NEW MARKET DESIGNS FOR THE POWER SECTOR IN ARMENIA

ENHANCING CAPACITY FOR LOW EMISSION DEVELOPMENT STRATEGIES (EC-LEDS) PROJECT

CONTRACT NUMBER AID-OAA-M-15-00005

September 2016

This publication was produced for review by the United States Agency for International Development (USAID). It was prepared by IRG, an Engility Company.

NEW MARKET DESIGNS FOR THE POWER SECTOR IN ARMENIA

Enhancing Capacity for Low Emission Development Strategies (EC-LEDS) Project

Contract Number AID-OAA-M-15-00005

September 2016

This page is intentionally left blank.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS

ANPP	Armenian Nuclear Power Plant
BM	Balancing Market
DAM	Day-Ahead Market
DISCO	Distribution Company
EC-LEDS	Enhancing Capacity for Low Emission Development Strategies
EMM	Electricity Market Model
ENA	Electric Networks of Armenia
EPSO	Electric Power System Operator
ETM	Electricity Trade Mechanism
EU	European Union
GTMax	Generation and Transmission Maximization Software
HPP	Hydro Power Plant
HVEN	High-Voltage Electric Networks
IRG	IRG, an Engility Company
kW	Kilowatt(s)
MoENR	Ministry of Energy and Natural Resources of Armenia
MW	Megawatt(s)
MWh	Megawatt Hour(s)
NPP	Nuclear Power Plant
PSRC	Public Services Regulatory Commission of Armenia
PSS/E	Power System Simulation for Engineers
PX	Power Exchange
SHPP	Small Hydro Power Plant
TPP	Thermal Power Plant
USAID	United States Agency for International Development
WG	Working Group

1. INTRODUCTION

The *New Market Designs for The Power Sector in Armenia* was prepared under the USAID Enhancing Capacity for Low Emission Development Strategies (EC-LEDS) project managed by IRG, an Engility Company and a team of local and international experts. The main goals of the EC-LEDS project in Armenia are: 1) to implement activities in support of the national energy strategy, 2) to propose a structure for market reforms, 3) to promote cross-border trade with Georgia and 4) working toward the harmonization of Armenian regulatory practices and electricity system standards with those of Georgia in compliance with European Union (EU) directives.

This report builds on the *Gap Analysis with List of Major Market Challenges and Legal Barriers Report,* which focused on necessary market design changes and opportunities for cross-border trade between Armenia and Georgia. This report also provides a new market model and several market opening scenarios, transitional phases, and an action plan for implementing mutually beneficial cross-border trade with Georgia.

Any reform process takes years. Implementation takes place in stages, and at each stage, detailed solutions flesh out concepts identified in earlier stages. This report presents the initial design for a proposed new market structure. As with other reform processes, further detailing will be needed in subsequent stages of implementation of this concept.

The issues relating to reforms of the Armenia domestic market in this report are grouped under the following four headings:

- Market Structure and Model
- Electricity Trade Mechanisms
- Implementation Stages Including Required Software Development
- Action Plan

This page is intentionally left blank.

2. EXECUTIVE SUMMARY

The Armenian power market's current design was primarily developed in 2004, when ArmEnergo's single-buyer responsibility was shifted to the Electric Networks of Armenia (ENA), the distribution company (DISCO).[1] The removal of ArmEnergo was a necessary, but insufficient and incomplete, step for creating an effective and transparent power market. The DISCO was established to provide electricity at regulated prices, even if generation costs rose for any reason. Prior to 2012, there was no balancing mechanism to compensate for DISCO's financial loses/profits due to mismatches of actual and forecasted cost of purchased electricity. Thus, end-user tariffs could increase or decrease on an annual basis to reflect the generation costs of the previous year in order to cover the full market cost of generation, but consumers did not receive better market reliability in return. The key disadvantages of the existing market and measures to increase its efficiency are presented in the *Gap Analysis with List of Major Market Challenges and Legal Barriers Report*.[2] This report explains the new market model and an electricity trade mechanism (ETM), proposes a path to implement it, and discusses how it can improve the performance of market participants through liberalization of overall market operation.

Armenia's transition to a fully competitive power market is based on the needs of the domestic market, but it also takes advantage of trade opportunities with Georgia. Cross-border trade would yield advantages while also improving the efficiency of the internal Armenian market. The key objectives of the new market structure are:

- Transition to an hourly market (at least) to enhance electricity sector operation
- Efficient allocation of responsibilities between market participants and end-users
- Protection of domestic consumers
- Realization of economic cross-border trade opportunities
- Creation of an enabling environment for investors

The new market model requires both structural and functional transformations, especially in the functions of market participants and operators. In particular, the following should be established:

- **Market Operator** – To carry out a wide range of functions in the new domestic market, including preparation of rules and cross-border trade processes

- **Suppliers** – To increase efficiency and competition in retail markets that enable unbundling of distribution and supply functions

- **Traders** – To conduct export/import transactions in wholesale markets and to aggregate individual generation units to increase their competitiveness in domestic markets and in regional trade

- **Large Consumers Entering the Wholesale Market** – To participate in wholesale and retail markets and provide more depth to those markets

---

[1] ArmEnergo was a government owned company which was responsible for buying electricity from the generation sector and selling it to the Distribution Company at average prices. The ArmEnergo Company was liquidated after the Single Buyer market was established.

[2] *Gap Analysis with List of Major Market Challenges and Legal Barriers Report*, IRG, an Engility Company, June 2016.

The suggested modifications for market participants and the System Operator in the new market require new regulatory approaches by the Public Services Regulatory Commission of Armenia (PSRC). These range from the planning of trading volumes and tariff calculation methodologies to monitoring overall market performance and participants' market activities in particular.

The new market model, presented in Chapter 4, includes several important differences from the existing market model. The new market model organizes electricity trade through the 1) Capacity Market; (2) Monthly Contracts (3) Day-Ahead Market; (4) Balancing Market; and (5) Ancillary Services. Such a market model will increase the efficiency of the power sector, provide better protection for domestic consumers, provide clearer assignment of responsibilities, enhance competitiveness, provide more transparency of functions, and enhance conditions to attract investments. Ideally, competitive markets begin with a competitive surplus of generation. Where a surplus is lacking, as is the case in Armenia, a transitional market model needs to be implemented. Chapter 5 discusses each option, the appropriate transition phases, and the details of the proposed ETM.

This major mechanism and options for each market time segment are as follows:

- **Capacity Market** through capacity tariff implementation
- **Monthly contracts** based on 1) a Partial Pool (PP) concept and 2) direct negotiations between market participants, including export/import transactions
- **DAM** based on 1) cost-reflective prices with partial liberalization, 2) generators' offers only, and 3) generators' offers and off-takers' bids. The marginal and weighted average pricing principle for settlement are used in this proposal
- **BM** –A deviations market without bids must be implemented at the initial stage. Deviations are distinguished based on source: 1) dispatcher-initiated orders ask generators to respond to external factors—generators may be rewarded with bonus payments; and 2) market participant-initiated deviations—penalties may be imposed for generator noncompliance. Marginal and weighted average pricing principles are again considered
- **Ancillary Services** through Capacity Market mechanism and System Operator's special fee

During the transition period, numerous multi-optional calculations and analyses for co-optimization should be conducted. The required software for this stage is presented in Chapter 6, namely:

- Month-Ahead Planning and Day-Ahead Planning for market participants to increase planning accuracy and price optimization. Using this software will allow market participants to improve skills on the hourly market
- Simulation software incorporating the main principles of the new market functions to enable more informed policy choices
- Parallel market operation. This software carries out all calculations in accordance with the new model and ETM (without financial obligations during the first stage) and provides results that can be compared with the existing market (settlement and invoicing will be performed by existing models until the final decision is made to transition to the new market)

Key milestones for the first stage of domestic market reform (see Chapter 7) are:

- Establishment and approval of the detailed Armenia Electricity Market Model (AEMM) and ETM

- Acceptance of the concept of the new electricity market in Armenia
- Establishment of the market development working group (WG) operating on a permanent basis with the inclusion of specialists from the PSRC, Ministry of Energy and Natural Resources of Armenia (MoENR), Electric Power System Operator (EPSO), and Settlement Center.
- Initial software development
- Implementation of multi-optional calculations and analysis in order to select the optimal principles of market functioning and ensure a smooth transition to the new market
- Creation of new and necessary amendments to the existing legal and regulatory framework, as well as their harmonization with EU legislation
- Development of new market rules and procedures
- Capacity building for market stakeholders (e.g., presentations, training, roundtables)
- Action Plan for transition to the new market

A timetable on the electricity market reformation process should be developed upon approval of the concept and formation of an appropriate WG.

Cross-border trade with Georgia is an important tool to enhance operation of the electricity sector. Possible principles for organization of such trade between Armenia and Georgia are considered in Chapter 8 and include:

- The need to transition to hourly trading for DAMs and BMs in both countries
- Trade through bilateral contracts between market participants (Market Operator and DAM are not needed in both countries; only System Operators are necessary)
- Implementation of the Power Exchange (PX) Node mechanism for cross-border daily trade (Market Operator or responsible bodies must be developed in both countries; domestic DAMs are not mandatory)
- Market Coupling mechanism implementation as a recommended option (market Operators and domestic DAM establishment are needed in both countries)
- The need to develop balancing rules, including metering and settlement

The main steps required for organizing Armenia-Georgia cross-border trade are presented in the Initial Action Plan (see Chapter 9), including:

- Declaration of transition to hourly cross-border trading based on both bilateral contracts and daily agreements in both countries
- Authorization of trading through bilateral contracts between market participants
- Agreement between Armenia and Georgia on establishment of Market Operators (or responsible bodies at the initial stage) in both countries
- Agreement on the introduction of DAMs to the domestic markets of both countries allowing Day-Ahead Trade using the Market Coupling mechanism and implicit auctions

- Selection of an optimal mechanism for Day-Ahead Trade
- Choice of cross-border trade options and decisions at the time of their implementation (e.g., timetables for establishment of Market Operators, domestic DAMs, Market Operator-to-Market Operator agreements, coupling software)
- Extending the existing Joint Working Group of Armenian and Georgian experts Working on the details and development of the following regulatory framework to support cross-border trade:
  - Bilateral contracts principles
  - DAM mechanism implementation
  - Balancing rules
  - Metering rules
  - Settlement rules

3. OBJECTIVES

The Armenian power market's current design dates back to 2004, when the MoENR and PSRC ended ArmEnergo's monopoly as a state-owned single-buyer and single-seller trading company with a primary charge to keep end-use prices stable when generation costs fluctuated. The disbanding of ArmEnergo puts the privately owned electricity distributor, ENA (the DISCO), and the generating companies in a new power market where ArmEnergo's single-buyer responsibility, including financial responsibility for the sector, has been shifted de facto to the DISCO. The removal of ArmEnergo was a necessary, although insufficient and incomplete, step for creating an effective and transparent power market.

The DISCO was created to provide electricity at regulated prices even if generation costs rise. Before 2012, there were no balancing mechanisms to adjust the DISCO's margin to make up for any loss or gain incurred by a mismatch between actual and forecasted cost of purchased electricity. Since 2012, PSRC has used a mechanism allowing the DISCO to compensate its losses/gains occurring when EPSO's results did not achieve the forecasted generation mix. This mechanism was based on an annual ex-post assessment of the generation mix; it allows recoupment of the losses/gains over the next three-year period without recognizing any interest rate. In April 2016, PSRC improved this mechanism by allowing an annual recoupment with interest at 12 percent. When the generation mix is not achieved, for whatever reason, the entire financial burden, including interest, will be covered by the end-users' tariff during next year. On one hand, this mechanism adds stability to the power market and avoids situations like the recent financial crisis. On the other hand, there is no longer a reason to keep the power market totally regulated if all risks resulting from the generation mix are shifted to the end-users on an annual basis, along with 12-percent interest. More simply, end-user tariffs fluctuate on an annual basis to reflect the generation costs of the previous year or cover the full market price without having sufficient market responsibility mechanisms. The value of not having responsibility mechanisms is included in the DISCO's interest rate covering the fluctuation of the generation mix. At this stage, it is unclear what value is provided by this market model.

The key disadvantages of the existing market and the measures needed to increase its efficiency are presented in the *Gap Analysis with List of Major Market Challenges and Legal Barriers Report*.[3] This report discusses the development of the new market model and ETM that will increase efficiency for market participants and avoid negative impact on end-users. In the course of developing a new market model, the following issues must be solved:

- Structure and management of the market
- Planning and approval of tariffs
- Optimization of the trade mechanism with sharing of responsibility
- Cross-border trading with Georgia as a tool to increase efficiency of domestic market
- Investment policy

The following issues are the first priority:

- Market structure optimization
- Market rules development
- Ensuring fair and impartial conduct of market participants

3. *Gap Analysis with List of Major Market Challenges and Legal Barriers Report*, IRG, an Engility Company, April 2016.

