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ENERGY MARKETS INTERNATIONAL

LOAD DISPATCH AND SYSTEM OPERATION STUDY FOR CENTRAL ASIAN POWER SYSTEM

TASK 1 – OVERVIEW OF CURRENT STATUS OF CAPS

TASK 2 – ASSESSMENT ON LOSSES AND OPPORTUNITIES IN ISOLATED OPERATION

TASK 3 – ECONOMICAL ESTIMATION OF BENEFITS OF JOINT OPERATION

World Bank

Developed by:

MERCADOS – ENERGY MARKETS INTERNATIONAL (SPAIN)

October 2010

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NEW DELHI
BEIJING

LOAD DISPATCH AND SYSTEM OPERATION STUDY IN CENTRAL ASIAN POWER SYSTEM

GLOSSARY

AGC – Automatic Generation Control

Bln - Billion

CA – Central Asia

CAPS – Central Asian Power System

CAR – Central Asian Region

CCCA UPS – Coordinating Council of Central Asia United Power System

CDC – Coordinating Dispatch Center

HPP – Hydroelectric Power Plant

Mln – Million

RES – renewable energy source

TPP – Thermal Power Plant

UES – Unified Electric System

UDC – United Dispatch Center

UPS – United Power System

USD – United States Dollar

1 INTRODUCTION

The main objectives of this short-term study are to provide a preliminary assessment of the opportunities and challenges in strengthening electricity dispatch and system operations across Central Asia. The key tasks include:

- Description of the current status of the Central Asia Power System (CAPS) (in terms of participants, flows, protocols, charges and settlements, intra-regional trade), paying particular attention to the critical events over the last year (2009).
- Identification of benefits of joint operation in CAPS, and losses in the case of independent power system operation.
- Preparation of preliminary SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis of joint/independent operation in CAPS.
- Identification of possible solutions and recommendations with particular attention to immediate opportunities for easing constraints or improving combined grid operation, without any major investments.

This report is based on the review of secondary information and discussions with stakeholders in participant countries. The intent is to highlight key issues and opportunities for further study or, where possible, immediate action. During this study, the Consultant also collaborated with USAID to coordinate on the past REMAP I study and upcoming REMAP II study.

2 SUMMARY

The power networks of Uzbekistan, Southern Kazakhstan, the Kyrgyz Republic, Tajikistan, and Turkmenistan constitute the Central Asian Power System (CAPS). This system was designed in the 1970s applying least-cost planning and sought to ensure security of supply to consumers through a jointly operated regional generation and transmission network. Present national borders were not taken into account. This produced, for all countries, a high level of interdependency on all of Central Asia's energy resources.

Water is a key element in the operations of this regionally integrated system. This stems from large hydropower plants that not only produce electricity, but also regulate the flow of rivers and provide water for irrigation. Historically, this integrated system was tightly managed; water was efficiently utilized for hydropower and crop irrigation. Fossil fuel based generation also contributed to power production, particularly when hydropower production was low in winter.

The disintegration of the Soviet Union resulted in the reduction of joint efforts to coordinate the operations of dams, water reservoirs, irrigated lands and fossil fuel generation. This integrated system is still partially managed as in the past, but separate decisions taken in each country are now significantly eroding and altering established practices, including the physical and technical parameters of the infrastructure. This is resulting in significant changes to the operations of generation facilities and network management.

The joint operation of CAPS, as examined in this report, is experiencing a dramatic decline. Out of the five original CAPS countries, only three members continue joint operations: Kazakhstan, the Kyrgyz Republic and Uzbekistan. Tajikistan and Turkmenistan have severed their electricity networks from the common regional network. The disconnection of these national systems, as discussed below, stem from a range of uncoordinated activity resulting in system emergencies and other power supply issues. In an attempt to insulate themselves from these events, all countries are attempting to increase the independency of their national power systems.

Network and Generation

Despite the disconnection of the regional transmission system from a legal point of view, CAPS continues to function in two areas: network coordination and generation sources, including agreements on the use of water and fossil fuel.

First, the power network continues to be operated under the terms of a 1998 legal agreement, the Parallel Operational Agreement, signed by all member countries. This agreement was originally developed to provide a legal basis for operational network rules, such as bilateral contracts, trading, balancing and ancillary services. In addition, the agreement indicates that technical rules must be followed that ensure safe and reliable network operations including maintaining reserves and appointing a system operator. Open access and cross border trading are also seen as essential for the **joint operation**[1] of the national and regional power systems. Other legal agreements detail the applied methodologies for working with other regional power systems, such as frequency control.

Second, intergovernmental agreements exist detailing fossil fuel supply and the use of water for irrigation and electricity generation. Agreements between Kazakhstan, the Kyrgyz Republic, Tajikistan and Uzbekistan detail summertime water volumes available for irrigation. The amount of compensation for this service, to be returned by downstream countries, is expressed in terms of fuel (natural gas, fuel oil, coal). Generation and physical power flow in the region are characterized by their seasonality. The Kyrgyz Republic and Tajikistan store water during spring when snowmelt occurs and then release water during summer, when irrigation is needed. Power production may be higher than necessary during summer because irrigation sets the volume of generation. This water release

[1] Joint (or integrated) operation of several power systems is the operation when:

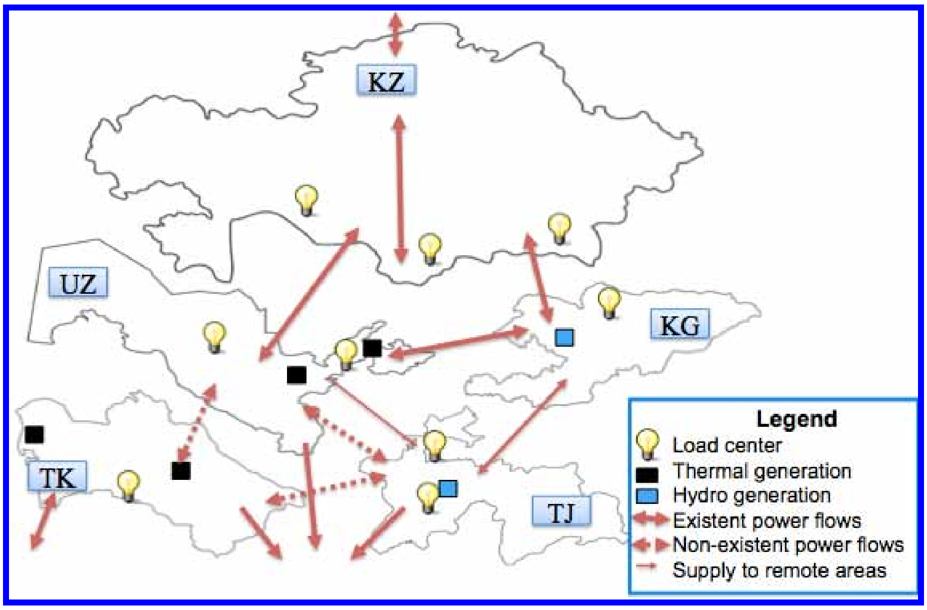
- The frequency is maintained equal in all power systems of the region;
- The operational regimes are coordinated;
- Power systems are interconnected between themselves by the active electricity transmission lines.

If the countries are operating their power systems jointly there is a possibility to define operational regimes that would optimize system costs (where the total system cost includes cost for grid operation and new investments in the network and in the generation side). The optimization mentioned before can be internally regulated or can be reached by the market instruments (when the dispatch is determined by bids of each particular power station.

