of oil and gas usage on ES. (As an ex., there are given a few ES.)

| Stations | Electricity, thousand kWh | Column1 | Fuel consumption, thousand $m^3$/ton | Column2 | $m^3$ / kVt hour | Column3 |
|---|---|---|---|---|---|---|
| | Production | Bus. Released | Gas | Fuel oil | Production | Bus. Released |
| "AzTPP" LLC | 17140.44 | 16475.4 | 4707.586 | | 0.275 | 0.286 |
| "Shirvan" TPP LLC | 0 | 0 | 0 | | 0 | 0 |
| "Janub" ES LLC | 15517.439 | 15276.768 | 3124.72 | | 0.201 | 0.205 |
| **Total** | **81445.149** | **79711.394** | **17939.713** | | **0.22** | **0.225** |

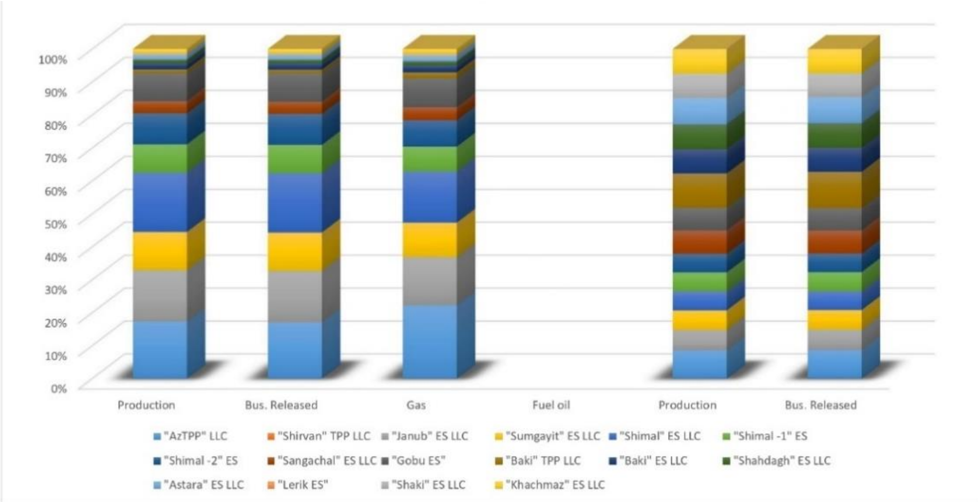



**Fig. 4.8.** Table of oil and gas usage on ES

### *4.3.2 Example of the price formation for liberal market model:*

Within our proposed liberal energy market model, we have outlined two main strategies for determining prices in day-ahead energy auctions. The initial model focuses on the incorporation of gas prices in the process of generating one megawatt of electricity by power stations. This entails a methodical analysis of the expenses linked to every gallon or barrel of gas or oil used in the generation of one megawatt. Afterwards, this expense is multiplied by the current market prices of oil and gas during the specified period, resulting in the cost of producing one megawatt for the power station. It is important to emphasize that this method focuses solely on the variable costs specifically related to fuel, while disregarding wider operational expenses such as equipment upkeep, logistics, salaries, and other fixed costs.

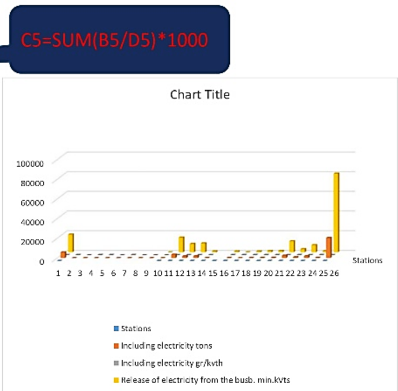
To address the shortcomings of the initial model in offering a complete cost analysis, we present the second model, which adopts a comprehensive approach to incorporate all variable costs and temporal fluctuations. In this enhanced model, a fixed percentage, precisely 10%, is included in the production cost to accommodate the various and variable expenses accrued by power stations. The comprehensive cost estimate is subsequently presented to the market operator during the day-ahead auction.

The second model is specifically designed to efficiently navigate the complex terrain of fluctuating costs over time, while simultaneously ensuring a careful equilibrium between cost coverage and competitiveness. The model aims to prevent financial deficits by simultaneously taking into account all pertinent factors, such as equipment maintenance, logistics, employee salaries, and other operational costs. At the same time, it aims to provide a persuasive value proposition by offering the most cost-effective and competitive price, thereby increasing the likelihood of being chosen during the day-ahead auction.

This approach, which combines two models, offers a detailed comprehension of the cost dynamics related to energy production. Additionally, it is in line with the fundamental principles of a liberalized energy market, where competitiveness and efficiency are of utmost importance. By implementing these models, our goal is to enhance price formation strategies in the Azerbaijan energy market.

**Table. 4.2**. Format of price forming based on oil and gas usage.

| Stations | Including electricity | | Release of electricity from the busb. |
|---|---|---|---|
| | tons | gr/kvth | min.kVts |
| Azerbaijan TPP | 5871.512 | 324.9172836 | 18070.79 |
| | 1 | 323.38 | |
| | 2 | 0 | |
| | 3 | 325.27 | |
| | 4 | 322.14 | |
| | 5 | 0 | |
| | 6 | 324.49 | |
| | 7 | 0 | |
| | 8 | 0 | |
| "Shirvan" TPP | 0 | 0 | 0 |
| Janub ES | 3515.104 | 233.8269853 | 15032.927 |
| "Shimal -1" ES | 1890.364 | 218.2887265 | 8659.925 |
| "Shimal -2" ES | 1946.833 | 212.2466 | 9172.505 |
| Baki TPP | 217.43 | 218.1599632 | 996.654 |
| ("Azneftyagh") | | | |
| Astara ES | 278.9782857 | 292.2523892 | 954.58 |
| Lerik ES | 34.33942857 | 306.7554185 | 111.944 |
| Shaki ES | 260.5325714 | 277.525455 | 938.77 |
| Khachmaz ES | 364.7791143 | 277.019376 | 1316.8 |
| Baki ES | 403.0148571 | 275.7165336 | 1461.7 |
| Sumgayit ES | 2541.297143 | 225.009761 | 11294.164 |
| Sengachal ES | 904.531906 | 272.5478806 | 3318.8 |
| Gobu ES | 1915.771429 | 257.5771719 | 7437.66 |
| Shahdagh ES | 358.6822857 | 279.5151966 | 1283.23 |
| Total | 20503.17002 | 256.1281077 | 80050.449 |