- Market operations transparency
- Transition to state-of-the-art hourly trading in DAM and BM time segments, improving on the monthly basis of trading currently used
- Sharing of responsibility between the participants and retail consumers
- Defining transition timing and mechanisms to prevent any possibility of a "shock scenario"

4. NEW MARKET MODEL

4.1 MARKET STRUCTURE AND ACTIVITIES

Development and implementation of a new market model is aimed at increasing the efficiency of market operations and improving the legal and regulatory basis of the market. The new model contemplates changes in market structure, new principles of operation, and reformed trade mechanisms. In particular, the following structural reforms are needed:

- **Establishment of a Market Operator** with the following functions:
  - Participation in the development of regulatory documents governing wholesale market operation
  - Organization of wholesale trading of electricity, capacity, and services
  - Registration of bilateral contracts for sale/purchase of electricity and capacity
  - Organization of metering and data acquisition of actual generation and consumption in the wholesale market
  - Interaction with entities to forecast the volumes of generation and consumption
  - Implementation and maintenance of software and information systems
  - Monitoring actions of the System Operator and market participants
  - Implementation of settlements in compliance with market rules
  - Ensuring transparent market functioning
  - Dispute resolution among market participants
- **Establishment of suppliers and traders** able to conduct the following activities:
  - *Export/Import Transactions* – The analysis of regional trading opportunities shows the economic benefit that can be gained from cross-border trading; suppliers and traders need to be prepared to choose the best options (e.g., export, import, daily exchange)
  - *Sale of Power* – With the gradual opening of the market, the traders may sell directly to customers competing with the ENA
  - *Aggregation of Individual Generation Units* – The 15-year period provided for by the law for guaranteed sale of electricity at approved tariff rates has expired for many small hydro power plants (SHPPs) but is currently being extended. In the future, the buyer (presently the monopolized ENA) will be able to dictate decreasing sales prices of these plants (although the price of these hydro power plants (HPPs) is currently lower than the price proposed by thermal power plants (TPPs)). An aggregator for the group of small generators may be a more effective negotiator on behalf of these plants. Moreover, an aggregator may be able to deal with foreign markets more effectively than single-plant operators
- **Entry of large consumers into the wholesale market.** Rules and mechanisms need to be identified for large countries to enter the wholesale market. Particularly to be addressed are rules

for electricity purchases, connection rules, and charges for use of the distribution network. These consumers will participate only when it is economically advantageous for them

Transitioning the DAMs and BMs at least to hourly trading units is justified by the following:

- Technological characteristics
- Modern principles of power markets in unbundled markets
- Principles of regional trading and strong interconnection with the domestic market
- The values of economic dispatch
- Congestion management
- Necessity to share responsibility between market participants
- The mechanism of market balancing

For **existing participants** (i.e., generators, consumers), enlargement of functions is required in compliance with trade principles of the new ETM (see Chapter 5). The main difference with the current situation is the requirement to participate in short-term and long-term planning, to prepare and submit bids (load schedules and prices), and to take responsibility for market deviations.

The **existing System Operator** (i.e., Independent System Operator or Transmission System Operator in new model) will have greater responsibilities to solve market challenges, in particular:

- Administration of economic mechanisms to support the maintenance and development of generating capacities in the required volumes, with required technical parameters, in time to meet customer needs and considering the network infrastructure development forecast
- Selection of generation dispatch configuration
- Actualization of the designed power system model
- Economic dispatch with consideration of limitations on the generators' regimes and network infrastructure (congestion management)
- Competitive selection of offers/bids of suppliers and buyers defining the prices and volumes of supply for each hour of the coming day, together with the Market Operator (DAM)
- Real-time management of balancing based on minimization of electricity supply cost (BM)
- Ensuring functioning of the system services market

4.2 LONG-TERM PLANNING

Accuracy of long-term planning is lower than short-term planning. Lacking short-term planning tools, the current market model uses annual planning volumes for calculation and approval of end-user and wholesale tariffs. It is recommended to keep this instrument mainly during the transitional period for tariff calculation.

4.3 CAPACITY MARKET

The main objective of the Capacity Market is to ensure sufficient amounts of operational generating capacity to cover electricity demand at any time with appropriate reliability and quality parameters (including generating capacity reserves).

A working Capacity Market prevents a capacity deficit in the middle- and long-term perspective, defines the responsibilities of owners of generating units to maintain equipment ready for operation, and compensates part of the fixed costs of operating power plants (the amount of fixed-cost coverage may vary depending on the characteristics of the power system). The investment attractiveness of construction is also enhanced. Availability of an efficient Capacity Market makes exports more competitive.

However, there is currently no mechanism to control capacity implementation, and the consumer actually pays for capacity as declared by generators. The specific nature of generation capacities in Armenia softens this requirement to a certain degree because several power plants consist of one unit only (e.g., Armenian Nuclear Power Plant (ANPP), Hrazdan-5, Yerevan TPP).

4.4 MONTHLY CONTRACTS

Monthly contracts are expected to be the most used competitive market in the first stage of reform. This contract market brings several advantages: 1) it ensures price stability for buyers (contracts should not be at tariffs exceeding the PSRC-approved tariffs) and 2) they allow a buyer to plan its activities while recognizing the anticipated expenses of power purchase. Although the contracts might be signed for a one-year period, it would be reasonable to specify the contracted volumes in months.

Monthly contracts might be either regulated or nonregulated. While signing nonregulated contracts, the market participants themselves may choose contractors and set prices and volumes of power supply.

Monthly contracts, will start bringing responsibility to the power market. The key principle of the contractual relationship will be the principle of firm supply contracts. Specifically, if the generator produces less than the contract volume, then the generator must buy the missing shortage on the DAMs or BMs to fulfill its obligation. Correspondingly, unused power is at the risk of the buyer and is settled in the same way. The monitoring of the contracts is on an hourly basis.

The contracts should also take into account network losses. The most acceptable method is for a contract to set the delivery point as the point of generation, meaning the buyer will cover losses (mechanisms to identify losses are discussed further in Chapter 5).

4.5 DAY-AHEAD MARKET

In electricity planning, longer term plans require more adjustment as the delivery time approaches. Volumes of electricity not anticipated by monthly contracts require fine tuning to adjust differences with day-ahead planning load shapes. The differences are traded on a DAM with volume and price determination for each hour. A DAM is conducted every day before the actual delivery day.

In general, the DAM price is defined as an equilibrium node price, which is characterized by a cross point of demand and supply curves, determined by prices and volumes set by bids and offers of consumers and suppliers. If this mechanism is applied and not all the day-ahead planning volume can be covered, the remaining part is traded on the BM.

If only the generators' offers are used, the consumers will buy electricity by the established generation price, and the day-ahead planning shape for each market participant will be fully covered. The alternative to this approach would be to include no price bids of market participants. In this case, the prices are determined by a centrally accepted mechanism; for example, application of the approved tariffs with the respective defined limits of increasing coefficients (partial liberalization of price).

These mechanisms will be discussed in detail in Chapter 5.

4.6 BALANCING MARKET

Actual usage varies from day ahead forecasts just as day ahead forecasts vary from monthly or annual forecasts. Consumption level alterations and network restrictions cannot be forecast in advance with absolute accuracy. Real-time management of the power system requires a way to compensate for the deviations from the regime planned even a day before.

Real-time management is based on minimizing power delivery cost, which calls for measures that encourage market participants to honor dispatch orders and make it disadvantageous to deviate from planned values.

Unauthorized deviations are traded on the BM, and market participants are either "fined" (if the deviation is self-initiated) or "rewarded" if the deviations are made to comply with dispatch orders.

Possible options for the BM will be addressed in Chapter 5.

4.7 ANCILLARY SERVICES

The main task of the system services market is to ensure functioning of economic mechanisms that stimulate support and development of power system equipment. These services are specific and nonobligatory; they depend on individual participants' characteristics, such as:

- Ability to participate in normalized primary frequency control
- Ability to participate in automatic secondary frequency control at the TPP
- Reactive power control
- Participation in emergency recovery

The System Operator defines the technical requirements, selects service suppliers, and makes long-term contracts to compensate providers for these services. The costs of these services are recovered across all energy usage.

5. ELECTRICITY TRADE MECHANISM

This chapter explains the principles and mechanisms of trading on the domestic market and with neighboring countries. These principles and mechanisms lead to a discussion of the modifications to Armenia's legal and regulatory framework that should be planned in the next stage of the project. The suggested ETM will ensure reliable power supply with minimum growth of tariff rates for end-users a prerequisite for efficiency of the domestic market. Cross-border trade with Georgia is treated as a tool to improve the efficiency of the domestic market. As described in Chapter 4, the new power market will be divided into several time segments of trade, which are presented below.

5.1 CAPACITY MARKET

In the current single-buyer model, capacity charges are paid for by the DISCO only, which allows generators to reduce prices for export. Capacity payments may be implemented almost without a special mechanism to control operating capacity due to these facts:

- The ANPP, Yerevan TPP, and Hrazdan-5 are power plants with only one unit each
- The Vorotan Cascade of HPPs operates at maximum load at peak hours. Its available capacity is easily monitored through implementation of the dispatch schedule
- The Sevan-Hrazdan Cascade operates, in general, on an irrigation schedule; thus, the availability of its full functionality can also be easily controlled

If several wholesale consumers appear on the Armenian power market, the payments for capacity will be made proportionally based on their consumption, and payments to each generator will be proportional to its capacity contribution.

When the market is opened, it will be marked by the appearance of energy retail companies and the entry of large consumers in the wholesale market. Export volumes will increase and will include new generation capacity. At that point, it will be necessary to develop payment methods in the Capacity Market that will include:

- Payment for capacity proportional to participation in the market
- Allocation of generation between consumers
- Possible distribution of payments between domestic consumers and exporters
- Control over construction, connection, and cost allocation for newly contracted generating capacity

5.2 ELECTRICITY TRADE

5.2.1 MONTHLY CONTRACTS

The Capacity Market is intended to satisfy multiyear needs. The market also needs a contracting mechanism for participants to supplement their annual, seasonal, and monthly requirements. For this, bilateral long-term contracts are recommended, with terms of at least a month and up to one year, with adjustment of their parameters at least each month. This will allow demand-side parties to account for

seasonal differences in consumption (the form of load shapes and volume changes) and for generators to reflect more accurate estimates of their capability. Although monthly contracts will differ from actual regimes, this will help consumers to predict and react to the expected level of prices. The first task is to establish monthly planning for each hour. The following format is recommended:

- Market participants prepare and submit offers (by producers) and bids (by users)
- The System Operator monitors offers and bids, making corrections if needed
- The System Operator (or Market Operator, if established) schedules optimal dispatch, recognizing congestion management needs
- The System Operator (and Market Operator, if established) approves the hourly balance for the planned month

Because market participants lack experience in trading on an hourly basis, the algorithm and software will be provided to them.

Preparing Bids

The bidding process anticipates that the following mechanisms will be available:

1. Historical load shapes for each market participant will be taken from the metering system database with one to three years' depth.
2. Load shapes are separated by type of day. For Armenia, breakdown by working days, Saturdays, and Sunday plus holidays is sufficient.
3. The initial load shapes are filtered to remove the anomalous days or hours where there may be problems with meter readings or data.
4. Curves are defined for typical days of the month.
5. "Daily coefficients" are defined, which account for the difference between anticipated daily volumes and typical days.
6. "Weekly coefficients" are defined, which account for the dynamics of changes of volumes by weeks.
7. The calendar is synchronized (to align the planned month with the corresponding historical month).
8. Weight coefficients are defined by each hour of the month.
9. Capacities are defined for every hour of the month as a product of the planned monthly volume and the corresponding coefficients from item #8 above.

This methodology has been tested in Georgia by Energo-Pro Company (it balances 15 power plants with over 400 megawatts (MW) total capacity) and has proven its functionality.[4] As is shown on **Figure 1**, there is a significant difference between daily consumption load shapes depending on the day of the week and the dynamics of changes by months (using metering data for 2013). This methodology yields a breakdown of the monthly volumes into volumes for each hour of that month. **Figure 2** shows the daily consumption load shapes for the third week of May 2014. Using this methodology produced

4. Hourly planning for market players for the Georgian electricity market based on hourly metering data from Energo-Pro, Deloitte, April 2014.

accurate results for February 2015 (**Figure 3**), even for the largest regulated generator, Lajanauri HPP, which is regulated in winter, but, in summer, due to the "high water" effect, it operates almost at maximum capacity.