Currently in the CAPS region there is joint operation of three countries (Kazakhstan, Kyrgyzstan and Uzbekistan).

aims not only to attend irrigation in the Kyrgyz Republic and Tajikistan, but also in the downstream countries. The excess of water that is not used for irrigation is stored to produce energy during the dry season (in winter). During these winter months, fossil fuel and/or power produced by fossil fuel generators in Uzbekistan and Kazakhstan are sent to the Kyrgyz Republic and Tajikistan. An important aspect of this cycle is if water is more fully retained in the reservoirs during summer, for hydropower use during winter, the result is less water for irrigation. This would impact power flows and compensation agreements for generation. The map below (see further explanation of existent and non-existent power flows in the Sections 3.4 and 4.4) details the location of generation sources and the current and past regional power flows.

Figure 1 - Central Asian Power System



Ensuring Security of Supply

The Coordinated Dispatch Center of Central Asia - Energy (CDC Energy), provides coordination services based on information requested and received from the national dispatch centers. These national centers take CDC Energy instructions into consideration for the daily operation of the power system. While CDC Energy has limited authority, it holds a central role within the operational framework of CAPS. This includes: evaluating the impact of new infrastructure on grid functions, reviewing bilateral schedules, operating the Automatic Generation Control (a system to control frequency and balancing power), hydropower and thermal generation output and the coordination of maintenance and system planning. Through these efforts regional security of supply in the transmission system can be properly balanced. This is particularly important in a region with national dispatch centers focused only on national markets, while generation – for most efficient operations – flows across borders.

The CAPS regional looped transmission system was designed to ensure a high level of security of supply, as mentioned above, and to appropriately handle the region's dispersed generation facilities. Hydropower and thermal power plants mirror the geographic distribution of natural resources in Central Asia. Therefore, it is important to assess the implications (and some current practices) on national and regional security of supply when the system is not operated through this regional design.

- The security of supply is reduced. This is indicated by power supply interruptions and the amount of non-served energy . This is becoming more common in CAPS, as some countries are unable to supply necessary power levels to the system. It is also a reason that countries are seeking to leave CAPS, as non-served energy is a significant problem, with negative social impacts, as well as causing unnecessary wear on the physical infrastructure.
- Security of supply is further impacted as power supply interruptions increase. The ability to recover from severe outages (such as those caused by unplanned outages of major generation or transmission facilities or natural disasters) becomes more difficult and expensive when countries operate isolated.
- Sub-optimal dispatch leads to an increase in operational expenses. For instance, countries with large thermal generation are spending more money on fuel to maintain active reserves in the system needed to cover daily peaks. In other cases, countries with significant hydro resources spill water in summer due to excessive levels of water. This is due to a lack of

water reservoirs and the ability to export, outside of CAPS, excess electricity. This results in wasted resources and lost revenue from any extra generation.

- Facilities for capacity and frequency regulation are not optimized at regional level, , but retained for national regulating services due to the uncertainty that neighbors will not maintain system stability. But isolated operation stems to much higher needs of regulating reserves, affecting both cost or security when these reserves cannot be provided internally.
- Due to different time zones, daily peaks are staggered across the region. However, the reduction in cross-border interconnections, limits electrical flows, and reduces the more efficient deployment of generation resources.
- It is well known that two systems sharing reserves need lower volume of spare capacity (for the same level of security) than in isolated operation. So there is a need to duplicate investments to ensure adequacy of supply. This results from insufficient system integration, which could enable the ability to share power in times of crisis. In the case of effective joint regional operations these investments could be shared between countries.
- Operational methods of dams used for power generation and irrigation are contentious because of the different uses of water, upstream and downstream. In the CAPS countries, as indicated above, these differing needs result in disagreement over how water is used. This issue is problematic as intergovernmental agreements over water use have not been revised for several years.

The analysis of CAPS highlights the heterogeneous generation mix in the region, and the seasonality of it. In a regional CAPS structure, there is the potential balance between a regionally integrated generation system and one divided by national borders. Based on security of supply criteria, there is incentive to support a jointly operated CAPS: significant hydropower potential (almost 100% of internal demand supplied by HPPs) in Tajikistan and the Kyrgyz Republic and the well developed thermal generation (more than 95% of energy produced by TPPs) in the rest of the CAPS.

The analysis shows that for electricity generation, in a joint operation, the Kyrgyz Republic, Tajikistan, Uzbekistan and Southern Kazakhstan can cover consumers' needs for the next three years. This is if imports from the neighboring regions, such as Northern Kazakhstan, Turkmenistan, and/or others are available. However, an integrated approach is necessary for these benefits to be realized – although this would be going against the grain of current efforts in all CAPS countries.

National Systems

Individual countries are now strengthening their own generation and transmission systems, but weaknesses persist. The current aim of all countries is to increase energy independence while increasing export opportunities to countries outside of CAPS. All five CAPS countries are looking to export power to countries such as Afghanistan, Pakistan, Turkey, Iran and Russia. This is despite most countries having difficulty reliably operating their own national power systems. Weaknesses include:

- Tajikistan cannot supply remote areas. The current infrastructure also cannot meet winter peak demand.
- The Kyrgyz Republic relies on the Uzbeks power system to supply consumers in the Northern part of the republic and two regions in the South.
- The Kyrgyz transmission network is used to supply the Fergana Valley in Uzbekistan.
- Uzbekistan, Turkmenistan and Kazakhstan are unable to cover the daily peak without regular service provided by the Kyrgyz Republic and Tajikistan.

Utilizing current interconnections in the Central Asian region is, as the modeling analysis shows below, the cheapest solution for reliably supplying all consumers in the region. A more local perspective, of how system reliability can be boosted to international standards, through joint operations, is expressed by CDC Energy: joint operation of CAPS is the only means to achieve the (N-1) reliability criteria.

For reasons[2] outlined above and in the full report, CAPS has declined as a jointly operated power exchange and regionally integrated grid. The following key attributes of current power exchange attest to the severing of the regional system mentioned earlier:

- The 500 kV interconnection lines, connecting Tajikistan with Uzbekistan, are switched off.

[2] Some reasons include: large volume of unscheduled flows, lack of a transit compensation mechanism, different levels of security, quality of primary and secondary regulation, etc.

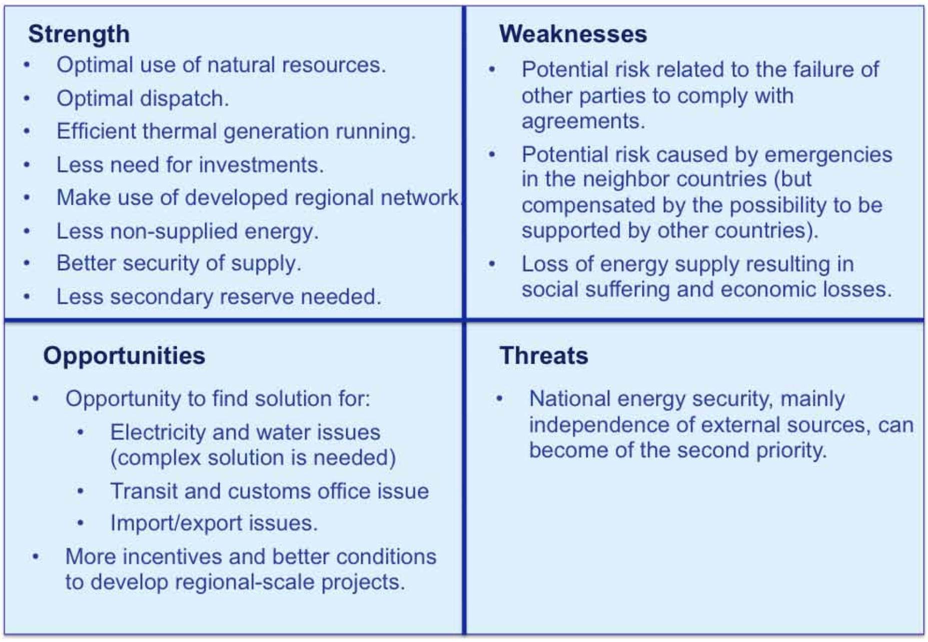
- Uzbekistan is supplying electricity to the remote areas in the North of Tajikistan, while the rest of the countries mostly engage in technical exchanges.[3]
- The Kyrgyz Republic and Kazakhstan are only trading electricity and regulation services;

It is important to assess whether this trend of disaggregation of generation and transmission assets is positive or negative for the region, as well as, for individual countries.