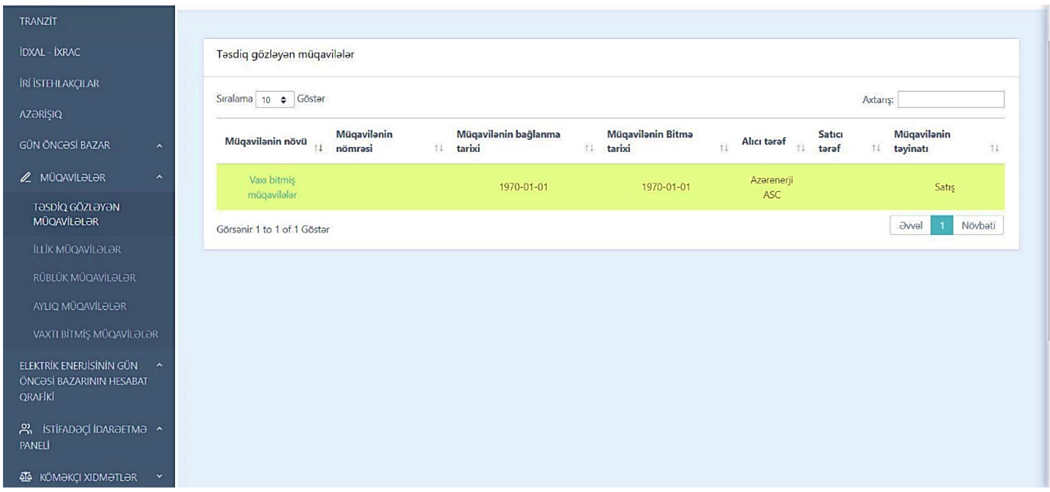



**Fig. 4.9.** Contracts section in the simulation software. 1.Azerbaijan TPP-C-01

**Figure 4.9** displays the contract section of the software, which allows all users to see the contracts signed between the regulatory side, system operator, and generating side. This is intended to enhance comprehension of the relationships among each player in the system, as well as their respective obligations and the legal framework laws that govern them.

## CHAPTER FIVE: International experience

The reform of the electrical sector has led to unequal outcomes for both the upstream and downstream sectors. Foster et al. (2017) found that the majority of developed countries (96%) and developing countries (70%) have implemented legal measures to support competition in the upstream market. However, the level of competition in these countries varies greatly, ranging from basic auction systems to fully competitive wholesale markets. The countries that have legislative provisions for retail choice are mostly found in Europe. This is due to the implementation of EU liberalization directives and rules, which have facilitated the development of power markets. Retail choice law is present in non-European industrialized nations such as Australia, Canada, the Russian Federation, New Zealand, Switzerland, and the USA. Within the category of emerging nations, only a limited number of regions have implemented rules allowing for retail choice. These regions include Argentina, Brazil, Chile, Guatemala, Peru in Latin America, Kazakhstan, Romania, Russia, Turkey, Ukraine in Eastern Europe, and India, the Philippines in Asia.

Nevertheless, the existence of laws does not guarantee the existence of a fully operational and competitive retail market in these nations. Retail competitiveness is lacking in several of the aforementioned emerging nations. Within the industrialized world, there exists geographical diversity within individual countries. For instance, the majority of US jurisdictions, with the exception of a small number of states, have implemented regulations on retail pricing. In places where customers have the option to choose their retailer (except Texas), this choice is typically only available to big consumers. Additionally, the prices offered by competitive retailers are frequently less appealing when compared to regulated rates (NREL, 2017). This principle is also applicable to the majority of Asian, Latin American, and Eastern European nations. Due to the varying levels of competition, retail markets can be more accurately defined as being on a spectrum between competition and regulation, rather than as a simple dichotomy between the two. On one end of the range, there are highly competitive retail markets in Great Britain, Germany, New Zealand, and the National Electricity Market of Australia (NEM). Conversely, there are marketplaces where retail prices are predominantly controlled for small consumers, as is the case in France. In certain markets, there is both retail competition and government involvement, either through the establishment of default tariffs or the approval of tariffs.

## 5.1 Complete deregulation of the power market (Experience of Japan. Cross-Section view)

In the past, households and businesses did not have the ability to choose their electricity provider, as the monopolistic power company in each region (such as Tokyo Electric Power Company and Kansai Electric Power Company) held exclusive control over the sale of electricity.

Starting from April 1, 2016, the retail energy industry will be completely deregulated, allowing households, businesses, and all customers to freely choose from a wide variety of power providers and pricing options.

This indicates that you will have the autonomy to choose the electricity supplier and services that are in accordance with your way of life and beliefs.

### *5.1.1 The liberalization of the electricity market is rooted in historical developments that have shaped the trajectory of energy policies.*

The energy market liberalization process has already been implemented for large-scale industrial facilities and other customers of considerable size.

The process of market liberalization began in March 2000. During the initial stage, establishments classified as "extra-high voltage," such as large-scale industries, department stores, and office buildings, were given the autonomy to choose their electricity supplier without any restrictions. Moreover, the introduction of new Power Producer & Supplier enterprises into the market facilitated the acquisition of energy from alternative sources.