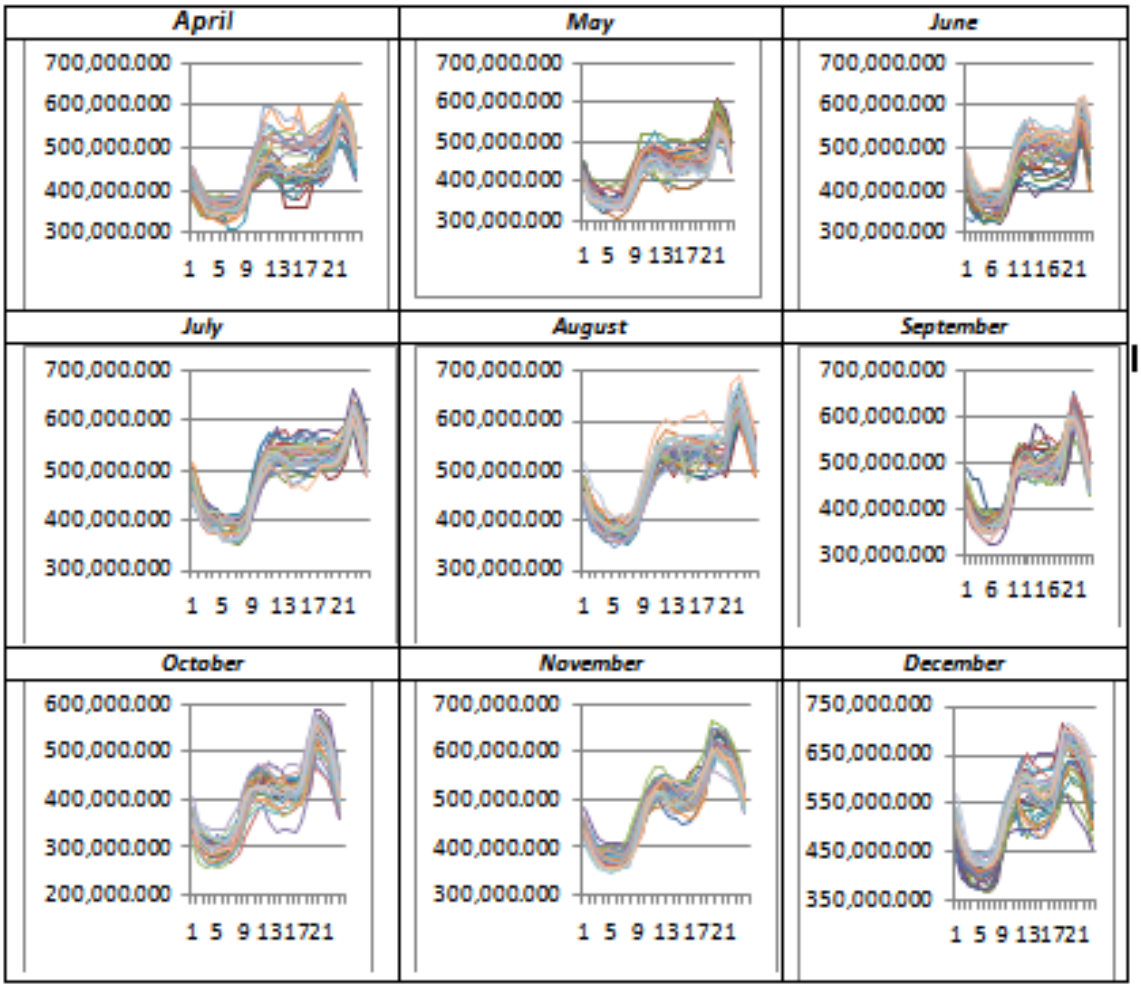


Figure 1. Energo-Pro Consumption Load Shapes for 2013 (in Kilowatts (kW))

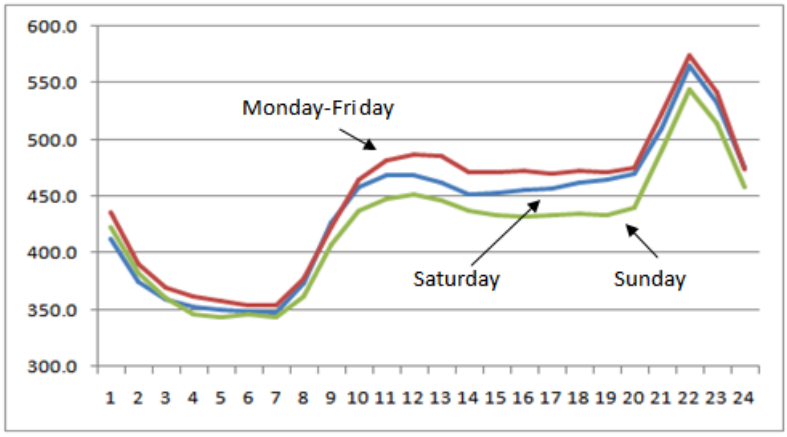


Figure 2. Consumption Planning Load Shapes for May 2014 (in MW)

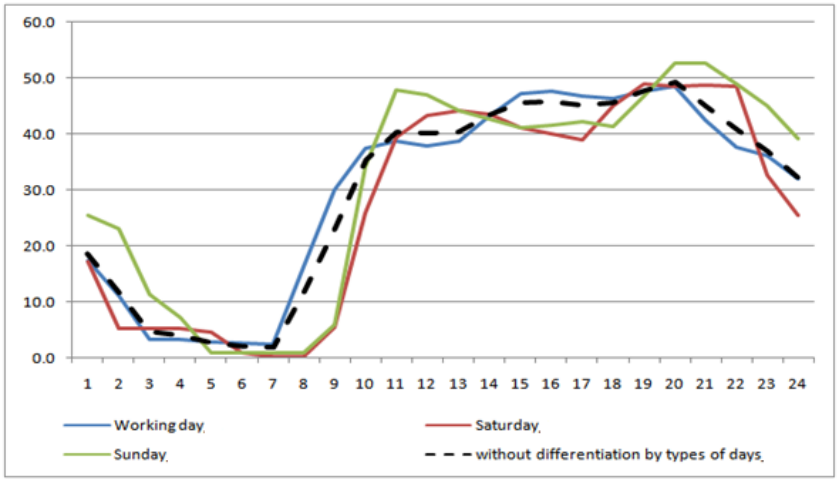


Figure 3. Ladjanuri HPP Planning Load Shapes for February 2015 (First Week)

Monitoring of Offers and Bids

The System Operator will initially review offers and bids it receives for apparent compliance with the following criteria:

- Incorrect monthly volume
- Incorrect minimal or maximal loads
- Large or unexplained difference between daily volumes
- Large or unexplained difference by weeks

If the System Operator detects violations, it should consult the market participant to make the appropriate correction(s).

Optimal Dispatch Scheduling and Congestion Management

The System Operator calculates an economic dispatch schedule covering all consumption based on consumers' bids using the price minimization criterion. This is called Optimal Dispatch Scheduling.

To solve the issue of generation dispatch in Armenia, the Generation and Transmission Maximization Software (GTMax)[5] software installed at the System Operator is being used. The suggested methodology of receiving offers and bids from market participants allows a significantly simplified use of that software because it already contains fixed load shapes for almost all participants; therefore, there is no need for detailed models of participants.

The initially calculated results are tested for feasibility (i.e., for possible network limitations). This is done by means of the load flow and stability Power System Simulation for Engineers (PSS/E) software also installed at the System Operator. If network limitations are exceeded, then a re-dispatching of generation is performed by changing the limitations in the GTMax software.

5. *Economic Efficiency of Armenian Power System Integration and Analysis of Impacts of New Renewable in Armenia*, Tetra Tech, November 2012.

Final Planning Balance

The System Operator determines the final hourly planning balance of the power system and gives each market participant its operating plan for the month. Based on that balance, the monthly bilateral contracts can be signed. Two options are proposed for execution of monthly contracts:

- Pool principle. In some cases, less than a full pool is available; for example, where the entities offer only a part of their planned monthly volumes (from 0 to 99 percent). This is referred to as a partial pool
- Direct negotiations between market participants

Partial Pool

Calculations in the partial pool suppose the availability of planned daily load shapes of market participants for the planned month. To protect the end-users, the prices may not exceed the PSRC-approved generator tariffs. All domestic consumers are partial pool participants, but the generators can be selected by criteria to be developed and approved. For example, generators may enter the partial pool when prices are cheaper than preliminary set values (this is a principle of economic generation dispatch that protects consumers). Another example is newly constructed power plants that are permitted to enter the partial pool even though the total volume of electricity to be purchased at the contract rate has already been determined in a signed power purchase agreement (supporting investors' interests). In yet another example, generators might be included in the partial pool by an agreement to reduce their offer price. Export/import operations with provisions for long-term deliveries are determined through direct contracts with specified volumes and prices; therefore, these volumes are not included in a partial pool.

The partial pool structure may differ depending on the season. Practically, the partial pool is an hourly allocation of generation of selected power plants among consumers proportional to their hourly consumption. Average prices in the partial pool will be different for each consumer depending on daily consumption load shapes. Generator prices will also be differentiated by hour in order to preserve the average daily price due to the following:

- Favorable night tariffs are sometimes modified when the price of that generation exceeds the corresponding price during the hours of maximum load (current situation in Armenia). This occurs particularly when production is limited at the Vorotan Cascade
- Hourly rates may be modified to provide economic incentives to TPPs to minimize production when nighttime export flows are constrained
- Prices may be reduced to increase potential export of night power

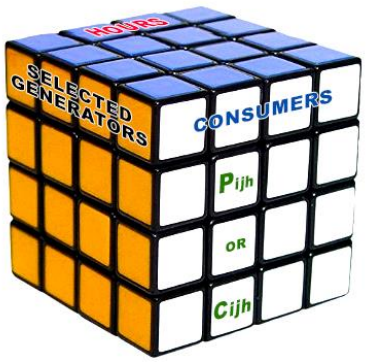
The partial pool calculations produce volumes purchased by consumer "i" from generator "j" for hour "h" (P_{ijh}) and the cost of each bilateral contract (C_{ijh}) (**Figure 4**).

These contracts are assigned at the point of generation, meaning that losses of electricity are also considered while calculating the cost of electricity to be paid by a consumer.

Considering that generators might be connected both to the transmission and the distribution network, the term "market losses" is used without differentiation and represents the difference between generation plus import and consumption plus export at the sell/purchase nodes (for example, in Georgia they use the notion "transportation expenses").

Based on the method of structural analysis[6] it is possible to calculate each consumer's portion of the occurring losses. However, this method has certain disadvantages for monthly planning:

- The need to plan for reactive load by hours
- The impact of the consumption level of one consumer on the portion of losses created by others
- Adjustment of monthly planned load shapes of market participants in the DAM
- The historically developed generation structure produces unequal conditions for consumers



$$P_{ijh} = L_{ih} / (1\text{-}loss\%_h/100) * G_{jh} * g_j * p_{ji} / \Sigma_i \; L_{ih} * p_{ji}$$

$$C_{ijh} = P_{ijh} * t_{jh}$$

Where,

L_{ih} = Planning capacity of consumer "i" for hour "h"

$loss_{\%h}$ = Percent of system losses for hour "h"

G_{jh} = Generator "j" net generation for hour "h"

g_j = Portion of generation of "j" generator in partial pool

p_{ji} = Coefficient of priority in the generation allocation of generator "j" for consumer "i"

t_{jh} = Price of generator "j" for hour "h"

Figure 4. Partial Pool Structure

The percent of losses will vary by hour. Differentiation of losses by hour is possible, for example, using the analysis of retrospective metering data. However, planned losses are not considered for DAM because final settlement calculation will include actual losses. Average percentages of market losses will be used in this stage.

In the abovementioned approach, the priority coefficient p_{ji} is also included. Ideally, all these coefficients will be equal to 1 (equal conditions for all consumers). However, depending on the target function and created conditions, certain adjustments will probably be needed (the decision will need to be justified). For example, if the target function is limitation of tariff growth for residential customers, then a higher coefficient might be accepted for DISCOs when allocating cheap generation.

As a result of these calculations, monthly bilateral contracts could be signed between all pairs of the partial pool participants. The structure of the partial pool may vary by seasons. The sum by months will be combined for annual bilateral contracts. In a general partial pool case, only a part of a consumer's demand may be satisfied due to the following:

- Not all generators participate with 100 percent of their generation

6. *Structural Analysis of Flows and Losses in Electric Network*, V. Safaryan, National Academy of the Republic of Armenia, 2001.

- Differences between monthly planned load shapes and day-ahead planning load shapes for a particular day

Direct Monthly Bilateral Contracts

Market participants should have the opportunity to sign direct contracts. Some generators may not be able to sell desired volumes in the partial pool; other generators may not be included in the partial pool at all due to competitive selection of offers. At the same time, consumers that did not cover their expected consumption demand should have the opportunity to make additional purchases. These contracts are executed on an hourly basis as a result of direct negotiations between two participants. The price in such contracts is negotiable.

This contracting opportunity is also available to export/import transactions, which should be equally accessible for each market participant subject to the overriding criterion—these transactions should not result in an increase of the generation price for domestic consumers. Relatively cheap power will presumptively be consumed inside the country. Exceptions are also possible. For example, if Armenia is disconnected from Iran[7] in the spring and summer months, the system will be operating in an isolated regime. Therefore, the low nighttime demand in Armenia will make it necessary to significantly reduce the load of the ANPP. Given that Georgia itself has a surplus of generation in these seasons, it may only be interested in cheaply priced imports -purchase of low cost nighttime energy will allow it to accumulate additional water for later use at peak hours. While export from Armenia's TPPs may not be possible, export from the nuclear power plant (NPP) may contribute in this indirect way to the reduction of the generation price in Armenia at peak hours.

Granting market participants the right to export power may create a situation where their aggregate export exceeds the transfer capability of the interconnection. In that situation, explicit or implicit auctions are usually conducted. In the absence of a unified regional market, explicit auctions are conducted. They can be annual, monthly, and day ahead.

As a result of such auctions, one or another market participant may reserve the transfer capability. If there is no restriction by transfer capability, all exporters get access free of charge. If there are restrictions, the priority of access to interconnection is be awarded based on the price proposed for the reservation.

It is possible to have both export and import contracts for the same hour even in the case of a single interconnection line. The physical flow will be equal to the difference of the contractual values. Operators of both countries participate in realizing such contracts. The limitation is lifted by trading, when, for example, a long-term contract on export had become a limitation on possible imports, either long term or short term.