Benefits and Costs

A rigorous assessment can be done of an integrated or independent systems approach, by using a SWOT analysis and a modeling exercise. It is possible to assess how cooperative or non-cooperative activity may achieve the best optimization of the region's resources. The SWOT analysis indicates greater cooperation, on the level of the CAPS model, would provide the region with a higher level of security of supply over independent national systems. The strengths and weaknesses of integrated operations are shown in **Figure 2.** Here it can be seen that the CAPS system of regional operation of generation and transmission provide a number of positive effects for all the participants, overcoming any possible downsides. This SWOT analysis also displays the positive and negative effects of integrated operations, in addition to showing the external conditions that would assist or obstruct the creation of a regional power system.

Figure 2 - SWOT analysis.



Representatives of CAPS agree on the benefits of joint operation in the region. This is supported by developing a mathematical least-cost expansion model, involving electricity generation and demand. This is based on the nodal representation of all the CAPS countries. The results support the assertion that there are advantages for regional cooperation. The modelling results indicate if the CAPS countries operate their power systems jointly, more than $1.6 billion can be saved in the first three years of operation. This is due to optimal dispatch, with more efficient (compared to isolated operation) thermal generation production. The only condition for reaching $1.6 billion of cost savings would be to allow cross-border flows in the region. No additional investments are needed during the first three years of integrated operation.

The joint operation of CAPS increases the level of security of supply (this is measured as a decrease of non-supplied electricity in the whole region and in each power sector). Electricity that is not supplied results in damages of at least $200/MWh. Savings associated with joint operation are estimated to be more than $0.5 billion. Therefore, more than $2.1 billion can be saved during three years (2010-2012) in the case of integrated operations.

The analysis provided in this report demonstrates, from both a technical and economic prospective, joint operation is beneficial for all the participants. Rebuilding confidence in CAPS requires mitigation

[3] Technical exchanges - I.e. parallel flows to support in special conditions in the event that part of a country's power system that needs to be supplied from another country, etc.

of the negative effects perceived by members. A range of measures can be acted on for establishing a more collaborative and beneficial climate in CAPS. These can be organised in three stages: short, medium and long term horizon measures.

1. **Short-term and low cost measures**. These measures would partially solve the existing problems in CAPS. Efforts should be made to:

    - organize seminars and discussions of all involved stakeholders;
    - improve the area control scheme to reduce unscheduled flows,
    - develop and implement methodologies for assessment and settlement of deviations and compensation for transit services;
    - once solved the problem of unscheduled flows, coordinate a scheme to share regulating and security reserves
    - develop approaches for regional coordination in the case of power system failures and review of primary frequency control coordination.

    These activities will provide the necessary legal and regulatory basis for regional collaboration, thereby addressing the problems that encourage members to leave CAPS. This stage could be highly successful, as significant and measurable benefits arise from integrated operations. This can be achieved with very little investment. At the same time, this stage is crucial for rebuilding countries' confidence in CAPS; a failure to achieve this target may produce irreversible negative effects.

2. **Medium-term targets and intermediate costs measures**. This stage would aim to improve the supervision and control hardware, install commercial metering, and install software for daily dispatch, real time re-dispatch, post operation calculations, settlement of deviations and transit compensations. At this stage it is suggested to identify the requisite expansion of the regional transmission system that would optimize the joint operation of CAPS members, including transactions with neighbouring countries.

3. **Long-term targets and higher costs measures.** Reinforcement of the transmission and generation system, which involves long development times and significant investments (hundreds of million USD or more).

Short-term actions are suggested to be considered as a first priority. If they are successfully achieved the drawbacks for greater coordination identified and discussed in this report would significantly diminish. Thus, after a successful implementation of the short-term measures, the medium and long term measures in stages 2 and 3 would aim to further increase benefits of joint operation of the CAPS network.

3 HISTORY OF THE CENTRAL ASIAN POWER SYSTEM

Power networks of Uzbekistan, Southern Kazakhstan, the Kyrgyz Republic, Tajikistan, and Turkmenistan constitute the Central Asian Power System (CAPS). The system is designed on the principle of least-cost operations. There is significant regional integration of transmission and diverse generation systems. Water is an essential element for the regional power system as well as for irrigation. During the development of the power system national boundaries were not considered important.

After the dissolution of the Soviet Union, a legal agreement was signed in 1998 by the CAPS countries. This addressed the joint operation of the power system. The Coordinated Dispatch Center of Central Asia – Energy, was established to provide regional coordination and control. Further intergovernmental agreements have attempted to prevent disagreements from developing, mainly involving the integrated use of water for power production, irrigation and in the absence of hydropower - fossil fuels.

3.1 CAPS STRUCTURE

The design of the Central Asia Power System (CAPS) was developed in the 1970s covering five former USSR republics: Uzbekistan, the Kyrgyz Republic, Tajikistan, Turkmenistan and Southern Kazakhstan. The electrical backbone of the region is a 500 KV transmission loop connecting the countries. The objective, at the time, was the integration and optimization of energy resources within this looped system. This regional system sat within the Unified Electric System of the Soviet Union (UES). This was based on vertical integration of the energy sector. Transmission networks and generation sites were developed through centralized planning. The UES consisted of ten interconnected sub-regional networks called, United Power Systems (UPS).

The centralized planning process did not view the countries, which made up the Soviet Union, as independent states. Because of this, borders between countries were disregarded. This resulted in a system which developed irrespective of national borders, later resulting in generation units and service territories on opposite sides of national borders.

The UPS of Central Asia was CAPS. It was one of the few that had sufficient generation and transmission resources. This enabled it to maintain operational control and power grid standards without relying on other interconnected systems. For example, the Tajik power system consists of two separate parts. One was connected through the Uzbek transmission network. In Uzbekistan, the major share of the Surhandarya region was supplied by the electricity produced at Nurek HPP (Tajikistan). In turn, Farhad HPP and Syrdarya TPP located in Uzbekistan were supplying several Tajik regions.

Following the collapse of the USSR, the maintenance of centrally controlled energy systems also crumbled. Each power system urgently undertook measures to ensure energy independence; they sought to reach self-sufficiency in terms of power generation and fuel supply. However, each country was at a different starting point. Limitations in each country's energy resources meant the system became unbalanced. For example, countries with significant hydropower started discharging more water from reservoirs in the winter period, this caused imbalances in the previously established irrigation and summer power generation patterns. Optimal joint operation, within the independent power system, was no longer the first priority. Significant political disagreement arose in the region.

3.2 LEGAL BASIS FOR JOINT REGIONAL POWER OPERATIONS

A common understanding eventually developed that none of the power systems could independently provide efficient and reliable power when operated separately. In 1998 senior management from these national power systems signed the 'Agreement on Parallel (Joint) Operations of the Power Systems of the Republic of Kazakhstan, the Kyrgyz Republic, the Republic of Tajikistan, Turkmenistan and the Republic of Uzbekistan' in order to maintain parallel operations. All technical issues related to operation of the existing 500 kV grid and intersystem 220 kV transmission lines became subject to review and approval by the Coordinating Council of Central Asia United Power System (CCCA UPS). This consists of authorized representatives of transmission system operators (KEGOC from Kazakhstan, NESK from the Kyrgyz Republic, Barki Tochik from Tajikistan, Kuvvat from Turkmenistan and Uzbekenergo from Uzbekistan). These five CCCA UPS country members founded the Regional Coordination Dispatch Center – Energy, located in Tashkent. It functions as the first coordination level for Central Asia dispatch. The financing for CDC Energy is provided on a cost sharing basis. Additionally, each national power system operator maintains its own dispatching authority; this functions as a second level for dispatch operations.