Following that, in April of both 2004 and 2005, the process of market liberalization experienced a gradual enlargement to include small and medium-sized businesses, as well as buildings classified as "high voltage".

Commencing on April 1, 2016, residential and commercial establishments categorized as "low voltage" will have the freedom to choose their desired electricity supplier.

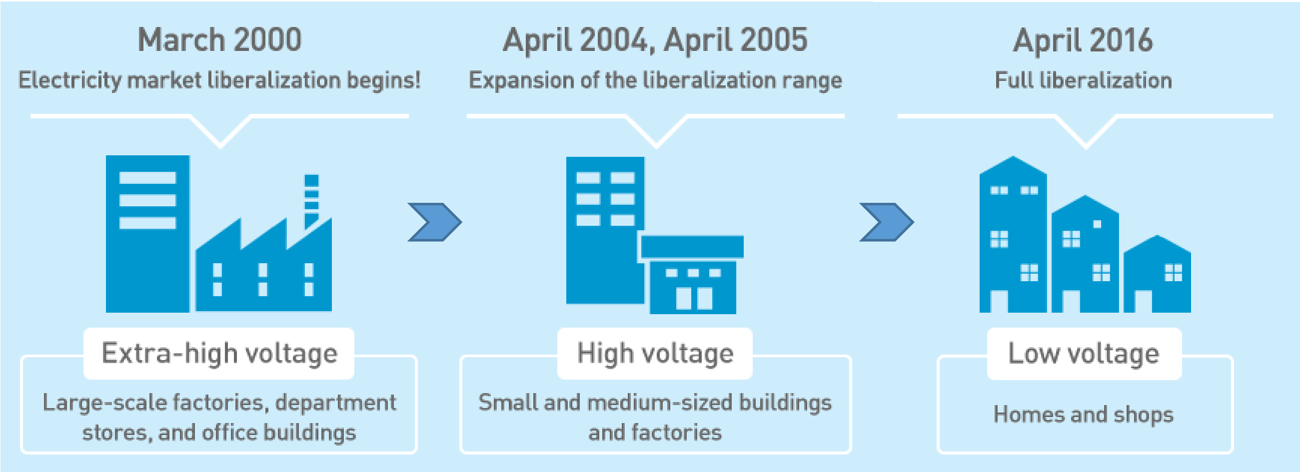



**Fig. 5.1.** Historical view of market liberalization process in Japan. [7]

### *5.1.2 Process of full electricity market liberalization*

Starting in January 2016, applications will be accepted for advanced applications pertaining to the "complete liberalization of the electricity market" for residential and commercial establishments. The implementation of this system is scheduled for April 2016.

The user's text is empty. Customers who do not take any specific action by April 2016 will continue to receive power from the contracted regional power provider in the same way as before.

**January 2016**

Applications for electricity provider or pricing plan transfers are currently being accepted, commencing in January of the upcoming year.

The user's text is empty. The forthcoming power company or local power company will reveal the pricing schemes and service details once they are prepared. The commencement of accepting advance change applications differs based on the firm.

**April 2016**

Full deregulation of the power market

* Therefore, it is possible to adopt the new pricing schemes or services provided by the recently established power companies or regional power companies. The local power firms will maintain the present regular pricing menu, which is subject to government regulations, until there is enough competition in place, at least until March 2020, in order to ensure consumer protection.

### *5.1.3 Power supply system*

After energy market liberalization, the power supply infrastructure is likely to stay mostly unchanged.

According to the figure below, families get electricity as follows: In the electrical grid, energy flows via the power plant, transmission lines, transformer substation, and distribution lines. The power supply system has three primary sectors: (1) power generation, (2) transmission, and distribution, and (3) retail.