Monthly Contract Principles

The order of signing monthly contracts may be random. However, after a market participant signs a bilateral contract, its participation in the partial pool is limited by the difference between the month-ahead planning load shapes and the aggregate load shape it has contracted.

All signed monthly contracts will follow the principle of firm supply contracts.

7. *Economic Efficiency of Armenian Power System Integration and Analysis of Impacts of New Renewable in Armenia*, Tetra Tech, November 2012.

Consumption that was not covered on the contracts market must be traded on the DAM, making adjustment for the difference between day-ahead planning load shapes and load shapes for that particular day developed on a monthly basis.

5.2.2 DAY-AHEAD MARKET

Volumes of trading on the DAM for each market participant will be defined by the difference between the day-ahead planning load shape and the load shape formed by the sum of the hourly values of its monthly contracts for the planned day. Planned losses calculated by the System Operator for the planned day are presented in the calculations.

A day before the given day, the market participants submit their load shapes to the Market Operator and System Operator, who calculates the optimal balance of the system taking into account the prices of generation and network limitations.

Prices on the DAM may be calculated based on:

- Generator tariffs approved by the PSRC (cost-based prices with possible partial liberalization)
- Generator offers (liberalized or limited prices)
- Both generator offers and consumer bids

Most developed competitive markets use liberalized generator prices for the DAM. Armenia may reach partial liberalization in the near future and allow generators to offer prices lower (any price) or higher (up to acceptable level); but, at the moment, there are few generators with similar price ranges. Permission to increase the price is often an incentive for investment into new generating facilities in markets with small volumes.

In all cases, generators would be permitted to differentiate prices by hours, which is also an element of competition. For example, run of river HPPs would prefer to generate at a lower price than release the water.

The first two options imply that by using contracts and DAM, the market participants will completely cover their day-ahead planning load shapes (**Figure 5a**).

It may happen that the volume of signed monthly contracts will exceed the day-ahead planning load shapes (**Figure 5b**); if so, the consumer becomes a seller and the generator becomes a buyer on the DAM. In other words, consumers sell back volumes which were committed to them for the month, but are not needed for the next day. Special mechanisms may be needed to limit the price for sale of surplus electricity to consumers. A market participant with this concern might reasonably adopt a strategy to limit the volumes of monthly contracts to the amount of planned consumption/generation and cover any remaining volume on the DAM. That strategy can also account for the difference between the day-ahead planning load shapes and load shapes planned for that day in the monthly plan.

Volumes being covered by monthly contracts may be assumed to be about 80 to 85 percent, becoming less as the competitive market becomes more developed. The DAM becomes a mechanism to cover the remaining required consumption volumes. Given that economic dispatch will be used to dispatch the power system, an increase of consumption will bring an increase of both marginal and weighted average prices (**Figure 5c**) compared to the prices used in the monthly contracts market. Prices will depend on the choice of a price formation mechanism.

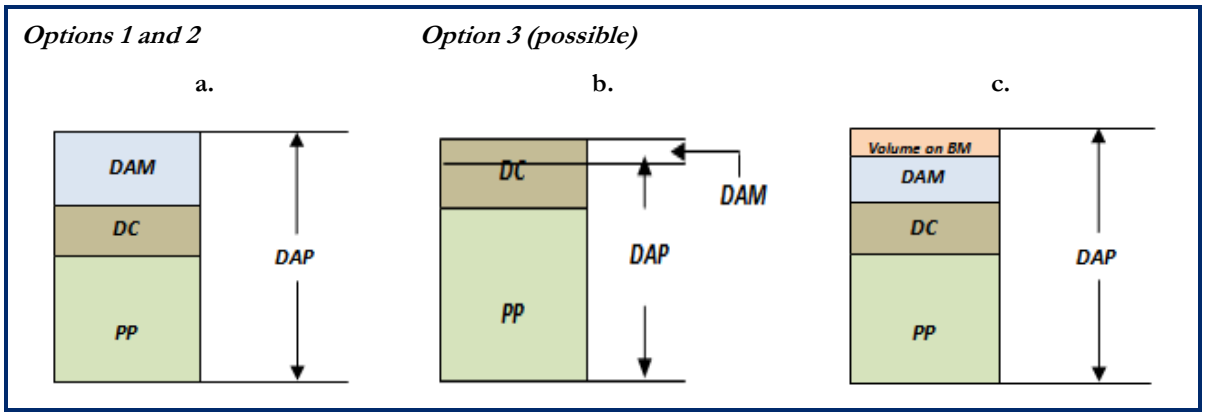


Figure 5. DAM Options for Each Hour

Option 3 (**Figure 5**) presents a case where consumer bids are used as well. The consumer always wants to buy at the lowest price and the seller wants the highest price, and it is possible to satisfy only a part of the buyers' bids at the equilibrium point of supply and demand (**Figure 6b**). If the total required day-ahead planning volume ($\mathbf{V_{DAP}}$) is not completely covered on the DAM, the clearing price on the DAM and the traded volume ($\mathbf{V_{DAM}}$) are being determined. The difference ($\mathbf{V_{DAP}}$ minus $\mathbf{V_{DAM}}$) will be traded on the BM. Making a further assumption that the balancing segment of the market is often the most expensive market, it would be more profitable for the consumer to offer maximum realistic prices while submitting bids on the DAM. At the first stage of reforms, allowing several optional bids for each hour is unreasonable.

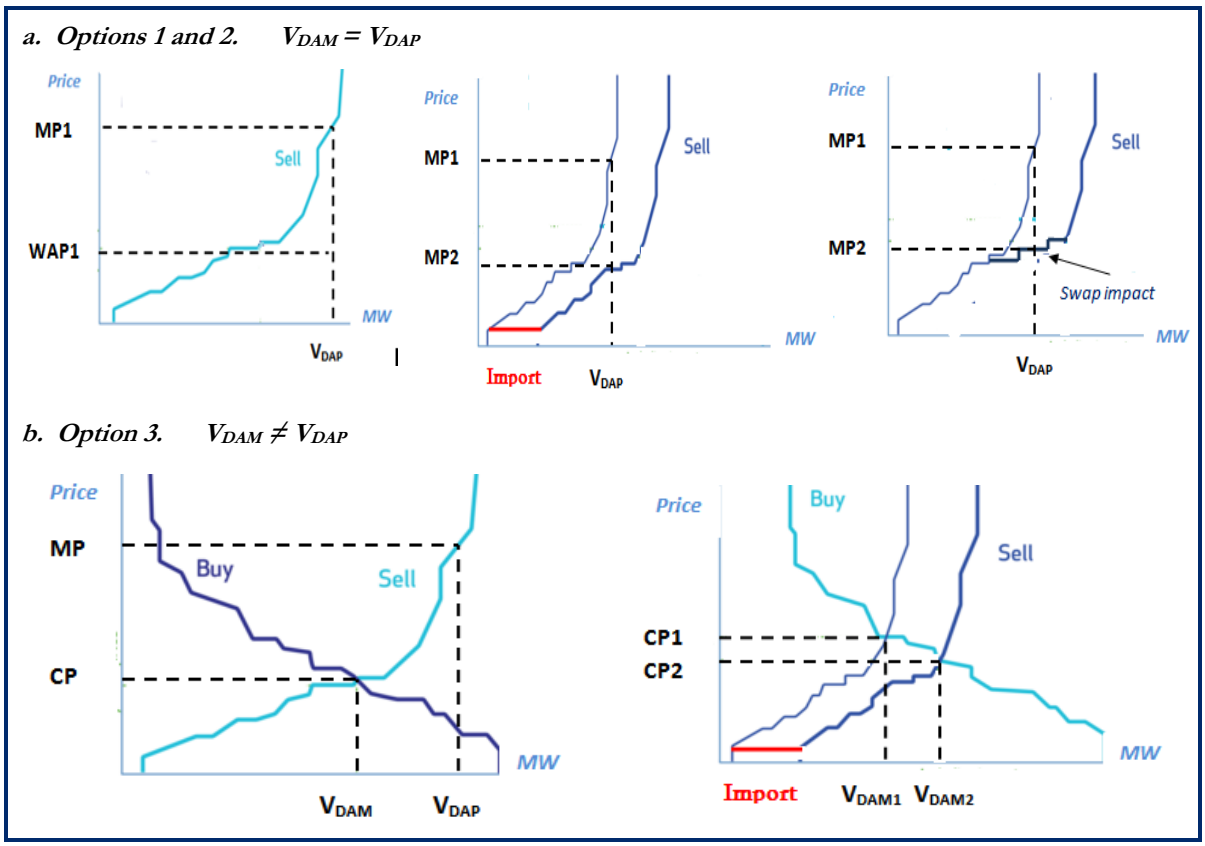


Figure 6. Pricing on the DAM

Participation in regional markets may have a favorable impact on domestic markets. **Figure 6a** demonstrates how a relatively cheap import or benefit from swap reduces the clearing price on the DAM. In particular, having efficient active traders helps to ensure availability of desirable import and export transactions. A unified regional market may ultimately provide this market depth.

Settlement options may take various forms:

1. Payments to all DAM participants are made at **marginal** or **clearing price** (the option with consumer bids available).
2. Consumers pay at **marginal** or **clearing price** (the option with consumer bids available), and generators are paid according to their offers. In this case, additional funds may be accumulated on the market (a special account may be used to support market operation).
3. Buyers (DAM participants) pay at generation weighted average price, whereas generators (DAM participants) are paid according to their offers.

The generation sector lacks real competitiveness due to limited technological resources and high variability of generation prices of power plants. In the early stages of Armenian market reform, it will make sense that generator prices will be accepted at a level not exceeding the PSRC-approved price, and settlements will be conducted according to Option 3.

5.2.3 BALANCING MARKET

Actual regimes almost always differ from those planned. These deviations are traded on the BM. Developed markets use the intra-day market model, where bids and settlements are submitted for every 15-minute interval (or shorter). For the initial phase of market reform in Armenia, it will be reasonable to apply the market of deviations as a balancing mechanism—a market formed on actual regimes without intra-day trade. This mechanism does not suppose the availability of bids for the BM, and settlements due to deviations will take into account the value, sign, and responsibility of a participant or the dispatcher.

Hourly deviations (**Figure 7**) are defined as a capacity of the actual regime, excluding capacities by contracts and the DAM.

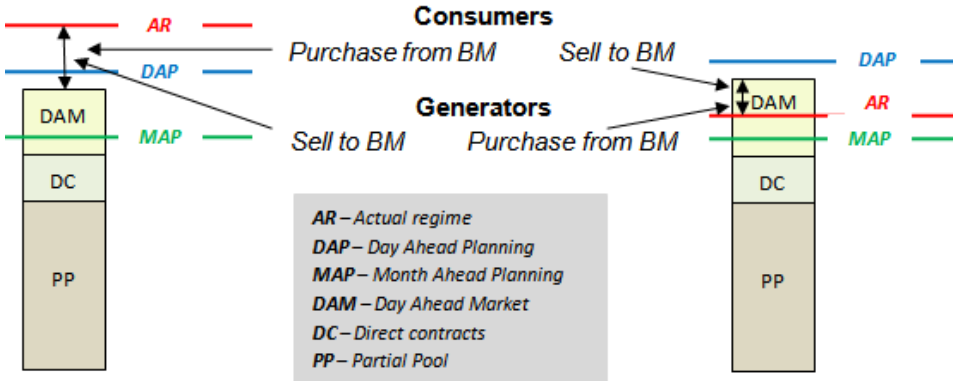


Figure 7. Hourly Deviations Traded on the Balancing Market

The reasons for deviations may be various, but they are classified into two groups based on initiatives:

- Dispatcher initiative (dispatch instructions in real-time market)
- Market participant initiative

The basic difference between these two types of deviations is that the first type should not impose any additional financial burden on a participant (a participant may even receive "bonuses"), whereas the second type is based on "penalties" for deviations.

Using the suggested mechanism for the situation when DAM=DAP (this precondition corresponds to the first stage of market reforms, although there is no material difference), the deviation for each hour initiated by the dispatcher ($\mathbf{\Delta_D}$) will be equal to the dispatch order minus capacity on the day-ahead planning load shape for that hour.

From a generator's viewpoint, this deviation may be either positive or negative. For such cases, ramp-up and ramp-down prices are used. Special methods exist for their determination; however, since the objective is to stimulate the adherence to the dispatcher schedule, they could be determined as the generator prices accepted on the DAM. These are the PSRC-approved tariffs plus a certain percent to award bonuses to participants.

Deviations initiated by market participants ($\mathbf{\Delta_{MP}}$) will be equal to actual capacity minus capacity in the dispatcher schedule (the planned schedule as modified by dispatch orders). Payment for deviations initiated by MPs will depend on the sign, but the results of the settlement should stimulate observance of the dispatcher schedule. Eventually, observance should lead to the lowest possible price of electricity.

Charges for deviations initiated by market participants will be based on the following:

- The price formation options selected for the DAM (marginal or weighted average prices)
- The sign of the deviation indicating sale or purchase on the BM

If marginal prices are used on the DAM, marginal prices should also be used on the BM (Option 1 in **Table 1**). If weighted average prices are used on the DAM (to limit at price growth in the market), either marginal prices or weighted average prices can be used on the BM (Options 2 and 3 in **Table 1**, respectively).