3.2.1 PARALLEL (JOINT) OPERATION AGREEMENT.

All Central Asian power systems that remain signatories[4] to the 'Parallel Operation Agreement' (signed in 1998) are members of the CIS Power Council and participate in CIS Power Council activities. They adhere to concepts and principles formulated by the Council, in particular they agree to:

- Maintain a common set of rules for the operation of the electricity market based on bilateral contracts, centralized trading, real-time balancing energy market and ancillary services market.
- Follow a set of technical rules to maintain safe and reliable operation of national and the regional power system. Including maintaining reserves – or financially supporting others for maintaining reserves. Each country appoints a system operator for technical operations and for the coordination of cross-border power flows.
- Maintain a high level of system reliability in cross-border trading and flows.
- Maintain open access to the transmission system and transparency in monopolistic services (transmission and system control). Including transit flows for power exchange.

3.2.2 BASIC DOCUMENTS AND METHODOLOGIES FOR CAPS JOINT OPERATION.

The main documents that regulate the power system operation in the region are:

- Agreement on coordination of intergovernmental relations in the CIS power sector (1992) signed by all the CAPS countries. This is the foundation for the operation of the regional power system.
- Parallel operation agreements in the CIS (1998) signed by all the CIS countries.
- Agreement on energy transit in the CIS (2000) that was signed by all the CAPS countries, except Turkmenistan and Uzbekistan.
- Agreement on mutual assistance in the CIS in the case of power system failures (2002) signed by all countries except Turkmenistan.

Among other documents, the next set of methodologies determines the rules for parallel CAPS operations in detail:

- Rules and recommendations on frequency and flow regulation for CIS and Baltic countries (2007). According to established rules, the Russian power system regulates the frequency, the rest of CIS countries must agree on net power flows.
- Methodology for determining the required reserve for frequency and power flow regulation (2006). The step-by-step methodology provides the calculation of the primary, secondary and tertiary reserve for CIS countries.
- Methodology on evaluation of the transit services (2001). The transit tariff calculation was developed for CIS countries.
- Methodology for calculation of monthly deviations. At the end of each month all the commercial metering data is reported to CDC Energy. A CDC Energy representative has stated that according to the methodology, the unplanned power flows should be returned back during the current N or the next (N+1) period (month). Penalties should be applied if this is not done. In (N+2) period the amount of energy to be return is 20% more than the actual consumed during the (N) period. Starting from the (N+3) period, this energy volume increases to 1.5 times the original amount.

  The methodology for the mechanism should be able to provide a high level of consistency to regulate the power flows in the region. However, because of the seasonality of hydropower, Tajikistan used the system based on its own seasonal cycle. It would consume electricity in winter and not return it until the summer months when hydropower is plentiful.

The power exchange in CAPS is based on bilateral agreements where agreed regimes are determined. Agreed regimes, include two payment components: energy and generation capacity.

[4] Turkmenistan withdrew from the CAR Parallel Operation Agreement in June of 2003. This made Turkmen base load capacity unavailable for the CAR Unified Power System and forces Turkmenistan to regulate their system on their own without access to high speed hydropower regulation systems in Kyrgyz Republic and Tajikistan. It also limited the potential for any power trade with Turkmenistan as every PPA now requires lengthy transit negotiations with the Uzbeks.

The analysis indicates that Central Asian countries tend to reach bilateral agreements that include water, fossil fuel and electricity components. Therefore, agreed regimes are most prevalent. However, there are consequences for these agreements when cross-linkages occur. In situations where there is disagreement on water issues, electricity supply may be affected, or there can be a unilateral adjustment in the price of fossil fuels. The analysis indicates these agreements can cause political, social and economical instability in the whole Central Asia region.

3.2.3 LEGISLATION ON WATER ISSUES.

During the Soviet period, dams were built and the flow of the Syrdarya River became regulated. The irrigation system was developed based on the assumption that during the wintertime all reservoirs located on the Naryn River would be filled. During the summer growing season, the water would be released and used for irrigation purposes while electricity was a by-product of this process.

However, with the breakdown of the Soviet system, the use of the reservoirs changed. Due to the lack of fossil fuels in the Kyrgyz Republic and in Tajikistan, hydropower plants on the Naryn cascade started to generate electricity to supply customers in wintertime. Economic losses emerged downstream as a result of this alteration in flows. Socially and economically, Kazakhstan, Uzbekistan and Northern Tajikistan were all negatively affected.

Water management issues are now an important consideration for intergovernmental agreements. In agreements between Kazakhstan, the Kyrgyz Republic, Tajikistan and Uzbekistan they declare the summertime water volumes to be used for irrigation purposes. The amount of compensation for this service is expressed in terms of fuel (natural gas, fuel oil, coal). The fuel supply must be performed during wintertime from Uzbekistan and Kazakhstan to the Kyrgyz Republic and Tajikistan. Bilateral agreements, since 2005 have been the mechanism to regulate water, electricity and fossil fuel issues.

Until recently, the distribution of water resources of the Syrdarya River was performed according to an operational agreement. This agreement, part of the agreement on the management of the Naryn-Syrdarya reservoirs, is reviewed at the annual meetings of the Interstate Commission for Water Coordination of Central Asia, and is based on the Four-side Agreement from May 17, 1998 (signed by Uzbekistan, Tajikistan, the Kyrgyz Republic and Kazakhstan).

3.3 OPERATIONAL COORDINATION IN THE CAPS

Operational coordination and control over UES was based on the three levels of dispatch hierarchy: 1) the Central Dispatch Center of UES (now System Operator of UES of Russia) was the first level of dispatch hierarchy. It was responsible for the overall UPS operations; 2) United Dispatch Centers (UDCs) acted as a second level of dispatch hierarchy, in Central Asia – UDC of Central (Middle) Asia (Coordinating Dispatch Center – Energy) located in Tashkent, Uzbekistan; and 3) national dispatch centers constituted the third level in the hierarchy.

3.3.1 REGIONAL SYSTEM OPERATOR

CDC Energy, in its role as a regional system operator, ensures principles of joint operation are implemented in the day-to-day operations of CAPS (as discussed in the previous chapter). CDC Energy responsibilities are limited in comparison to other top-level control centers. The role of CDC Energy is to:

- Evaluate the impact of new and altered transmission and generation facilities on the interconnected grid. Identify potentially adverse effects and to suggest preventative or mitigating measures.
- Review the bilateral schedules, provided by the national system operators. This is done using a power flow model.[5] This ensures there are no transmission or other problems. If problems are identified changes to the schedules are suggested.
- Operate an Automatic Generation Control (AGC) system to control frequency and provide any necessary balancing power (not already provided by the individual national system operators). They do this by providing control signals to two large hydro power plants; one in the Kyrgyz Republic and one in Tajikistan.[6]

[5] The introduction of the recently acquired PSS/E model will enhance the reporting capability, but will not necessarily expand the scope of the parameters/data that were already being analyzed using different tools.

[6] According to our information the AGC system is currently disabled because of equipment malfunctioning caused by outdated technology

CDC Energy has guidelines on the amount (MW) of AGC for the hydro power plants. These vary depending on the configuration of the transmission system. The amount of AGC also includes an allowance for 250 MW of operating reserves. There is no separate payment for the operating reserves (or, for that matter, AGC capability (see next item)). A working group is attempting to develop agreed guidelines that would establish the amount and location of local operating reserve requirements. These would be in addition to the regional requirements.