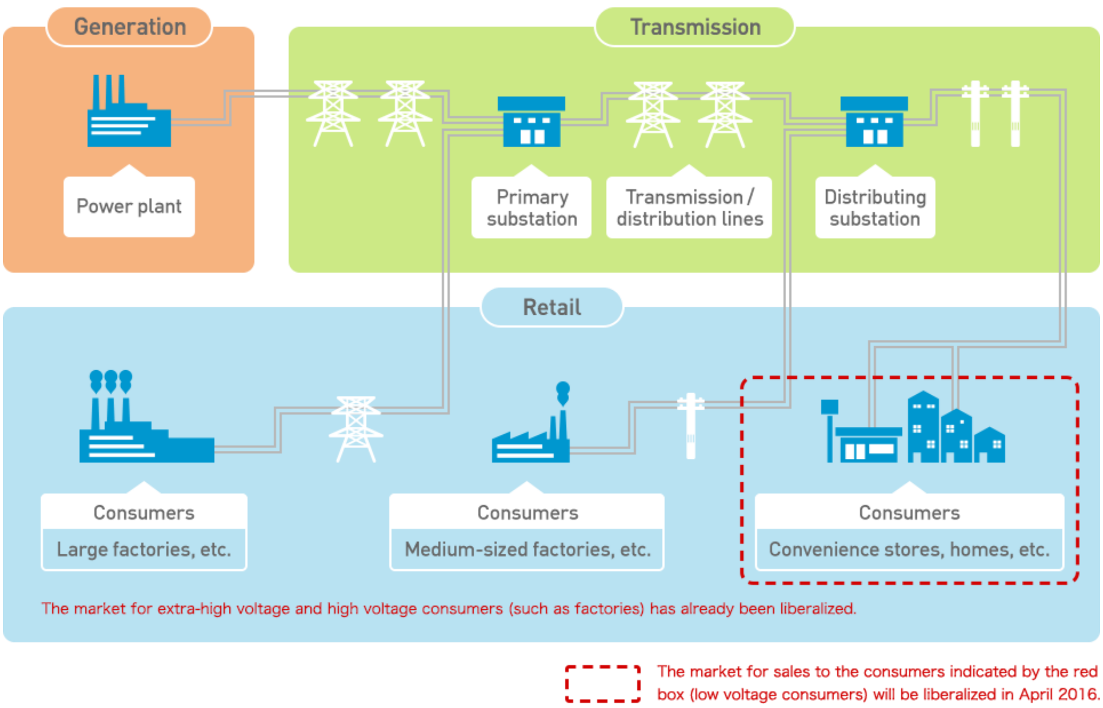



**Fig. 5.2.** Main actors of the energy market in Japan. [14]

*5.1.3.1 The power generation sector.*

This industry encompasses the operation of various power facilities, including hydroelectric, thermal, nuclear, solar, wind, geothermal, and other forms, with the primary objective of electricity generation.

*5.1.3.2 The transmission and distribution sector*

This sector refers to the segment of the energy industry responsible for the transportation and delivery of electricity from power generation facilities to end consumers.

This sector is responsible for overseeing the power transmission network, encompassing the transmission lines and distribution lines that provide the connection between power plants and users, including individual residences. The aforementioned industry is accountable for the physical distribution of power to residential dwellings. Additionally, it assumes the responsibility of effectively managing the power equilibrium, including factors such as frequency, across the entirety of the network. This function serves to avert power outages and guarantee a consistent and reliable provision of electrical energy.

*5.1.3.3 The retail sector*

Is an industry that encompasses the sale of goods and services to consumers. It plays a significant role in the economy by providing a platform for businesses to distribute their

This industry engages in direct interactions with consumers, including individual houses, and provides a range of services, such as the establishment of power supply agreements. Additionally, it procures the necessary amount of power from the power producing sector to meet the demands of customers.

The complete liberalization of the energy market would facilitate the unrestricted entry of new enterprises into the retail sector (3).

Essentially, there is a regulatory framework that enables new businesses to enter the electricity production sector without any obstacles (1). Nevertheless, despite the complete liberalization of the electricity market, the transmission sector (2) will continue to be regulated by government-licensed entities, such as regional power companies like Tokyo Electric Power Company and Kansai Electric Power Company, in order to ensure a dependable power supply. Therefore, when a consumer switches to a different retail electricity provider, the quality and reliability of electricity supply, as well as the occurrence of blackouts, will not change. This is because the power transmission will still use the same network of distribution lines, regardless of the specific company from which the electricity is purchased.

The stability of the power supply throughout the transmission and distribution network relies on attaining an equilibrium between the demand for electrical power (consumption) and the supply of electrical power (production). Failure to uphold this balance can lead to instability within the network. Therefore, if a new retail company in the retail sector is unable to meet the power requirements of its contracted customers, the transmission sector operator will provide compensation for the deficit and ensure the efficient delivery of electricity to those customers.

#### *5.1.4 The deregulation of the energy market is anticipated to give rise to many challenges*

The complete liberalization of the electricity market would create a variety of energy retail firms. This will allow consumers to choose from many power providers, including newcomers.

The proliferation of energy retail companies is expected to increase competition, resulting in a variety of price and service options. Discounted packages that include electricity, gas, and mobile phones, reward points, and energy efficiency diagnostics are expected.

Consumers can also buy electricity from renewable energy companies like solar, wind, hydroelectric, and geothermal. Additionally, electricity generated elsewhere can be purchased. Urbanites can get power from home. One option is to use locally generated power from a nearby government-operated firm.

*The price menus offered are tailored to accommodate individual lifestyles, with flexible pricing that vary based on the time of day.*

For instance, individuals will have the opportunity to select the most suitable plan for their lifestyle from a diverse selection of pricing options, which may include plans offering variable power costs based on the time of day.

*The introduction of novel services such as energy conservation diagnostics and bundled discount programs.*

It is anticipated that corporate innovations would yield a diverse array of novel services, encompassing cheap packages that combine electricity with gas or other offerings, loyalty programs based on reward points, and services aimed at diagnosing domestic energy reduction.

*The services that are centered on the utilization of renewable energy sources.*

Consumers will have the opportunity to get their electricity from firms that predominantly derive power from renewable energy sources, including solar, wind, hydroelectric, and geothermal power.

*Local generation for regional electricity usage*

One may efficiently use local power by buying from a local government-run supplier. Additionally, you may buy power from another area.

### *5.1.5 How consumers can switch their providers?*

*Beginning in January 2016, advance applications will be allowed.*

Commencing in January 2016, applications for switching power companies are now being accepted as each firm reveals its price plans and services for home electricity.

Conduct a comparison of the menus provided by each business and select the power company, price plan, and services that align most suitably with your preferences and needs.

### *5.1.6 Process of switching power companies*

*5.1.6.1 Applying to the electricity company for a switch request.*

To switch providers, users should submit an application at the service desk, telephone number, webpage, or any other point of contact provided by each organization.

Upon the user’s consent, the new power company can undertake the process of canceling client’s current contract with the regional power company.

*5.1.6.2 Changing a Smart Meter (if smart meter is not installed yet)*

If your family does not currently own a Smart Meter, it will be necessary for you to transition to a Smart Meter.

Upon submitting the application to the new power company, the regional power company with which you presently have a contract will inform you of the scheduled date for the meter replacement.

*5.1.6.3 Commencement of the agreement with the newly selected electricity provider*

Client can commence using electricity from the newly established power corporation commencing in April 2016.