Table 1. Pricing Options for Deviations Settlement

N	Price Option on DAM	Price Option on BM	Selling Price to Market	Purchasing Price from Market
1	MP_{DAM}	MP_{BM}	**All Market Participants** Min (MP_{DAM} or MP_{BM})	**Generator** Max (MP_{DAM}, GP_{DAM}, or MP_{BM}) **Consumer** Max (MP_{DAM} or MP_{BM})
2	WAP_{DAM}	MP_{BM}	**Generator** Min (WAP_{DAM}, GP_{DAM}, or MP_{BM}) **Consumer** Min (WAP_{DAM} or MP_{BM})	**Generator** Max (WAP_{DAM}, GP_{DAM}, or MP_{BM}) **Consumer** Max (WAP_{DAM} or MP_{BM})
3	WAP_{DAM}	WAP_{BM}	**Generator** Min (WAP_{DAM}, GP_{DAM}, or WAP_{BM}) **Consumer** Min (WAP_{DAM} or WAP_{BM})	**Generator** Max (WAP_{DAM}, GP_{DAM}, or WAP_{BM}) **Consumer** Max (WAP_{DAM} or WAP_{BM})

MP = Marginal Price
WAP = Weighted Average Price
GP_{DAM} = Deviated Generator Price on DAM

The choice of the set of mechanisms to apply should be based on the results of analysis. The burden of participation in the BM will diminish with higher accuracy of planning and adherence to dispatcher

schedules. For example, if a consumer makes a small purchase on the BM (meaning a small portion of total consumption), the choice of settlement method may affect insignificantly the average price of its total purchase. Thus, the BM is a mechanism to encourage responsibility by wholesale market participants, and it lowers the financial burden on end-users. It represents an improvement over the current situation, where all market losses, and not only objective losses, are borne by the end-users through periodic growth of tariffs.

5.2.4 APPROACHES TO SETTLEMENT (ELECTRICITY TRADE)

Hourly data is accepted as a basis for Settlement (i.e., calculations by all sectors of trade are made for each hour). The main principles for Settlement are described in the paragraphs that follow.

The payment amounts on the contracting market are determined in accordance with the "firm supply" or "take or pay" principle. The calculations are carried out hourly in accordance with each contract, and each market participant pays the appropriate amount directly according to each bilateral contract (PP, direct).

To illustrate Settlement on the DAM and BM (**Table 2**), a model composed by two generators and one consumer is used. The example supposes that ramp-up and ramp-down regulation prices are 15-percent higher than bids on the DAM (the "premium" price for executing dispatcher's orders).

Example 1. The consumer has no deviation from the planning volume. Generator 2 produces more than directed in the DAM by its own initiative (e.g., the generator has not been offloaded). The dispatcher instructs Generator 1 to unload, and it executes the order—**Table 2, Case 1** (weighted average prices are used for both the DAM and BM) and **Case 2** (marginal prices are used for both the DAM and BM).

As can be seen from the results, execution of the dispatcher's instruction leads to a 5-percent increase in sales prices on the DAM plus BM for Generator 1, while Generator 2 that has acted contrary to instructions receives a decline in sales prices of 17.14 percent (i.e., this generator actually sells electricity on the BM for only $34 per megawatt hour (MWh) when using the weighted average prices principle or $59.5/MWh when using marginal prices. This result indicates the "penalties" and "premiums" on the BM.

Table 2. Settlements Options on the DAM and BM

Case 1			Generator 1	Generator 2	Consumer
Capacities	DAM	MW	20	10	30
	Actual	MW	15	15	30
	Deviation	MW	-5	5	0
Initiative			Dispatcher	MP	
Prices	DAM	$/MWh	**40.00**	**70.00**	**50.00**
	Ramp-Up	%	115	115	
	Ramp-Down	%	15	15	
	DAM+BM	$/MWh	**42.00**	**58.00**	**50.00**
Sum		$	**630**	**870**	**1,500**
Price Growth		%	5.00	-17.14	0
BM Price		$/MWh	**34.00**	**34.00**	**0**
			Purchase from BM	Sell to BM	

Case 2			Generator 1	Generator 2	Consumer
Capacities	DAM	MW	20	10	30
	Actual	MW	15	15	30
	Deviation	MW	-5	5	0
Initiative			Dispatcher	MP	
Prices	DAM	$/MWh	**70.00**	**70.00**	**70.00**
	Ramp-Up	%	115	115	
	Ramp-Down	%	15	15	
	DAM+BM	$/MWh	**73.50**	**66.50**	**70.00**
Sum		$	**1,102.5**	**997.5**	**2,100**
Price Growth		%	5.00	-17.14	0
BM Price		$/MWh	**59.50**	**59.50**	**0**
			Purchase from BM	Sell to BM	

Case 3			Generator 1	Generator 2	Consumer
Capacities	DAM	MW	20	10	30
	Actual	MW	25	15	40
	Deviation	MW	5	5	10
Initiative			Dispatcher	Dispatcher	MP
Prices	DAM	$/MWh	**40.00**	**70.00**	**50.00**
	Ramp-Up	%	115	115	
	Ramp-Down	%	15	15	
	DAM+BM	$/MWh	**41.20**	**73.50**	**53.31**
Sum		$	**1,030**	**1,102.5**	**2,132.5**
Price Growth		%	3.00	5.00	6.62
BM Price		$/MWh	**46.00**	**80.50**	**63.25**
			Sell to BM	Sell to BM	Purchase from BM

Case 4			Generator 1	Generator 2	Consumer
Capacities	DAM	MW	20	10	30
	Actual	MW	25	15	40
	Deviation	MW	5	5	10
Initiative			Dispatcher	Dispatcher	MP
Prices	DAM	$/MWh	70	70	70
	Ramp-Up	%	115	115	
	Ramp-Down	%	15	15	
	DAM	$/MWh	70	70	70
Sum		$	1,802.5	1,102.5	2,905
Price Growth		%	3.00	5.00	3.75
BM Price		$/MWh	80.50	80.50	80.50
			Sell to BM	Sell to BM	Purchase from BM

Example 2. As a result of a consumption increase (at consumer's initiative) Generator 1 and Generator 2 increase generation following the dispatcher's orders. This results in an increase of both generator prices (3 percent and 5 percent, respectively) and an increase of consumption price by:

- 6.62 percent using weighted average prices (**Case 3**)
- 3.75 percent using marginal prices (**Case 4**)

5.2.5 ANCILLARY SERVICES

As discussed in Chapter 4, the nature of the Armenian power system predefines use in the Capacity Market and payment for almost all available power plant capacity, eliminating the necessity of additional payments for capacity reserve. Other services that are usually paid for on markets can be included in the fee for the System Operator's services since they are rendered in a centralized manner.

5.2.6 ELECTRICITY TRANSMISSION

Payment for electricity delivery from generator to consumer is carried out through the transmission tariff and the distribution tariff if the wholesale market participant is connected to the distribution network. As previously mentioned, the points of sale/purchase are the generator nodes. Thus, consumers pay for network losses, meaning that losses are included in transmission and distribution tariffs, and therefore the existing regulations mainly will remain largely unchanged.

6. REQUIRED SOFTWARE

Settlements on hourly markets will require developing and installing special software both for participants and for Market Operators. The new software will extend the current practice of settling the market on actual monthly operating data. This chapter mainly focuses on the description of the software that must be developed for the initial stage of market reforms. When the market matures, the list of needed software will grow. For example, the development of software for intra-day trade could be delayed, but certain other software is critically needed at the initial stage. Stage-by-stage application of software development should pursue the following main objectives:

- Planning operating regimes of participants by hour for the DAM
- Conducting simulation estimates of market functioning with a variety of alternatives within the ETM to select the optimal one
- Parallel use of the existing model for financially binding settlements while the proposed model operates without financial responsibility to participants. Parallel operation is useful to prepare market participants to transition successfully to new market operations
- Transition to the new model

6.1 MONTH- AND DAY-AHEAD PLANNING

This software is designed:

- By market participants for automated filling of load shapes and calculating offers and bids for month-ahead planning and day-ahead planning
- For the System Operator to simplify the calculation of economic dispatch

For month-ahead and day-ahead planning by market participants (see Section 5.2), both historical (for month-ahead planning) and current (for day-ahead planning) metering data are required. For this purpose we need to develop separate software for coupling the Market Software database, in which metering data conforming to the market structure is entered, with the Alpha Center software (the metering system used in Armenia). All required data may be provided to market participants through the corresponding system of access to the market software.

Month-ahead optimized regimes for each participant are calculated using historical data from the metering system. Both market participants and the System Operator have functions, described in Section 5.2.1, that will require the use of new software.

For day-ahead planning, the market participant will make adjustments to its load shape for the planned day that it received as part of the month-ahead planning process; its day-ahead adjustments will increase the planning accuracy. Upon optimization of the power system regime, day-ahead planning load shapes for all market participants are received (**Figure 8**).

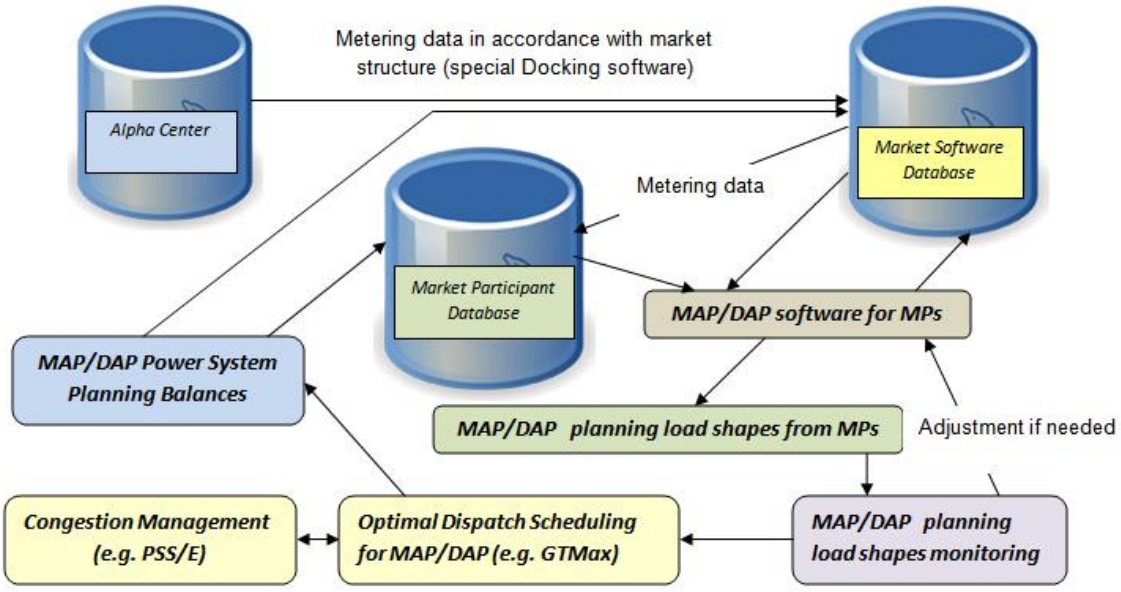


Figure 8. MAP/DAP Software

6.2 MARKET SIMULATION SOFTWARE

Market simulation software will be developed to enable consideration of possible changes for the market structure (see Section 4.1) and to provide the opportunity for test calculations, which will help to address the following issues:

- Determination of optimal partial pool structure by seasons
- Optimization of the bilateral contracts system
- Establishing optimal principles for DAM trading
- Determination of the best degree of pricing liberalization on the DAM
- Optimization of the balancing mechanism, including rules for deviations and choice of the appropriate pricing system
- Impact of partial liberalization of generation prices on average generation price and comparison with the existing market model
- Impact of large consumer entry into the wholesale market and the proper degree of market opening
- Assessment of the impact of new ETM implementation (first stage) on retail tariffs

There is no need to use month-ahead planning in this software (**Figure 9**). To do so would require more time and effort. It is sufficient to use only day-ahead planning load shapes for selected typical days by seasons.

The main task of this study will be the choice of the applicable principles for operation of the new market based on multi-optional calculations and answers to the above questions.