- After the fact billing is the process used to allocate the amounts of balancing power provided and consumed. This process provides market participants/national utilities the ability to settle on a bilateral basis (CDC Energy does not perform any settlement or billing). There are no specific payments for AGC capability or, as indicated above, for the operating reserves, only for balancing electricity and for the regulating capacity.
- Monitors real and reactive power:
    - flows on the 220 kV and 500 kV transmission system;
    - output on the larger hydro and thermal units;
    - demand at certain nodes; and
    - schedule deviations.

  CDC Energy collects this data and sends it to the national system operators. There is not sufficient data for CDC Energy to calculate, by itself, total CAR regional-wide demand. To make this calculation, data is first transferred from the national system operators. This data is collected each hour in calculating national demand. Also CDC Energy monitors, via analogue telemetry, voltages at certain control points.

- Directs the national system operators to increase or decrease their aggregate generation in response to schedule deviations (they are not generation specific). Also directs contingencies and, when necessary, coordinates system restoration efforts.
- Coordinates maintenance outages for transmission and generation.
- Coordinates planning for regional transmission expansion.

3.3.2 National System Operators.

National dispatch centres are the lowest level in the hierarchy with direct subordination to CDC Energy. Under an agreed information schedule, (as discussed above) all requested data is sent to CDC Energy. In turn, the information for day-to-day operations of CAPS is shared with all the national dispatch centres. Previously national dispatch centres had to follow all issued recommendations. Now recommendations are not always considered by NDCs.

3.4 HISTORICAL POWER EXCHANGES IN THE CAPS

The table below illustrates the average power flows from 2000 to 2008. Discussed in more detail below are the **flows and key events** between countries on these lines.

Table 1 - CAPS electricity power exchanges – 9 year average (2000-2008).

		Power Flows To (GWh)				
	2010	**Kazakhstan**	**Kyrgyz Republic**	**Tajikistan**	**Turkmenistan**	**Uzbekistan**
Power Flows From (GWh)	**Kazakhstan**	X	0	2	0	0
	Kyrgyz Republic	1 642	X	223	0	516
	Tajikistan	70	63	X	0	561
	Turkmenistan	9	0	420	X	7
	Uzbekistan	0	88	705	5	X

Connections with Kazakhstan

The strong interconnection and the high flows of electricity between **Kazakhstan** and the **Kyrgyz Republic** are based on two 500 kV and four 220 kV lines. The Kyrgyz Republic has been supplying Southern Kazakhstan with energy and ancillary services. This covers its power deficit and the need for frequency and capacity regulation.

According to historical data, power flows between **Kazakhstan** and **Tajikistan** are relatively low. In 2008-2009 KEGOC (Kazakhstan) and Barki Tochik (Tajikistan) agreed on the volume and on the corresponding payment for energy withdrawn from the Kazakh power system, this is not reflected in the bilateral agreement. Currently Tajikistan has no unfulfilled obligations to Kazakhstan.

In 2000-2001 **Turkmenistan** was supplying around 9 GWh each quarter to **Kazakhstan**. Electricity was transferred through the Uzbek interconnection, the Serdar-Karakul substations. However, due to difficulties reaching agreement on the transit services this led to the severing of supplies to the Southern territories of Kazakhstan.

Reliability events with Kazakhstan connections

Southern **Kazakhstan** is connected to the **Uzbek** power system by one 500 kV line and two 220 kV lines. The transmission capacity of 500 kV line is equal to 1500 MW. Unscheduled power flows in the CAPS leads to the congestions of North-South connection and consequently to the cutoff of Southern Kazakh consumers. This is caused by triggering the automatic protection system. An example of this is the shut down on February 26, 2009 and the decision by **Kazakhstan** to switch to an isolated operational regime. In March 2009, the parallel operation of CAPS was reestablished.

However, in the autumn of 2009 there was a repeat of the unscheduled power flows and the tripping of the automatic protection system. As a result on October 24, 2009 it was decided to disconnect the 220-500 kV lines in Southern Kazakhstan. Currently, the northern part of Kazakhstan and Almata region are operating jointly with Russia, while the Chimkent and Djambul regions with CAPS. However, there are no agreements between Uzbekistan and Kazakhstan on the power supply.

Connections with the Kyrgyz Republic

Between the **Kyrgyz Republic** and **Tajikistan** power exchanges usually take place during winter periods when the Kyrgyz Republic covers winter deficit in the north of Tajikistan. Power flow from Tajikistan to the Kyrgyz Republic is mainly caused by the reimbursement of unplanned power withdrawals from the Kyrgyz power system.

The **Section 3.1** described the overall design of the system and how it was developed based on regional and not national characteristics. In accordance, transit services through **Uzbekistan** were essentially used to supply northern regions of the **Kyrgyz Republic**. In turn, the Kyrgyz Republic was supplying Uzbek consumers with cheap hydropower and frequency regulation services. Power flows from Uzbekistan to the Kyrgyz Republic were largely caused by the reimbursement of unplanned power withdrawal from the Kyrgyz power system.

Connections with Turkmenistan

According to a 2007 five-year intergovernmental agreement, **Tajikistan** would import each year, from **Turkmenistan**, 1200 GWh of electricity during the September-May period. Until the end of April 2009, energy was supplied to Tajikistan through the territory of Uzbekistan. In 2007 the export, based on a direct contract with Aluminum Plant TALCO, was conducted on a scheduled free capacity basis (mainly during the night). Winters 2007/2008 and 2008/2009 in Tajikistan were colder than average, even with the electricity imports from Turkmenistan, load shedding could not be avoided. In 2009 Tajikistan did not reach an agreement on transit services with Uzbekenergo. It should be stated, from a technical perspective, power flows from the **Turkmen** to the Tajik territory, were influencing the **Uzbek** grid in a positive manner. This was done by decreasing congestion and overload in the Western part of Uzbekistan, this resulted in an overall decrease in network losses. This could be considered a 'win-win' situation for all stakeholders involved. However, the Uzbekistan-Tajikistan (Surkhan-Guzar) line was switched off in November 2009 and it is now technically impossible to transport energy (discussed below). Tajikistan fulfilled all the financial obligations with Turkmenistan.

Connections with Tajikistan

Over the past two years there has been no agreement reached on the joint operation of the power systems of **Tajikistan** and **Uzbekistan**.

The Tajik power system, designed in Soviet times, operates on a seasonal basis; in the summer-time power is exported, while it is imported in the winter. In addition, significant hydropower production during spring and winter provides the additional advantage of supplying the water needed for irrigation purposes in Uzbekistan.

Previously, Uzbekistan was supplying 3 TWh/year to Tajikistan in the wintertime. In return, Tajikistan was providing Uzbekistan with hydropower (with an approximate volume of 2TWh/year) in summer. This contract on the power exchange is part of the general "water-electricity-fossil fuel" agreement (as explained in the section devoted to the operational and legal framework).

Reliability event with Uzbekistan-Tajikistan connection

In August 2009 Nurek HPP (Tajikistan) was operating under an agreed regime. However, it led to the overloading of the 500 kV line Guzar-Regar (Uzbekistan-Tajikistan). The automatic protection system was not activated and there was a failure at the Talimarjan TPP. The repair was financed by Uzbekenergo.

An incident in August of 2009 prompted Uzbekistan to declare in October 2009 its decision to leave CAPS. From analyzing this situation, there are two important ramifications. The first is this decision will have a large influence on security of supply issues in some regions of Tajikistan, the Kyrgyz Republic and Southern Kazakhstan. The second effect is that the Uzbek power sector will be strongly affected by withdrawing from CAPS. There now emerges a challenge to cover the daily peak, which can only be met by using Uzbekistan's own generation facilities (TPPs), these are not designed for peak loads. Previously peak generation was done by the neighboring countries' hydro capacities which could be quickly ramped up to meet high demand periods.

According to published data, at the beginning of November 2009 because of the accident on Nurek HPP 500 kV line Surkhan-Regar was disconnected. As a consequence, the line Naibabat-1 to Afghanistan was switched off as well.