*The following are the primary prerequisites for switching electricity companies in or after January 2016.*

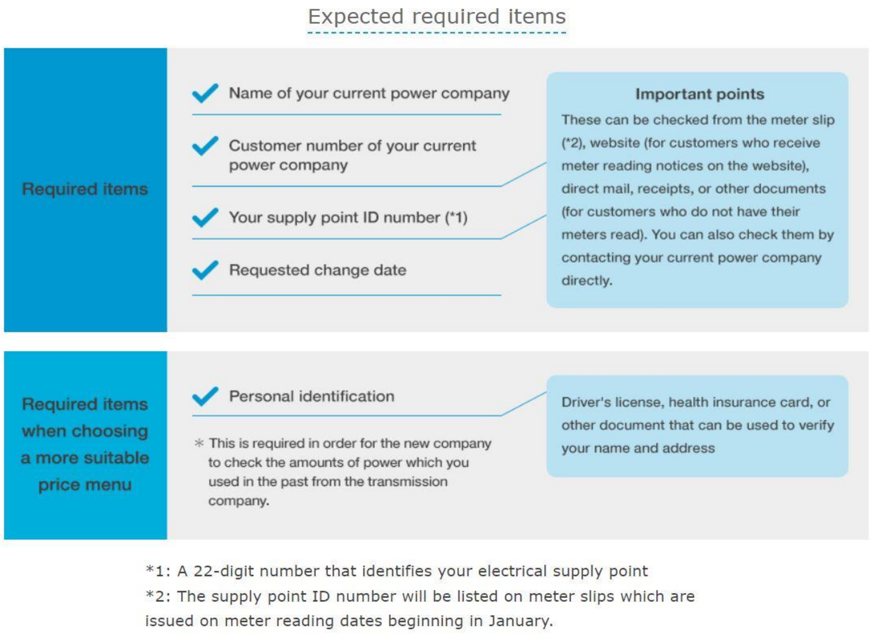



**Fig. 5.3.** Primary requirement for switching electricity companies in Japan.

### *5.1.7 Customer numbers and supply point ID numbers notification*

A power company change application requires verification of the customer number and supply point ID number from meter slips or other documents submitted by your present power provider on meter reading days commencing in January. If you can't find a meter slip or other paperwork, contact your electric utility provider.

### *5.1.8 Retailers available for foreign languages*

| Network Areas | Retailers |
|---|---|
| Hokkaido | Hokkaido Electric Power Company<br>PDF: 160KB (English) |
| Tohoku | Tohoku Electric Power Co.,Inc<br>0120-175-266 |
| Tokyo | Tokyo Electric Power Company<br>Website (English) |
| | Kyuden Mirai Energy Company, Incorporated<br>0570-031-031 |

**Fig. 5.4.** List of providers and their contacts for consumer.

## 5.2 US Electricity Markets:

US areas sell power differently. Investor-owned utilities, which may be vertically integrated monopolies controlled by public utility commissioners or deregulated marketplaces where the market determines electric energy rates with government supervision, serve most consumers. Regulatory structures determine retail and wholesale energy rates and buy power plants.

Before 1990, most investor-owned electric utilities owned generators and power lines and were vertically integrated and regulated. Integrated utility markets provide just one third of US power consumption due to deregulation in several jurisdictions.

Traditional utilities are monopolies, because consumers can only purchase electricity from them. To keep rates low, state authorities regulate electric utility prices. Retail electricity tariffs in these locations meet the utility's running and investment expenses and a “fair” return on investments (revenue requirement). Utilities cannot overcharge power consumers since the state's public utilities commission must accept this revenue requirement.

State clearance is needed for power plant investments by regulated utilities. Electricity tariffs cover generator selection by vertically integrated utilities. Integrated resource planning (IRP) is required by many state regulators to justify utility investments. This approach puts consumers at risk of investments since utilities may recoup expenses via rates regardless of power plant performance.

FERC oversees wheel market transactions. Many US states deregulated energy in the 1990s to enhance competition and cut prices. Restructuring pushed electric utilities to sell its generators and form independent energy providers. Electric utilities kept these assets and became regulated transmission and distribution utilities because new independent energy suppliers could not install power line infrastructure cost-effectively.

Retail customer choice and wholesale marketplaces altered retail and wholesale power sales most after deregulation. In deregulated locations, customers may pick an electric provider over their utility. This promotes retail power pricing competition, although independent enterprises generally ask consumers to sign long-term contracts.

After deregulation, RTOs managed wholesale power markets instead of utilities. FERC governs multistate wholesale RTOs. Due to competition from other retailers, deregulated retail utilities acquire energy at market wholesale rates and sell it to consumers at market retail prices.

Auctions manage daily power output in energy markets. To satisfy customer energy demand, load-serving organizations bid for electric providers' power plant-generated electricity at a defined price. Generators get this price per megawatt hour when supply balances demand and the market "clears". RTOs trade energy day-ahead and real-time.

In the day-ahead market, RTOs rank next-day generators by cost. The market dispatches units by lowest cost to satisfy energy demand. High demand raises wholesale costs because more costly units must fulfill electric load. Base wholesale market prices represent electricity pricing as it flows freely throughout the RTO's region without transmission limitations. When that's not practicable, RTOs allow pricing vary by geography to reduce transmission line congestion.

Energy market capacity marketplaces let retailers recoup fixed expenses regardless of energy generation. Some RTOs auction capacity to assist merchants and generators recoup fixed expenses. Generators bid what it costs to maintain their facility if required. When bids exceed the amount all retailers need to fulfill peak demand plus a reserve margin, the market "clears," or supply meets demand. Generators that "cleared" the market or were selected to offer capacity earn the bid price of the last generator utilized to fulfill demand.

RTOs reward traits not covered by energy or capacity markets in ancillary services markets. These services generally maintain grid frequency and offer short-term backup power if a generator fails.

Many states have deregulated and regulated. West Virginia utilities engage in PJM wholesale markets while rate-regulated and owning their generation. Wholesale but not retail markets were deregulated in California, which runs the grid.