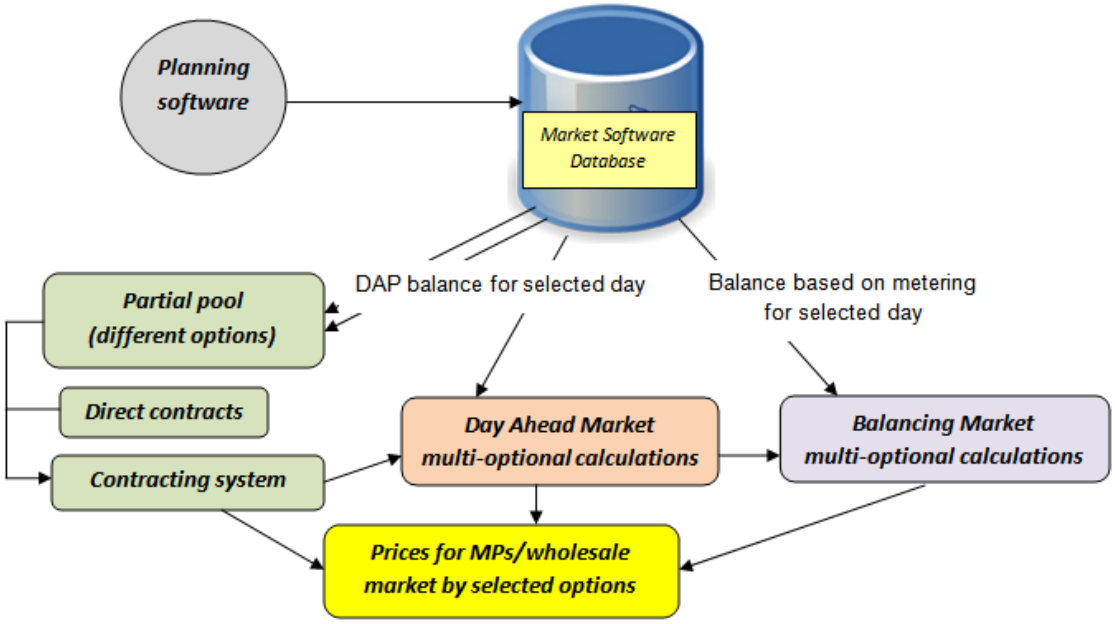


Figure 9. Market Simulation Software

6.3 SOFTWARE FOR PARALLEL PROCESS OF MARKETS OPERATION

The purposes of conducting parallel calculations for the new market model and the existing model are as following:

- Reduction of risks associated with transition to the new model. Parallel operation will reveal any price growth at an early stage, allowing corrective measures to be designed and implemented
- Preparation of market participants and Market Operators to operate in the new market structure
- Additional adjustment of some market operating principles based on actual results
- Determining the appropriate time to transition to the new model

During parallel operations, the results calculated in accordance with the new market model will not impose financial liabilities on market participants. Financial responsibility only attaches upon final transfer to the new model.

Development of this software will not start from scratch. Above mentioned planning software will be completely retained and most simulation software modules will be integrated into that software (**Figure 10**). This combined software will actually become the basis for the working software of the future.

Moreover, additional modules will be added to the combined software, such as Settlement and Dispatch Instructions. The existing modules will be enlarged and transformed. For example, the contracting market will move from a monthly basis and to a daily basis in the simulation software.

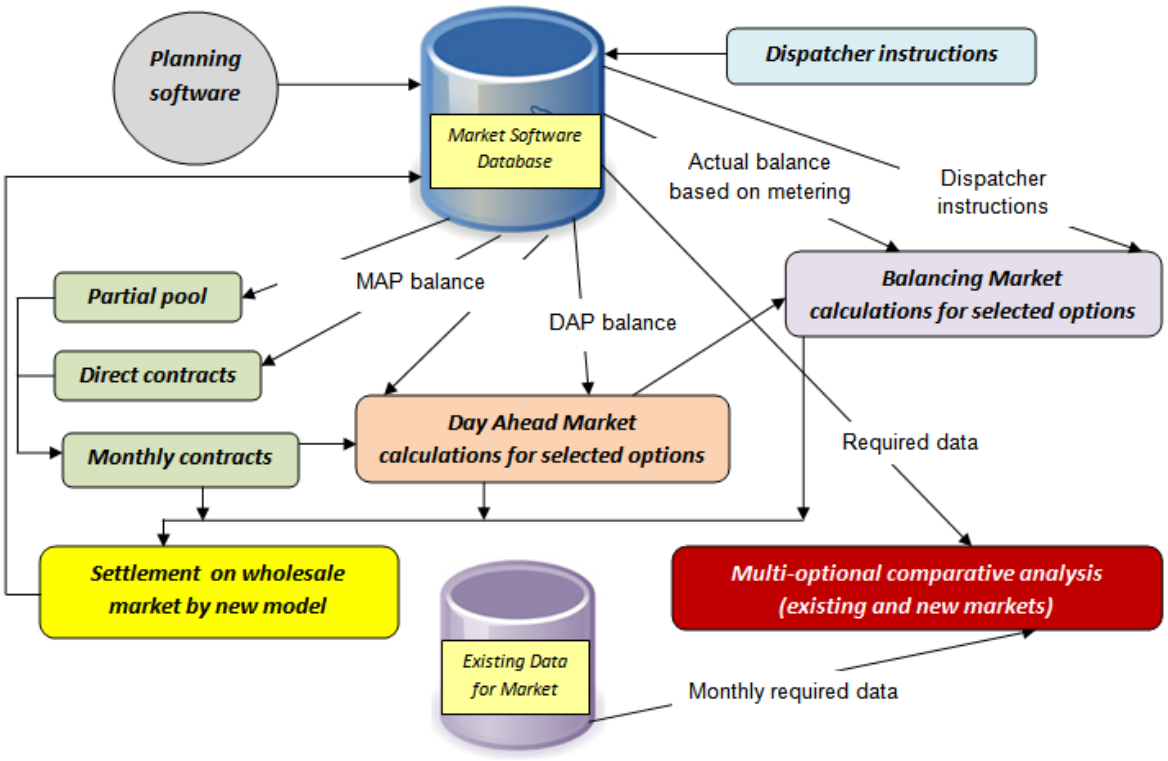


Figure 10. Software for Parallel Markets Implementation

7. KEY MILESTONES FOR THE FIRST STAGE OF REFORMS OF DOMESTIC MARKETS

Key milestones for the first stage of reforms of the domestic markets are as follows:

1. Development and approval of the Action Plan for transition to new electricity market,
2. Development of necessary amendments to the existing legal and regulatory framework, as well as their harmonization with the Georgian/EU legislation, including export/import transactions.
3. Establishment and approval of the detailed AEMM and ETM, including:
    - Structural changes, including the creation of a Market Operator, the creation of traders, and large customers entering the market
    - Defining the principles of market operation for each of the time segments of market trade (i.e., contracting, DAMs, and BMs)
    - The allocation of responsibility between market participants and end-users
    - Enhanced capabilities of trading with neighboring countries
    - Creating incentives for investments through the liberalization of the market and providing more clarity and certainty
4. Establishment of a market development WG to operate on a permanent basis, with representatives of the MoENR, PSRC, EPSO, and Settlement Center with the support of EC-LEDS team.
5. Initial software development:
    - Hourly planning based on offers/bids of market participants and Optimal Dispatch Scheduling
    - Simulation software for multi-optional principles testing using historical metering data
    - Software for parallel operation of the new market with the existing model without financial obligation
6. Implementation of multi-optional calculations and analysis to select the optimal principles of market functioning and ensure a smooth transition to the new market.
7. Development of new market rules and methodologies.
8. Capacity building for parties with market responsibility (e.g., presentations, training, roundtables).
9. Roadmap for transition to the new market.

This page is intentionally left blank.

8. ARMENIA-GEORGIA ELECTRICITY TRADE OPTIONS

Armenia-Georgia trade is an effective tool to increase efficiency of domestic markets. Since regional trade is not possible without achieving community of interests of all parties, it is important that domestic market reform be accompanied by steps to implement cross-border trade. This chapter will focus on the issues of implementing such trade.

The main elements of a cross-border trade design are the following: (1) bilateral contracts, (2) DAM trading, and (3) intra-day trading. Recognizing that Georgia and Armenia are both in the initial stages of transition to hourly markets, the third option is not discussed in this report. Trading shall be implemented on hourly basis.

8.1 BILATERAL CONTRACTS

Bilateral contracts are relatively long-term contracts (for not less than a month, as a rule) that can be signed between two market participants. Before individual contracts can be entered, an agreement between the System Operators of both countries is needed.

In Georgia, the legislation allows generators to export electricity during nine months of a year (except for winter months). The Armenian legislation restricts export opportunities of generators by the provision that only the most expensive electricity can be offered for export. The Armenian provision should be changed to allow exports that will not increase the price of generation for the domestic market. That change would attract a number of potential exporters and will require explicit auctions for transmission capacity. Sometimes the possible power flow is limited not by transmission capacity, but by the volume of purchase that also becomes subject to an auction. Moreover, current trade between Georgia and Armenia is possible only when the direction of flow is determined in advance.

To implement cross-border trade it is not necessary to have the Market Operator and DAM available in both countries. All terms and responsibilities are defined by the parties to transactions. System Operators check the technological feasibility and conduct explicit auctions and, only after that, may the contracts be signed. After commissioning of the back-to-back facility, participants will be able to sign contracts for both directions for as little as one hour and even with only one interconnection line available. The physical power flow (the difference between the contracted capacities) is regulated by Transmission System Operators. This mechanism is presented in **Figure 11**.

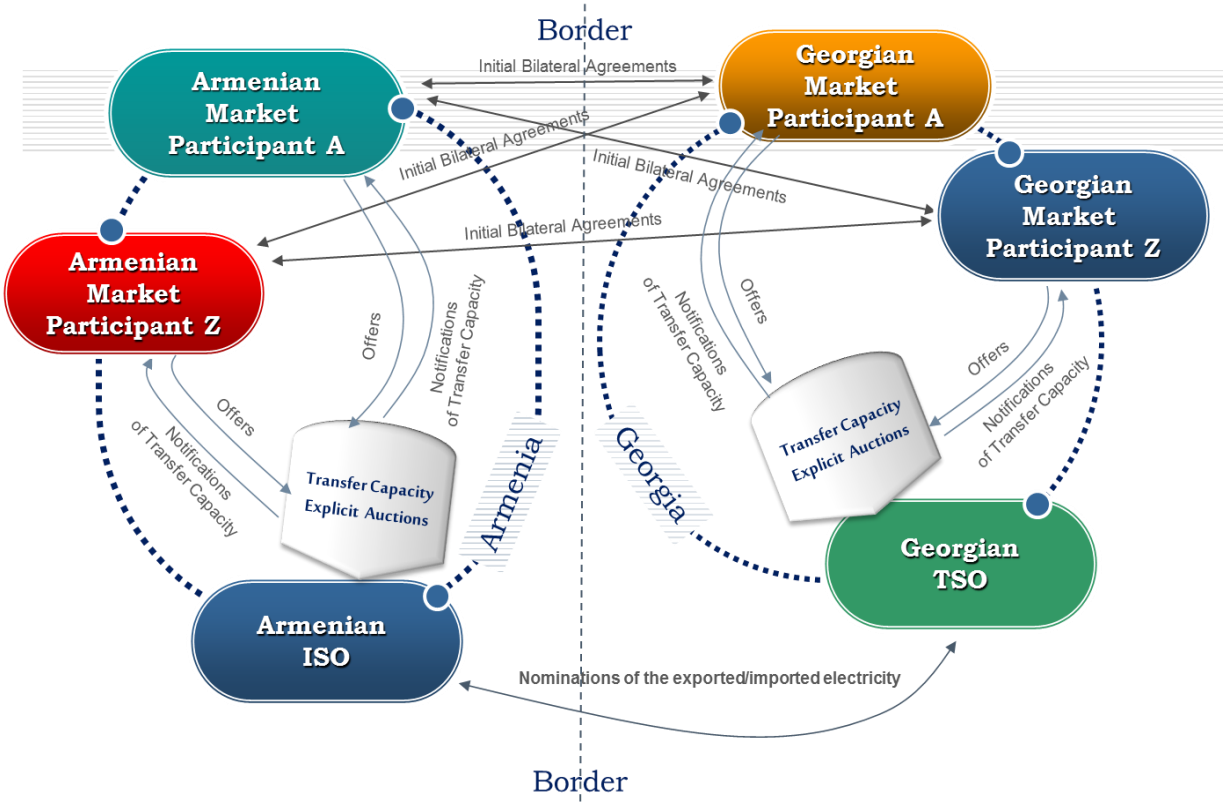


Figure 11. Bilateral Contracts Mechanism

8.2 TRADE OPPORTUNITIES ON THE DAM

Trading on the DAM can be carried out through two main options:

- Trading through the PX Node
- Market Coupling

The first option is currently being considered for trade between Turkey and Georgia (**Figure 12**), but, as of today, only future exports from Turkey to Georgia are under study.[8]

For this approach, it is not necessary to have a fully operating DAM in Georgia. Only a Market Operator or a responsible central body is required at the first stage

8. *Trade Opportunities Between Georgia and Turkey, Project Report 2*, Hydro Power and Energy Planning Project (HPEP), Deloitte, June 2014.

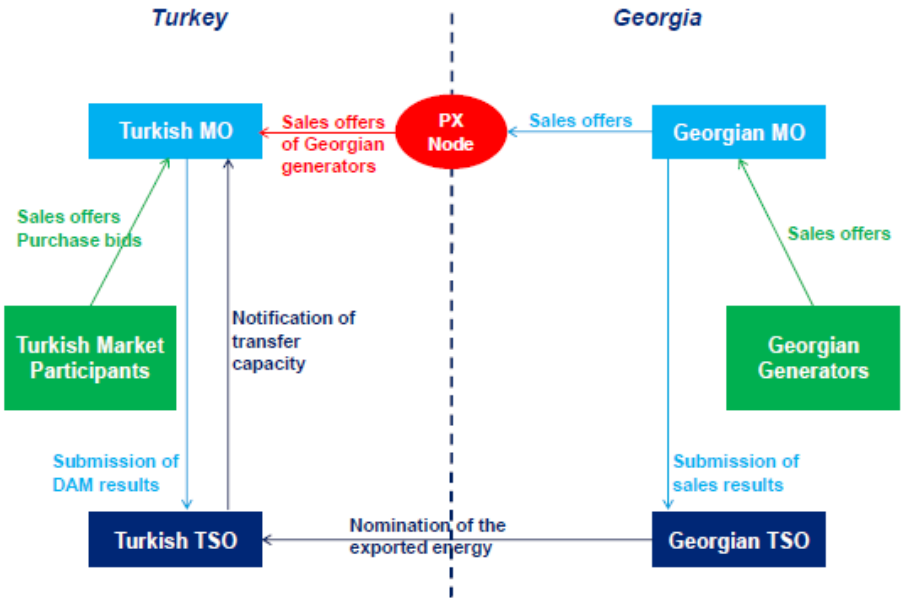


Figure 12. PX Node Mechanism Between Georgia and Turkey

8.2.1 PX NODE MECHANISM FOR ARMENIA-GEORGIA TRADE

Application of the PX Node mechanism in terms of Armenia-Georgia trade is simpler because no differentiation by price zone will be used in the markets of these countries due to small market volumes and local conditions. Nevertheless, established Market Operators (or responsible central bodies at the initial phase) will be needed for both countries. The transaction point between these countries will be the Armenia-Georgia border—this will allow having specific volumes of power flows and, more importantly, including losses, when balancing and settlements are done by actual regimes.