On November 17, 2009, two 220 kV lines were disconnected that supply the Surkhandarya region in Uzbekistan. The reason for the shutdown was the technical breakdown of the Regar substation in Tajikistan.

Power exchange profiles in the CAPS clearly show the roles between participants: some of them were large exporters while others significant importers. As shown in the next Chapter, this tendency still remains; however, the trading volumes have significantly decreased.

4 CURRENT STATE OF THE CENTRAL ASIAN POWER SYSTEM

The complementary structure of the generation mix in the Central Asian region reveals opportunities for collaboration. Energy demand and supply projections show the Kyrgyz Republic, Tajikistan, Turkmenistan and Southern Kazakhstan able to meet demand for the next three years if imports from neighboring regions, such as Northern Kazakhstan, Turkmenistan, and others are available.

Countries are now strengthening their own generation and transmission potential, aiming for national energy independence and to increase export opportunities outside of CAPS. However, countries are still not able to reliably operate their own national power systems. Using current interconnections in the Central Asia is the cheapest solution to adequately supply consumers in the region. However, the exchange of power between CAPS countries has significantly decreased. A main priority of these countries is looking at new trading opportunities with Afghanistan, Pakistan, Turkey, Iran and Russia.

4.1 CAPS DIAGNOSTICS

4.1.1 INTRODUCTION.

Currently CAPS is an electricity grid that connects four Central Asian countries: Uzbekistan, Southern Kazakhstan, the Kyrgyz Republic and Tajikistan. These countries are largely different in terms of political order, economic development, reserves of energy resources, and natural and climatic conditions. In 2003 Turkmenistan withdrew from the Parallel Operation Agreement, and now operates independently. Among the reasons for withdrawal was the failure to reach agreement on transit services. This centered on the export of power from Turkmenistan to Kazakhstan through Uzbekistan.

Power sector assessment in CAPS.

Kazakhstan is the only country that has introduced an internally restructured electricity market with a separate transmission system operator. Tajikistan, Uzbekistan, Kyrgyz Republic and Turkmenistan still maintain centralized state owned systems that are not unbundled. The main electric utilities involved in CAPS are:

1. Kazakhstan:
   - KEGOC – Transmission System Operator
2. Uzbekistan:
   - Uzbekenergo – vertically integrated public electricity company – generation, transmission, distribution
   - SredAzEnergoSetProekt – transmission network design institution in CAPS
3. Tajikistan:
   - Barki Tochik – vertically integrated public electricity company– generation, transmission, distribution
4. Kyrgyz Republic:
   - NESK – transmission system operator
   - JSC Electric Plants – generation
5. Turkmenistan:
   - Kuvvat Corp. – vertically integrated public electricity company – generation, transmission, distribution

4.1.2 SECURITY OF SUPPLY ISSUES IN CAPS.

Security of supply is the major beneficiary in joint operations of power systems. In this Section the issue will be analyzed from three dimensions:

- Primary resources: security of supply includes the ability of the system to provide the necessary amount of resources for power production.
- Adequacy of:
  - Energy: security of supply includes the ability of the system to provide the necessary energy volume (MWh) on demand for customers;

  - o Production and transmission capacity: Security of supply introduces the ability of the system to provide the required power (MW) at any time and at any point in the network.
- Operational security is the ability of the system to resist sudden disrupting events (e.g. sudden disconnection of transmission lines or power stations).

4.1.2.1 PRIMARY RESOURCES

The distribution of natural resources in the region is uneven due to some parts of the region having significant hydropower potential, but barren of other resources; other parts of the region have well-developed thermal generation with scarce hydro resources, such as:

- Large coal reserves in Kazakhstan;
- Large natural gas reserves in Turkmenistan and Uzbekistan;
- The Kyrgyz Republic and Tajikistan have strong hydro potential, sufficient enough to provide ancillary services and low cost electricity for their neighbors.

In Kazakhstan, Turkmenistan and Uzbekistan thermal generation prevails but with a lack of flexible hydro resources. Therefore to cover peaks and changing loads they need to request balancing services from neighboring countries or invest in peaking power plants, as is done in Turkmenistan.

There is a lack of fossil fuel reserves in the Kyrgyz Republic and Tajikistan. For these countries, this is balanced by the large hydro potential that has not been fully exploited. The current operation of facilities in these two countries is marked by large seasonal variations. Only the Toktogul Reservoir (the Kyrgyz Republic) is operated as a year round facility with all the rest being seasonally managed. This highlights the strong dependence on natural conditions, especially precipitation. In order to secure electricity supply to the consumers during the dry periods (winter), countries will need to provide electricity from thermal generation. This can be accomplished by imports of fossil fuel or other electricity imports.

In analyzing the situation, **the unequal distribution of electricity generation sources**, as in the case of CAPS, serves as a clear indicator of the necessity of an integrated grid operation.

The major disadvantage for Kazakhstan and Uzbekistan, if joint operation were discontinued, would be disruption of water regimes for irrigation. However, taking into account the close interrelations between fuel, water and electricity in the intergovernmental agreements, the difference could be bridged, if the Kyrgyz Republic and Tajikistan adjust their power production, to satisfy irrigation needs of Kazakhstan and Uzbekistan.

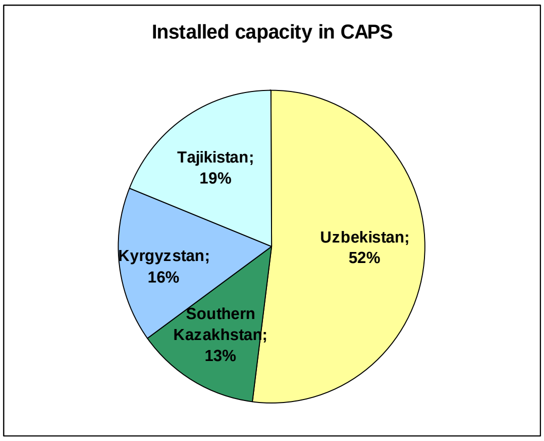
It should be stated that due to the unfavorable characteristics of the Kyrgyz Republic about 80% of energy resources including up to 59% of coal, and almost all gas and oil products, are imported for the operation of TPPs and CHP. The situation in Tajikistan is very similar, almost all fuel is imported.

4.1.2.2 GENERATION AND TRANSMISSION ADEQUACY

Installed generating capacity of CAPS is about 24 074 MW. The share of hydropower is about 40%, with the remaining generation capacity for the whole region represented by thermal power plants. The distribution of installed capacity in CAPS is shown in **Figure 3:**

- In Tajikistan and the Kyrgyz Republic the installed capacity is mainly represented by hydro generation;
- In Kazakhstan and Uzbekistan – by thermal generation.

Figure 3 - Installed capacity distribution in CAPS



In Tajikistan and the Kyrgyz Republic the backbone of the generation mix consists of highly flexible (with high storage capacity) HPPs. In other countries, the generation mix is represented by TPPs, which are mainly composed of base-load power plants. Due to this diverse generation mix between countries, and drawing from experience elsewhere, a joint dispatch operation would lead to the optimal utilization of these different types of power plants including the renewable hydro resources. The detailed description of the CAPS-5 power sector can be found in the Annex I.

The transmission network in the region is composed of:

- 1600 km of 500kV lines, and
- 1400 km of 220 kV lines.

The transmission network is managed by CDC Energy in Tashkent that carries out coordination and provision of technical support to the member states, as well as monitoring, control of demand and supply balance, and voltage and frequency control (discussed above). Frequency is usually maintained at 50 Hz.

Energy adequacy.

The graphical illustration of the energy adequacy of the CAPS-4 system can be seen in **Figure 4**. Due to the lack of corresponding data, Turkmenistan is not included in the current analysis.

Figure 4 - Energy balance in the CAPS-4 in 2009.