Many states have programs to encourage long-term wind and solar electricity. As renewable producers gain grid share in deregulated jurisdictions, wholesale market structure may change. Renewable energy sources bid $0 in energy and capacity markets since they don't require fuel. Wholesale markets may need to adjust to new resources when they enter the grid.

### 5.3 EU Countries:

Since 1996, significant initiatives have been taken to harmonize and liberalize the EU's energy sector. These policies improve market access, transparency, regulation, consumer protection, interdependence, and supply. These policies aim to create a more competitive, customer-focused, adaptive, and equitable European electricity and gas market with market-determined pricing. They do so to improve consumer and energy community rights, address energy poverty, clarify market participants' and regulators' roles, ensure electricity, gas, and oil supply security, and establish trans-European electricity and gas transportation networks.

#### *5.3.1 Structure of the wholesale electricity market*

Electricity is traded on multiple markets at different time frames for a specific location, enabling financial hedges and speculation to manage risks and maximize profits. Table 7.1 summarizes the value chain of electricity markets.

**Table 5.1.** Simplified electricity market value chain

| | Futures and forwards | Day-ahead auction | Intraday | Balancing |
|---|---|---|---|---|
| **Time frame** | - Up to several years ahead | - Day before delivery | - Last hours before delivery | - Last minutes before delivery |
| **Main use case** | - Buy and sell in advance to secure business against price fluctuations | - Optimise and balance portfolio<br>- Nominate volumes to be fed into the grid | - Adjust for short-term changes | - Deliver commited volumes<br>- Balance the grid to match supply and demand |

When trading occurs more than a day before power delivery, derivatives markets allow participants to hedge or speculate on price changes. One of the most prevalent derivative market contracts is base futures. A contract with a single fee for all hours at a single place for a longer term (e.g., a month).

Complex financial tools like options and swaps are recommended for derivative markets.

Intraday markets allow players to trade energy through auctions or continuous trading within 24 hours of delivery. Shorter MTUs are possible (15 minutes). These markets accommodate recent projected adjustments (demand, weather) and unexpected outages. Intraday markets complement day-ahead markets and are gaining popularity owing to power system concerns. Balancing markets activate minutes before delivery to match supply and demand. In these marketplaces, algorithmic trading is gaining popularity.

The marketplaces described above provide an overview of pool-based power trading on exchanges. Over-the-counter (OTC) transactions enable market players to trade power using standard or bespoke bilateral contracts. These arrangements between businesses are less transparent and less conducive to scientific examination. Corporate Renewable Power Purchase Agreements (CPPA) are rapidly expanding due to significant firms seeking green energy and RES producers seeking production hedges. RTE's block exchange service enables responsible parties to trade and avoid fines by balancing their portfolio, similar to other OTC transactions.

ACER maintains a list of standard energy contracts issued by organized market centers (broker exchanges).

Some wholesale energy deals are off-market. Transactions coordinated by governmental entities, such energy regulators, are tailored to energy regulations. These affect French RES and nuclear energy. Historical RES projects can still profit from feed-in tariffs, which provide set pricing regardless of demand. New projects like offshore wind farms are established through tenders, with governmental policy determining installed capacity and investor bids determining pricing. Companies can purchase nuclear power from EDF at a fixed price set by public authorities using the ARENH mechanism (Accès Régulé à l'Electricité Nucléaire Historique).

**Price formation across markets**

The European Federation of Energy Traders (EFET) advocates a flexible approach to electricity price development, including several markets with varied time frames. Trading is a method for managing imbalance costs between electricity sales and purchases and observed power usage. From years ahead to real time, these risks and opportunities are arbitraged.

Market players should choose trading modalities based on commercial, technical, and/or economic assessment, including markets, time periods, volumes, and pricing. Too many limitations or fears of fines might hinder the market's capacity to respond to price surges. This may prevent investments in flexible capacity and new energy services, as the accompanying development and investment costs may not be recouped.

Observing day-ahead auction prices is valuable as they are distinct for each hour and place, providing a transparent price indication. Note that this price signal often informs pricing on other markets, such as forward markets.

**Energy transition, market design**

Energy regulators and TSOs dispute whether present market dynamics and design can offer investment signals for long-term supply security. A rising percentage of low-cost RES may lower wholesale energy prices and drive dispatchable assets out of the merit order, making them unprofitable despite their importance for supply security. Capacity market is the key risk mitigation strategy.

Market options are being examined for effective congestion management and suitable ancillary services in the present and future EU power system. While definitive solutions are not yet implemented, local flexibility markets are emerging as a supplementary alternative.

The local markets aim to address the poor geographical granularity of the zonal market concept. However, the presence of zonal and local markets can lead to increase-decrease gaming (inc-dec), where market participants intentionally bid in the zonal market before the redispatch market.

**Optimizing pricing strategies to improve societal well-being**

The equilibrium of supply and demand is determined by a closed auction, also known as a blind auction, in which market players submit orders without knowledge of the bids made by other members of the exchange. An elementary transaction to sell or purchase involves specifying a quantity and a cost for a certain duration and place. Within Europe, these specific areas align with bidding zones, and this particular market structure, known as zonal, is explained in chapter 3. [5]

Orders are forwarded to a nominated electricity market operator (NEMO) one day prior to the actual delivery and before a certain deadline known as the gate closure time (GCT). Subsequently, the EUPHEMIA algorithm, which operates on a single price coupling mechanism, decides the execution or rejection of orders.

The computation results in the determination of a market clearing price for each unit of time in the market, which is now set at one hour.

**Standardized pricing**

Irrespective of the price at which an order is received, all accepted orders are traded at the market clearing price. The market design being referred to is known as uniform pricing, in contrast to pay-as-bid and marginal pricing.