Application of such a mechanism will not be limited to participation of generators on one side only; it will allow selecting the most mutually beneficial trades. This rule should be stated in the Market Operator-to-Market Operator trade agreement subject to signature. With regard to Georgia-Turkey trade, this mechanism actually provides better access for Georgia to participate in already established Turkish markets, and trades would be conducted using the defined Turkish market rules, such as the BM.

Transition to the hourly market in Armenia and Georgia is not yet a reality; however, both countries are on the way to developing domestic market rules. The rules of the two countries need not be identical; although, as they are developed, issues of harmonization should be considered to provide a consistent regulatory basis for cross-border trade.

The concept of PX Node trading for Armenia-Georgia is shown in **Figure 13**.

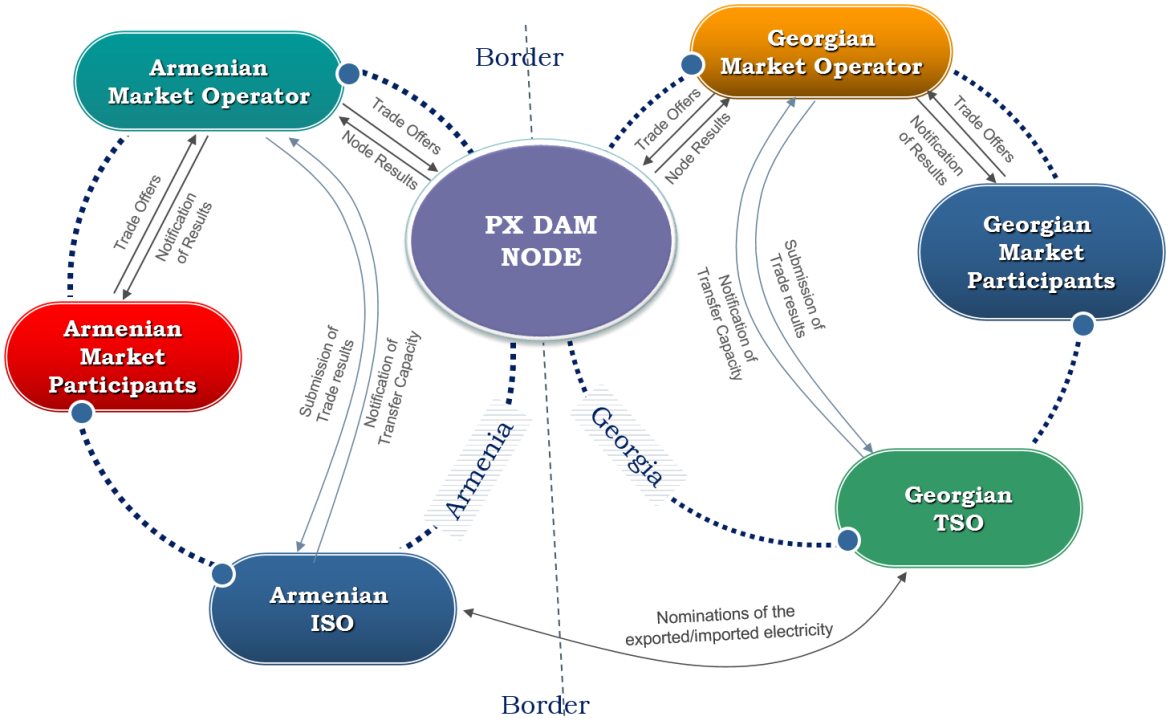


Figure 13. PX Node Mechanism Between Armenia and Georgia

To put this mechanism into operation, the following steps are required:

- Establishment of Georgian and Armenian Market Operators (or determination of responsible central bodies)
- Preparation of an Market Operator-to-Market Operator trading agreement that covers the details of the mechanism and responsibilities of both parties
- Defining operational procedures for market participants (e.g., offers, daily planning and scheduling, liabilities)
- Development (or purchasing or leasing) of the software that will be used by market participants to submit offers in Georgia and Armenia
- Enhancing coordination between the Market Operators and Transmission System Operators of both countries

As opposed to the Georgia-Turkey trade where acceleration of the trade process is critical because of the "idleness of the existing expensive interconnection," the development of Armenia-Georgia trade needs a period of two to three years for construction of a new interconnection and for the selection, development, and coordination of principles of optimal trade between the countries. This period is sufficient for reformation of domestic markets as well.

If the PX Node trading option is implemented without domestic DAMs, offers/bids of participants (in both countries) will be submitted to their own Market Operators, which should combine all the offers/bids into aggregated bids for purchase and offers for sale by each hour. Then the bids can be accepted or denied according to the Market Operator-to-Market Operator agreement.

8.2.2 MARKET COUPLING MECHANISM FOR ARMENIA-GEORGIA TRADE

The Market Coupling approach significantly differs from trading through a PX Node. Market Coupling is an efficient way of also utilizing the interconnection line capacity. Availability in both countries of DAM functioning on an hourly basis is a mandatory prerequisite for Market Coupling. Each market may function according to its own principles—each of the countries may have its own software to operate the market. Only the required information is sent to the coupling software, which must be common for both countries. Market results combined with the coupling results are announced to the market participants. The approach is illustrated as **Figure 14**.

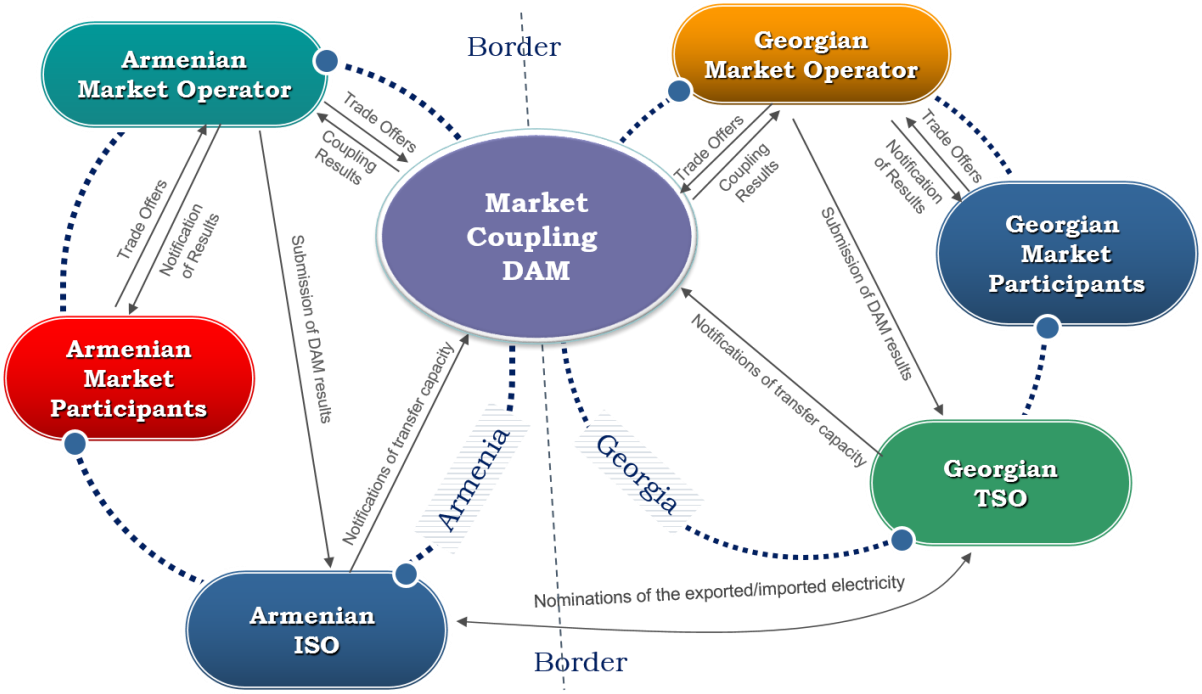


Figure 14. Market Coupling

The functions of the System Operators are the same—determination of transfer capacity, nomination and control of the power flow, etc. Steps that must be completed to make this mechanism operational are the following:

- Establishment of Georgian and Armenian Market Operators
- Preparation of the Market Operator-to-Market Operator Market Coupling agreement
- Definition of operational procedures (which can be different for domestic markets) for Georgian and Armenian participants
- Updating the necessary regulations corresponding to the defined operational procedures
- Development or purchase of DAM and settlement software (which can be different for each country)
- Development or purchase of Market Coupling software (same software must be used for both countries)

- Enhancing the coordination between the Market Operators and System Operators of Georgia and Armenia

This mechanism provides better transparency, gains maximum advantage of cross-border trade, and protects consumers of both domestic markets. For customer protection, Market Coupling may be superior to the automatic equalization of a unified regional market, which in any event is unlikely to be adopted in the near future.

To illustrate Market Coupling, below are specific simplified examples.

Assuming the internal DAM of Country 1 is defined by volume (V_1) and price (P_{DAM_1}) (**Figure 15**). As a result of bids for purchase by participants of Country 2 (suppose the prices are higher and no offers are available from their own generators), the total demand on the DAM increases and will be covered by the export from Country 1 to Country 2 (V_Σ minus V_1).

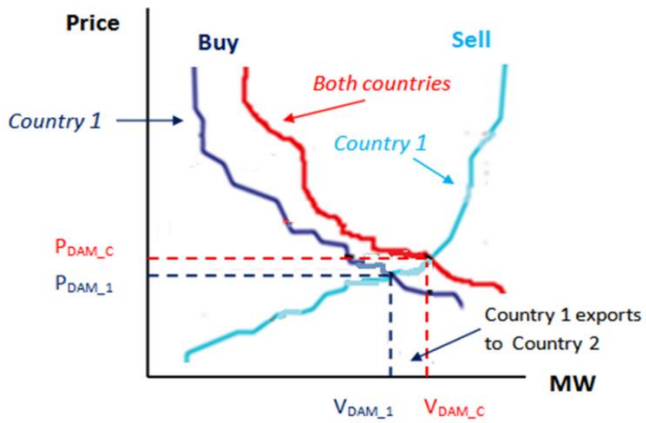


Figure 15. Export from Country 1 to Country 2 on the DAM

It should be noted here that if a unified market exists for both countries, the price on the DAM would increase to P_{DAM_C} (i.e., export from Country 1 would bring an increase of generation price for the domestic consumers of Country 1). That is true regardless of what type of price formation on the DAM (marginal or weighted average) is applied (see Chapter 5). However, the freedom to choose the price formation type in each country while applying the Market Coupling mechanism avoids the conflict between domestic consumers and exporters. Thus, for consumers of Country 1, the trade can be carried out at the price P_{DAM_1}. For exporters, P_{DAM_C} will be applied, which will provide the incentives for them. Purchase by the consumers of Country 2 is at the price P_{DAM_C}, which is not higher than prices of their bids on the DAM.

If cheap import is available from Country 2 (**Figure 16**), there may be an opportunity to decrease the price for domestic consumers of Country 1 with the increase of volume on the DAM.

The most common case will include participation of generators and consumers of both countries. However, in any case, each country will conduct its own internal settlement, and it will be able to ensure a price lower or at least equal to its internal DAM price while implementing export/ import transactions.

The mechanisms described in Section 8.1 (bilateral contracts) and Section 8.2 (DAM) may function in parallel, and trade for each hour may be carried out in both directions. This trade is based on planned regimes.

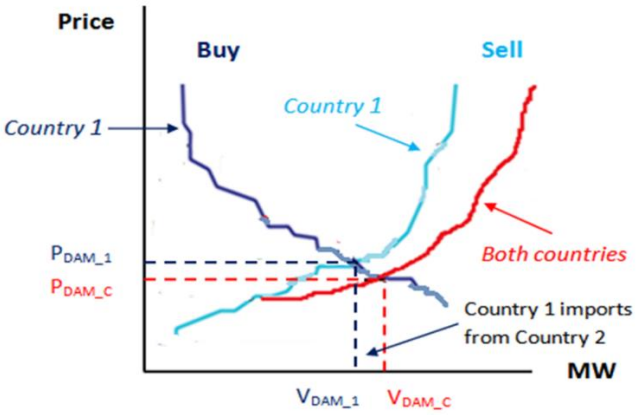


Figure 16. Import to Country 1 from Country 2 on the DAM

Actual regimes will differ from the planned regimes and, to perform settlements, it is necessary to have a way of calculating payments for deviations. If the DAM is not operating on domestic markets, it is highly probable the hourly BM would not be available either. Temporary balancing and settlement rules should be stated in the Market Operator-to-Market Operator agreement to apply a single price for imbalances in both countries for the same time interval. For example, if the DAM and BM are absent (these markets are not a mandatory requirement for implementation of the PX Node mechanism), it is unclear how deviations are settled in either country. A settlement price should be agreed on—a reasonable choice might be based on preliminary fixed prices by seasons at this stage for participants of both markets.