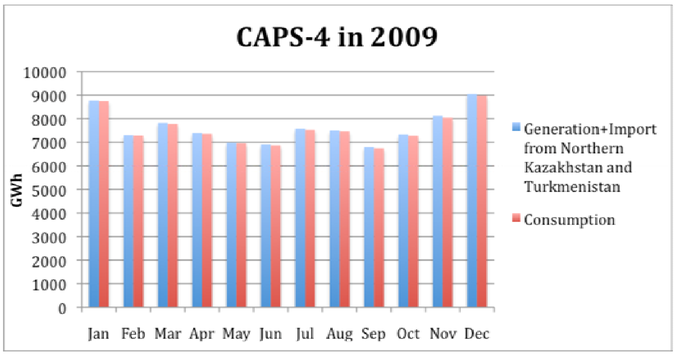


Figure 4 shows that the CAPS-4 countries can provide sufficient energy volumes to consumers if imports from the Northern regions of Kazakhstan and Turkmenistan are available. The import volume differs from 140 GWh in July to 780 GWh in December. This electricity is imported mainly to cover the deficit in Southern Kazakhstan (see Annex I).

In March and April last year power flows from Turkmenistan took place. The total import volume from Turkmenistan during those two months was close to 700 GWh and was a part of the electricity supply agreement between Turkmenistan and Tajikistan.

In the next two to three years several new generation units are expected to be commissioned:

- 2012 – 220 MW at Sangtuda-2 in Tajikistan,
- 2012 – 300 MW at Moinak HPP in Kazakhstan, and
- 2013 – second unit of 190 MW at Kambarata -1 in the Kyrgyz Republic

According to the available information, new gas turbines are planned to be constructed in 2013-2014 in Uzbekistan. However, it is highly realistic that only 710 MW of new hydropower can be expected in the next three years in the four countries of CAPS.

Based on the import data for 2009, the monthly average import volume is equal to 800 GWh. This energy deficit cannot be covered only by new hydropower plants that are to be commissioned (even if the load factor for those power plants is considered to be equal to 0.5 at the best, then the total monthly generated energy would be 256 GWh). By making this simple analysis, the necessity of continuous imports to the region and the need for operational interconnectors within CAPS can be confirmed, especially if demand is expected to grow in the next several years.

Generation and transmission capacity adequacy.

The transmission network in the CAPS region is a radial-ring circuit. The design of the existing grid aims at covering regional demand and at providing import-export opportunities to the countries.

Matched peak demand in CAPS-4 that took place in 2009 is equal to 15 738 MW, when the total installed capacity corresponds to 24 074 MW.

Considering that 7 336 MW of installed capacity should be enough for reserves it is important to consider that **generation capacity and transmission/distribution networks are of significant age**. Most equipment is from the Soviet period and has not been upgraded and/or repaired for a considerable period. According to the opinion of CDC Energy specialists, (N-1) reliability criteria can barely be reached, and this is only possible if CAPS is operated as a joint system. There is a strong need for investment, such as in generation and in transmission/distribution facilities, depending on the country. Under current operations the (N-1) principle is impossible to reach.

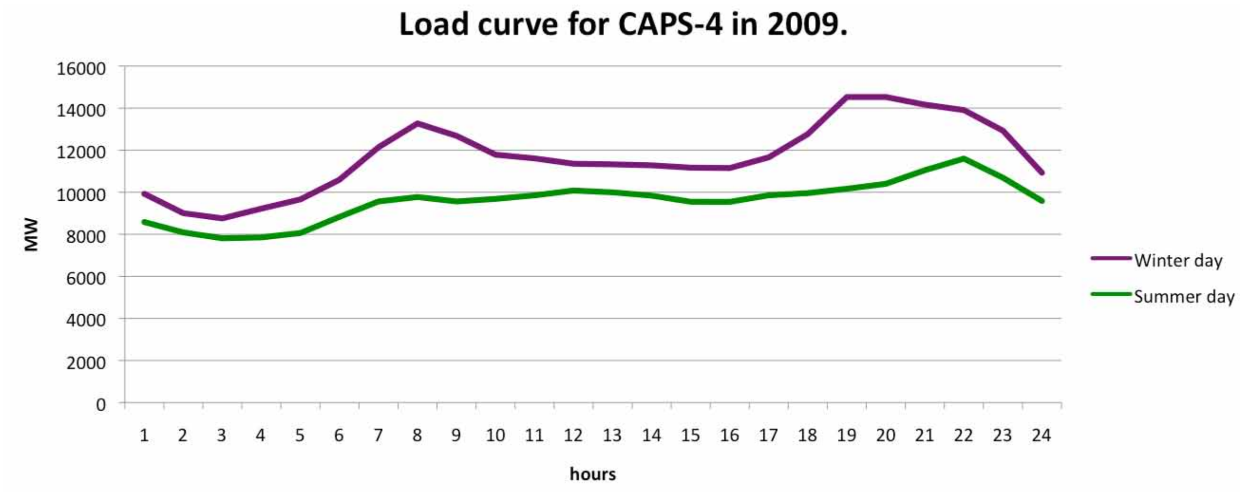
According to the country data (see Annex I) generation **capacity is unequally distributed** in the region and the transmission network was developed in order to satisfy regional (not national) demand, some of the CAPS countries cannot cover domestic demand with their own facilities:

- Uzbekistan, Kazakhstan and Turkmenistan cannot cover their daily peak demand because of the lack of flexible generation capacity
- Tajikistan:
    - cannot supply remote areas due to the lack of transmission capacity and
    - cannot fully cover demand in winter because of insufficient hydro generation available in winter and due to the lack of transmission capacity
- The Kyrgyz Republic cannot satisfy demand in the North of the country and in some parts of the South because of the lack of transmission capacity

Another issue that has to be pointed out is **the seasonal hydropower production in the region**: in the summer period hydro production is higher than in winter due to melting snow.

At the same time**, demand in winter** is approximately 2 833 MW **higher than in summer** (see **Figure 5**).

Figure 5 - Aggregated load curve for the CAPS-4 in 2009.



There is high demand in winter, but there is also a lack of electricity generation in the sub-regions of CAPS during this period. Considering the high deterioration of equipment in the region, the amount of remaining capacity, dramatically decreases when considering how much is needed for exceptional demand variation and unplanned outages – the capacity that system operators need to cover with additional reserves.

After the 1990s electricity consumption in all the ex-Soviet republics collapsed, this was down to the shutdown of the large industrial sector; this caused a lack of base load in each country's load profile. Industrial production, after 20 years has still not returned to pre-1990s levels. This leads to an even higher need for investments to increase extra capacity dedicated to the frequency and capacity regulations in the CAPS. Such countries as Uzbekistan and Kazakhstan currently negotiate the frequency and capacity regulation services to cover daily peak demand.

Making use of the existing interconnections between CAPS countries is a viable solution. The appropriate levels of security of supply can be reached without any large investments in generation and transmission capacity.

4.1.2.3 OPERATIONAL SECURITY.

Current network operations in Central Asia are not as stable as they once were. During the period November 1, 2009 – May 25, 2010, the automatic protection system was activated 49 times and one emergency situation was declared when the North-South transmission line in Kazakhstan was disconnected. The North-South connection in Kazakhstan experienced the activation of the automatic protection system 923 times and experienced 12 disconnections, for the period of November 1, 2008 – May 31, 2009. During the period November 1 – May 31, 2008, the automatic protection system was activated 1 834 times, along with 18 disconnections that lead to the CAPS-4 isolation.

According to statistics, and as discussed above, unscheduled power flows (withdrawals from the neighboring power system in CAPS) resulted in most of the disconnections and a high number of activations of the automatic protection system. Among other cases is inopportune loading of power stations, or the emergency shutdown of power units. This can be caused from unscheduled power flows as a result of ill placed incentives in the present power regime. As explained above, this is from the 'power debt practice' that allows the delayed return of electricity withdrawn from the neighboring power system. Taking into account the seasonality in electricity generation in some parts of the CAPS, this agreement provides additional incentive to not meet a pre-agreed regime and to withdraw power.