## Ranking based on the order of merit

The social welfare maximization aim leads to bids being completed in merit order. In the simple example, each period and bidding zone accepts orders to sell at the lowest price and purchase at the highest price, maximizing energy exchange volume. In reality, order acceptance relies on technical constraints related to bidding zone interconnections and order types that reflect market participants' requested constraints for profitable execution. To depict merit order, the supply curve is created by sorting hourly orders in a bidding zone by ascending bidding price.

The aggregated demand curve is created by sorting demand orders by decrease in price. Initial bids are kept private to prevent collusion, but anonymized supply and demand curves are published after market clearing for analysis and price forecasting. Figure 7.5 illustrates the market clearing that occurs when supply and demand curves cross.

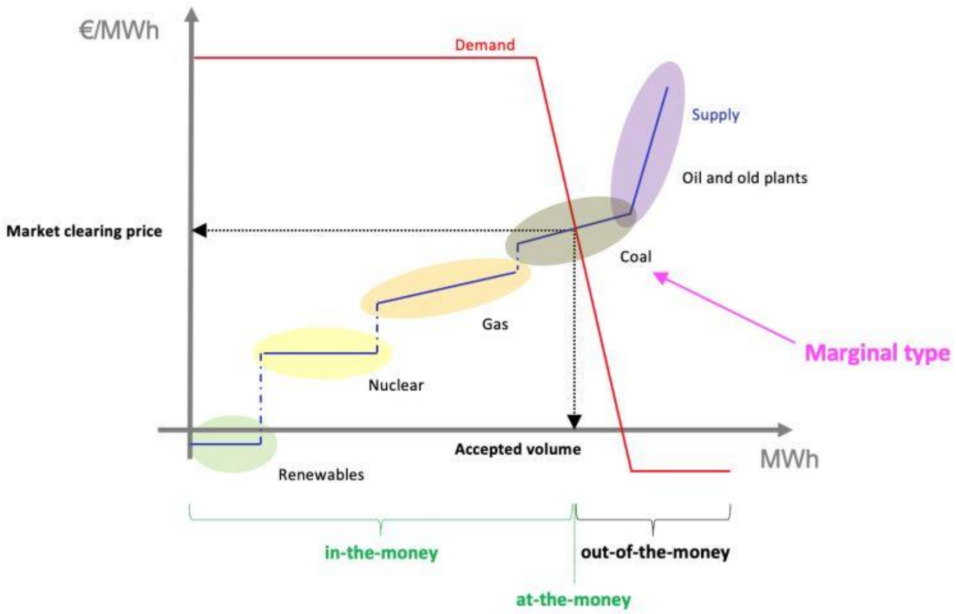



**Fig. 7.5.** Concise depiction of the process of market equilibrium,

## Market order types

Day-ahead power sales and purchases must be within a price range. The "price floor" and "price cap" are the minimum and maximum prices. These variables enable EUPHEMIA algorithm daily resolution in a short time. However, the price floor and ceiling should not limit price creation. As of 2021, the floor is EUR -500/MWh and the ceiling is EUR 3000/MWh. Regulatory systems review these limits if they are hit too frequently, restricting price formation.

The simplest maket order has a sense (supply or demand), volume, price limit, market time unit, and bidding zone. Power exchanges accept complicated and block orders.

A market player adds conditions to a complicated order, making hourly orders interdependent. A minimum income (MIC) and load gradient condition may be applied. These conditions are precisely described in the EUPHEMIA algorithm description:

According to the Minimum Income economic constraint, the order must cover production costs, which are determined by a fixed term (representing startup costs) and a variable term multiplied by the total assigned energy (representing operation costs per MWh).

In general, the Load Gradient restriction limits the amount of energy matched by hourly sub-orders in one period to the amount matched in the preceding period. The maximum increment/decrement permitted is the same value throughout all periods.Block order allows connection between hours and minimum acceptance ratios. For such orders, the premise is similar to the minimum income criteria, but it focuses on volume rather than total daily revenue. The order must achieve a minimum amount to stay valid.

# CHAPTER SIX:

## 6.1 Future Works

This study not only highlights the present status of energy market liberalization in Azerbaijan but also lays the groundwork for potential progress in policy, technology, and strategic planning. The following areas suggest prospective paths for future study and development:

Enhanced Regulatory Frameworks: Explore possibilities to improve and strengthen the regulatory frameworks that control the liberalized energy sector in Azerbaijan. Evaluate the efficacy of current legislation, identify areas that need improvement, and suggest adjustments to enhance market efficiency, transparency, and fair participation.

Explore advanced technology and software solutions that may enhance the application of renewable energy models. Examine progress in energy prediction, market modeling, and digital systems to improve decision-making, simplify operations, and encourage innovation in the energy industry.

Renewable Energy Integration: Examine methods to enhance the incorporation of renewable energy sources into the deregulated market. Examine regulatory incentives, technical solutions, and investment frameworks to promote the sustainable expansion of renewable energy capacity, in line with worldwide trends towards a more sustainable and varied energy combination.

Stakeholder Engagement and Public Awareness: Analyze strategies to improve the involvement of stakeholders and increase public understanding of the advantages and difficulties associated with energy market liberalization. Create communication methods to inform customers, industry players, and the general public on the changing energy landscape, promoting well-informed decision-making and support for liberalization activities.

Long-Term Impact Assessment: Perform longitudinal research to evaluate the enduring effects of energy market liberalization on crucial variables such as energy security, sustainability, and economic growth in Azerbaijan. Conduct a comprehensive analysis of long-term patterns to assess the efficacy of liberalization policies and pinpoint areas that may need modification or improvement.

Facilitate international cooperation to facilitate the sharing of information and best practices in the liberalization of energy markets. Form alliances with institutions, professionals, and politicians from countries that have successfully implemented liberalization measures in order to acquire valuable knowledge, exchange experiences, and determine tactics that may be adapted to the specific circumstances of Azerbaijan.