This mechanism can be improved while using Market Coupling, but to develop it, one should clearly define the principles of the daily trade between countries. The payment for deviations from bilateral contracts should be defined based on the approved principles of the BM. This issue can be better solved after final decisions are made on DAM options.

While cross-border trade is actually implemented, it is necessary to involve participants in the metering system and to develop metering rules.

In summary, as soon as the principles of cross-border trade organization described in Section 8.1 and Section 8.2 are defined, the following rules should be developed with coordination between the countries:

- Balancing rules
- Metering rules
- Settlement rules

Successful organization of cross-border trade requires availability of efficient power volumes as well as substantial work to ensure a legal framework for conduct of the trade. The following chapter focuses on the first required steps, which need joint efforts of specialists of both countries.

This page is intentionally left blank.

9. INITIAL ACTION PLAN TO SUPPORT CROSS-BORDER TRADE

To institute trade between Georgia and Armenia, a first step is to define and coordinate the principles and conditions of trade applicable for both countries. For this purpose, a joint WG is established, consisting of decision-makers and specialists. The WG should be directly involved in developing the market on a continuous basis. This kind of coordinated solution will provide a solid basis to identify necessary changes in legal and regulatory frameworks of both countries.

This Initial Action Plan identifies the objectives and principles of cross-border trade by both countries. If these principles are approved, changes and supplements to the existing legislations of both countries are recommended.

Although domestic market reform can make simulation calculations using historical metering data, that technique is not available for cross-border trade due to the absence of trade between Armenia and Georgia in recent years. Episodic power flows to isolated islands are not sufficient enough experience to consider. To substitute for historic data, decisions will have to be based on expert assessment.

The suggested Initial Action Plan contains the following steps:

1. Decision to use an hourly base at least for cross-border trading to be implemented in bilateral contracts and daily agreements in both countries.
2. Authorization of trading through bilateral contracts between market participants according to the mechanism described in Section 8.1 with explicit auctions such as Georgia's current auctions for export to Turkey.
3. Agreement between Armenia and Georgia on establishment of Market Operators (or responsible bodies at the initial stage) in both countries, enabling daily trading between countries. If the DAM is not established in domestic markets, cross-border trade could be carried out by the PX Node mechanism, as described in Section 8.2.1. This mechanism is now in development for possible trade between Georgia and Turkey.
4. Agreement between Armenia and Georgia on the introduction of the DAMs to the domestic markets of both countries (principles may differ for each country), allowing Day-Ahead Trade using the Market Coupling mechanism and implicit auctions. Compared to the PX Node, Market Coupling:
    - Is more clear and transparent for participants
    - Ensures maximization of trading and is an efficient way of using the capacity of interconnections
5. Selection of an optimal mechanism for Day-Ahead Trade. The recommended mechanism is Market Coupling, although the mechanism currently approved for Georgia-Turkey trade is the PX Node. Time is available to develop and introduce Market Coupling in Armenia-Georgia trade. The greater efficiency of Market Coupling (once demonstrated) may encourage Georgia-

Turkey trade to adopt it. PX Node trading has been considered mainly from the viewpoint of Georgian export, whereas Market Coupling may make imports possible with a reduction of prices in Turkey.

6. Choice of cross-border trade options and decisions and dates for their implementation (e.g., timetables for establishment of Market Operators, domestic DAMs, Market Operator-to-Market Operator agreements, coupling software).
7.
8. Conduct meetings to implement these steps where the Action Plan can be discussed and approved with deadlines. After decisions are made, it is necessary to start working on the details and developing the following foundations for cross-border trade:

    - Bilateral contracting principles
    - DAM mechanism implementation
    - Balancing rules
    - Metering rules
    - Settlement rules

10. CONCLUSION

Armenia's power market needs substantial structural changes. It is necessary to start with amendments to the existing legal and regulatory framework to harmonize with Georgian/EU legislation, especially relating to export/import transactions. Establishment and approval of a detailed AEMM and ETM is the next necessary step for starting reforms. The approval should include structural changes; in particular, the creation of a Market Operator; authority for traders and large customers to enter the market; definition of market principles for each of the time segments of trade (i.e., contracting, DAMs, and BMs); allocation of responsibility between market participants and end-users; enhanced capabilities of profitable trading with neighboring countries; and creating incentives for investments.

Initial software development is the basic instrument to make markets work. It is especially necessary to establish hourly planning based on offers/bids of market participants and Optimal Dispatch Scheduling. Moreover, simulation software should be developed to allow testing for multi-optional principles and provide parallel operation of the new market with the existing model (without financial obligations). Testing is important to give multi-optional calculations and analysis in order to select the optimal principles of market functioning and ensure a smooth transition to the new market. Based on those assessments, new market rules and procedures can be developed.

The suggested Initial Action Plan generally proposes two options for the organization of regional trade: a PX Node mechanism and Market Coupling mechanism. The joint WG of representatives of both countries must discuss and chose an appropriate option, taking into account future restructuring plans of their internal markets. Later, it will be necessary to develop bilateral contracts principles; DAM mechanism implementation; and balancing, metering, and settlement rules to accommodate cross-border trade.

To support internal market reforms and regional trade, given multiple challenges, the IRG team as a very basic step developed a Regulatory Concept for PSRC (see **Appendix 1**). The challenges are presented in Armenian *Gap Analysis with List of Major Market Challenges and Legal Barriers Report*; in the government of Armenia's middle-term perspectives[9] envisioning gradual liberalization of the Armenia power market, regional integration, and tariff reforms; and in the solutions provided in *New Market Designs for The Power Sector in Armenia*.

9. https://www.e-gov.am/u_files/file/decrees/arc_voroshum/09/qax35-12_1.pdf.

This page is intentionally left blank.

APPENDIX 1. REGULATORY CONCEPT

OF IMPROVEMENT OF THE ARMENIAN POWER MARKET AND IMPLEMENTATION OF NEW MECHANISMS

1. GENERAL PROVISIONS

The objective of this concept is to introduce new mechanisms in the Armenian power market by means of improving regulatory tools. These tools are aimed at gradual liberalization of the market and at opening opportunities of electricity trade with neighboring countries. The concept is developed in accordance with international best practices and adapted to the Armenian power market with priority to the requirement to protect, first of all, the domestic consumers' interests. It employs responsibility sharing mechanisms in generation and consumption markets, improves the tariff structure, promotes investment for construction of new energy efficient technologies, and contributes to the step-by-step limitation of regulatory frameworks.

The order of priority of introducing new regulatory mechanisms in the power market of Armenia by corresponding groups is provided below.

2. POWER MARKET STRUCTURE REFORMS

The Armenian power market structure must be improved and new regulatory mechanisms introduced in order to withstand further challenges and be able to take advantage of new opportunities. The required priority actions for the improvement of the power market structure are discussed in the paragraphs that follow.

2.1 GRADUAL LIBERALIZATION OF MARKET

Currently, the power market of Armenia is completely regulated both in generation and consumption sectors. The Public Services Regulatory Commission of the Republic of Armenia (PSRC), taking into consideration the power market developments during the last decade, believes there are good reasons to further steps for gradual liberalization of these markets.

Transformation of the power generation market into a competitive one is still modest due to big difference between generation prices in Armenia. Establishment of a fully competitive market could be more realistic, if a unified regional market is created. However, the limited opportunities for creation of a competitive regional market do not hinder the transition from "single-buyer (seller)" market model to the liberalized model thus providing opportunities for more number of participants to enter the wholesale market.

According to current market rules, planning of power generation and consumption volumes is carried out on an annual basis only for tariff regulation purposes. At the same time, neither the generating companies nor the consumers bear responsibility for sale and consumption volumes, and this may bring

disproportionate variations in tariff regulation. In international practice applied in the EU member countries and the United States, both generators and consumers share that responsibility. Both long-term and short-term markets, including month-ahead, DAMs, and BMs, are based on mutually born responsibilities.

The power market of Armenia is in need of installing such mechanisms of sharing responsibilities. The PSRC believes that by preserving the tariff regulation mechanisms and by installing a complex of new tools and approaches for allocation of responsibilities between generators and consumers, it is likely the transition to the month-ahead, DAM and Balancing markets. The generators on the one hand and the distributor, eligible consumers, newly created suppliers and traders on the other hand may participate in such markets.

Market structure reformation is a time-consuming process, and it is essential that interests of domestic consumers be protected at each stage of that process. For implementation of month-ahead markets and DAMs, it is necessary to develop an electronic site with appropriate software that will allow optimizing market risks and developing new market rules.

2.2 MARKET OPERATOR ESTABLISHMENT

The Market Operator is a leading force in any power market. Establishing this structure is a top priority for successful development of the Armenian power market. Considering that the Settlement Center is already acting as a licensed entity rendering services to the power market of Armenia and a state-of-the-art metering system is already available, PSRC consulting with the Ministry of Energy and Natural Resources (MoENR) will make amendments to the terms and conditions of the Settlement Center license and delegate to it all required authorities and resources complementary with Market Operator functions in accordance with international best practices. As a result, the Settlement Center, empowered with the authorities of a Market Operator, will represent a major driving force bringing new approaches to the market. The Market Operator in cooperation with the System Operator will develop additional mechanisms applicable to the domestic market and also for the development of cross-border cooperation within the region.

2.3 UNBUNDLING OF THE POWER SUPPLY AND DISTRIBUTION FUNCTIONS

Unbundling the power supply and distribution functions is one of the priority steps for development of a competitive market, even if these functions are completely or partially regulated at the initial stage. Setting tariffs for transit of electricity through the distribution network created, for the first time, an opportunity for customers to purchase electricity from other suppliers, including from importers and eligible generators directly. The first step has therefore been taken.

Supply and distribution functions should be unbundled at the legislative level. For the further development of the power market of Armenia, these functions should be studied to adopt the best international practices with results included in a new package of legislative regulations, particularly with regard to the Republic of Armenia Energy Law.

At the same time, there are separate organizations involved in electricity trading (hereinafter referred to as Traders) that operate in power markets of the European Union (EU) member countries and certain power markets of the United States of America. They do not provide power supply services, but they

contribute to the effectiveness of electricity trade both within the domestic wholesale markets and with the neighboring markets. A legal regulatory framework for the establishment and functioning of Traders as an institution also needs to be considered in detail in the process of developing the abovementioned legislative package.

2.4 UPCOMING IMPROVEMENTS OF MARKET RULES

As previously mentioned, improvement of the currently effective market structure is a gradual and time-consuming process. However, there are certain tasks that can be initiated right now. The following will be taken into consideration:

- The U.S. Energy Association provides assistance for the development of Power Market Grid Code and, till the mid of 2017, these rules planned to be approved
- Market Trade Rules are currently represented in various documents, however, they are not yet developed as a single document

Therefore, the PSRC considers it necessary to combine the Market Trade Rules and Grid Code and approve the first transitional rules for the market. As a result, they will become available and transparent for all interested parties, including investors. Within the framework of this document, it will be possible to introduce the first transition package of market rules regulating direct sales of electricity from cogeneration power plants and renewable energy sources to consumers and to focus on other opportunities for market liberalization.

3. DEVELOPMENT OF CROSS-BORDER TRADE MECHANISMS

For the efficient development of the Armenian power system, it is quite important to capture all the potential of regional trade with the neighboring markets. In this context, to successfully use all opportunities for electricity trade, a clearly defined rule for import and export transactions is needed, including new mechanisms for regulation of import/export functions through market rules that do not rely on licensing tools.

Simplifying the import/export rules will create additional advantages for electricity trade with Georgia, although will not reach the entire trading potential. That will come by organizing electricity trade on a day-ahead basis. Market Operators and System Operators of both countries would have to coordinate their operations; moreover, the rules should provide for electricity trade in two directions as well as appropriate electronic site and integrated software.

4. FURTHER IMPROVEMENT OF TARIFF STRUCTURE

Further improvement of the tariff structure is also a high priority issue for the PSRC since it is quite possible to additionally stimulate the development of the system through the adequate tariff structure.

It is highly recommended now to carry out new studies for the development of principles and corresponding methodologies on distribution of costs and investments between the tariffs for various voltage levels, as well as for further improvement of calculations of the defined values of the distribution network margin. The efficiency of two-part tariff (capacity charge and energy charge) for certain groups of consumers, as well as the nighttime and daytime tariffs, also needs to be reviewed in terms of their values and the hours of their application. In this regard it would be necessary to address the requirement

for setting new tariffs differentiated by seasons or hour zones, including tariffs for peak or under-loaded hours. The issue of reasonable tariffs for reactive and active power used by large commercial consumers should also be considered.

This page is intentionally left blank.

U.S. Agency for International Development
1300 Pennsylvania Avenue, NW
Washington, DC 20523
Tel: (202) 712-0000
Fax: (202) 216-3524
www.usaid.gov