Examine methods to guarantee the capacity of policies to be flexible and adaptable in order to address changing market dynamics and developing difficulties. Examine frameworks that enable prompt modifications to rules, market structures, and support systems, guaranteeing adaptability in response to unexpected developments.

The investigation of these prospective research paths seeks to enhance Azerbaijan's energy market by promoting sustainability, competitiveness, and flexibility in accordance with worldwide energy patterns.

### 6.2 Consclusion:

In conclusion, this master thesis embarked on a comprehensive journey to explore and compare the international experience and outcome indicators in the application of the liberal market model in the electricity sector, with a specific focus on the ongoing process of energy market liberalization in Azerbaijan. The examination of global practices revealed a dynamic landscape shaped by the interplay between efficiency, innovation, and the quest for sustainability.

The liberalization of energy markets, as observed in diverse regions such as the European Union, the United States, China, and Post-Soviet nations, underscores the potential benefits of fostering competition, attracting investments, and integrating renewable energy sources. The interplay between efficiency and innovation was a recurring theme, demonstrating that private sector involvement often brings cutting-edge technology and management practices, enhancing the overall effectiveness of energy systems.

The comparative analysis of Zonal and Nodal Energy Market Models provided insights into the diverse approaches adopted by different regions. The Zonal Model, despite its simplicity, demonstrated drawbacks related to market inefficiencies and challenges in accurately reflecting locational constraints. On the other hand, the Nodal Model, with its granular approach, presented a more precise representation of market dynamics but posed challenges in terms of complexity and implementation costs. The exploration of these models aimed to provide policymakers and industry stakeholders with a nuanced understanding of their respective pros and cons.

Turning our focus to Azerbaijan, the thesis highlighted the nation's efforts to harness its substantial energy resources through the liberalization of the electricity market. The discussion on the potential of renewable energy sources, particularly wind energy, underscored the importance of a supportive legal framework and incentivization measures in promoting sustainable energy practices. The case study on Azerbaijan scrutinized the legal and regulatory changes, market frameworks, and the role of key agencies in driving the liberalization process. It also examined the impact on energy security, sustainability, and the attractiveness of foreign investments in the Azerbaijani electricity market.

This thesis drew from worldwide experiences and applied them to Azerbaijan to inform policymakers, industry actors, and regulatory bodies engaged in energy market liberalization. Comparative investigation revealed transferable best practices, possible hurdles, and a worldwide energy sector growth path for Azerbaijan.

As we finish this thesis, we must acknowledge that energy market liberalization is impacted by geographical differences, geopolitics, and technology. These results add to energy market liberalization discourse by underlining the significance of adaptable tactics, ongoing review, and international cooperation in navigating a rapidly changing energy environment.

**Results:**

The essence of this master's thesis is the thorough investigation and application of a deregulated energy market model inside the structure of "Azerenergy" OJSC. The creation of the Market Operator in December 2020 was a significant milestone in the shift from a conventional energy market framework to a more flexible and competitive approach.

**Scope of work:**

**Simulation of the Day-Ahead and Balancing Markets:**

The introduction of a test mode for the Day-Ahead and Balancing Market allowed a thorough analysis of market dynamics.

The prioritization of proposals from power plants according to their cost facilitated the process of accurately determining prices.

The involvement of the Central Dispatching Office allowed modifications to enhance the dependability of the system, resulting in the establishment of hourly pricing.

**Optimal Demand Prediction:**

The implementation of a methodical procedure for obtaining demand lists from Azerishig OJSC enabled precise prediction of demand for several time periods, including hourly, daily, and weekly forecasts.

The incorporation of renewable energy sources (RES) into the bidding process emphasized the need of achieving a harmonious equilibrium between sustainability and cost-efficiency.

**Pricing Mechanism:**

The market became more flexible with the implementation of various pricing plans and services, which were influenced by global market models.

The first pricing bids from power plants were based on a 10% profit margin on variable expenses, which was in line with the transition to a liberal market.

**Two strategies for determining prices:**

The investigation of two separate frameworks for determining prices in day-ahead energy auctions revealed their capacity to adjust to varying cost dynamics.

The first model prioritized variable costs associated with gasoline, but the subsequent model included a constant proportion to account for diverse operating expenditures.

**Execution:**

**The role of the Market Operator:**

The Market Operator had a crucial role in easing the auction process, guaranteeing openness, and coordinating with the Central Dispatching Office to maintain system stability.

**Integration of Renewable Energy:**

Notwithstanding the variable characteristics of renewable energy sources, the system operator gave priority to their integration, underscoring the significance of sustainability in the energy composition.

**Integration of the Global Market Model:**

By analyzing market models from North America, Europe, and Latin America, it has been determined that including a 10% margin on variable expenses is in line with worldwide best practices.

**Potential Avenues:**

**Iterative Enhancement of Market Models:**

Continual examination and improvement of the liberalized market model will be crucial in order to adjust to changing energy environments and market forces.

**Improved Cost Analysis:**

Our future efforts will prioritize the improvement of cost analysis techniques to achieve a more thorough evaluation of operational expenditures, therefore improving our pricing plans.

**Adjustment to changes in regulations:**

It is crucial to continuously monitor and react to regulatory developments in order to connect the liberalized market model with growing energy policies and standards.

**Engaging with stakeholders:**

Upcoming endeavors will prioritize involving stakeholders actively to get input, tackle problems, and promote a cooperative approach to market growth.

Ultimately, the findings and applications outlined in this thesis provide the foundation for a vibrant and competitive energy market in Azerbaijan. The continuous dedication to improvement and adjustment will guarantee the long-term viability and efficiency of the liberalized market model in fulfilling the energy needs of the country.

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