Withdrawal from CAPS

The ongoing problem of system deviations have led to two major CAPS members Kazakhstan and Uzbekistan declaring in 2009 their intention to operate their systems independently from CAPS. Reasons behind this declaration include the absence of international agreement, lack of close political cooperation and mutually beneficial partnership between the Central Asian countries. Efforts are now underway to build nationally independent systems. A North-South internal transmission line was recently completed in Kazakhstan, while there are transmission lines in Uzbekistan currently under construction (500kV line at Fergana, line Surhan-Guzar, and two more lines of 500 kV).

Construction of secure infrastructure

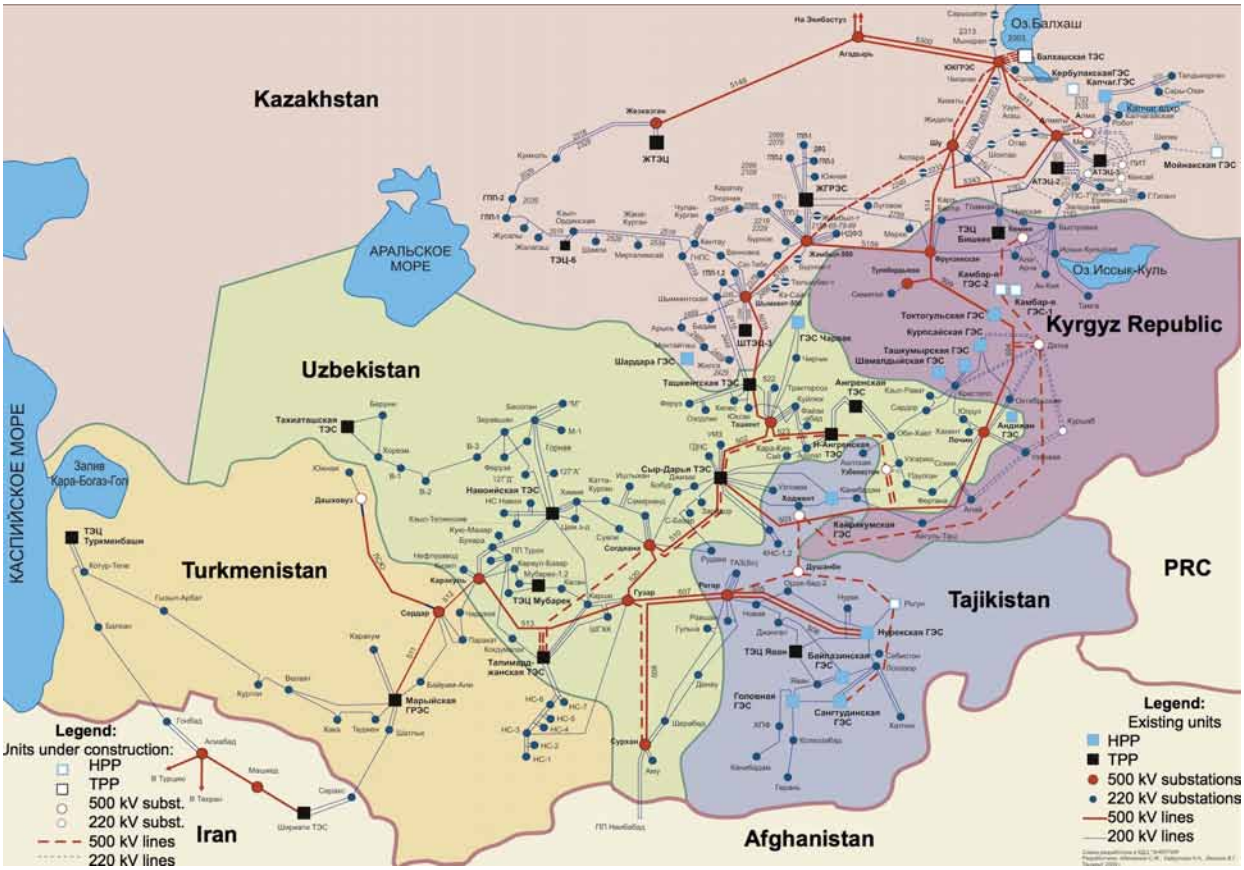
Despite new investment into the electricity transmission sector, network restrictions in CAPS still exist because of the lack of transmission capacity. This happens largely in the sections of the Kyrgyz-South Kazakh interconnections and leads to the need for power grid restrictions in the Northern region of the Kyrgyz Republic, and in the Almaty node in Kazakhstan.

Among other restrictions, the delay in network construction should be mentioned. Construction was planned of a 220 kV double circuit transmission line at the Kristall s/s – Yulduz s/s section. However, only one circuit line was developed. This leads to the 80-100 MW locked capacity at the lowest level of Toktogul HPP cascade.

According to the opinion of specialists from the CDC Energy, analyzing the current system indicates that (N-1) reliability principle can barely be reached in CAPS.

An important issue now emerging is the building of automatic protection systems at several locations. The CAPS was developed as an integrated power system, where all countries operated in a joint regime; the automatic protection system was designed correspondingly. Nowadays, countries are expanding their own national generation and transmission systems. However, the introduction of new infrastructure in one country can lead to overloads spilling into the region's (and other countries') older lines, which are not taken into account during these upgrades; this results in problems with the automatic protection systems in other areas of CAPS. As an example, the North-South Kazakhstan connection should be mentioned. It was constructed without consideration of the automatic protection control system, nor the automatic regulation of frequency and capacity.

Figure 6 - Central Asian Power System



Isolated planning

Tajikistan is now commissioning new transmission capacities, as well. As a consequence, substations in CAPS also need to be modernized. However, at present there are no mechanisms that would obligate the Kazakh and Tajik sides to pay for broader infrastructure upgrades - or likely disruptions to the wider transmission system. Under the former system, there were procedures in place for preventing system disruptions and instability. The SredAzEnergoSetProekt institution was responsible for regional network planning in CAPS, and in upgrades to the power network, providing affected parties with particular recommendations. However, currently there is no mechanism or institution to review the proposed plans for the construction of new facilities. Through this analysis it can be determined that countries are making investment decisions independently without fully considering the impacts on the broader regional system.

Joint planning

Theoretically, from an environmental, social and economical perspective, the development of a regional power sector is more sustainable, if the power system is jointly operated. From this perspective, it is viewed that the unique Power Sector Development Plan needs to be developed at the regional level. Some regional movement is underway, it was proposed by CDC Energy to submit the National Power Sector Development Plans from each country to develop a joint plan. A unified regional plan should include both national (increase of energy security and security of supply, etc) and regional (reinforcement of the network and automatic system, installation of additional transformers, etc) interests, as well. Until now only Kazakhstan and Uzbekistan have provided CDC Energy with a power sector development plan from 2015-2020. In the Kyrgyz Republic and Tajikistan these strategies are still under development.

Finally, it is essential to mention that because intergovernmental general agreements are widely used in the Central Asian countries a high level of dependence between countries, especially in water and electricity sectors is created. It appears that the Uzbek and South Kazakh power systems are essential for providing stable operations in the Kyrgyz Republic and Tajikistan. There is a strong dependence on the position of the Kyrgyz Republic and Tajikistan in solving water issues that represent a general agreement along with electricity. Therefore, secure operations and a high quality of electricity supply to CAPS consumers strongly depends upon the willingness to collaborate and to find a beneficial equilibrium of interests for all parties at the political level.

4.2 RECENT LEGAL BASIS DEVELOPED FOR JOINT OPERATION IN THE REGION

System Operators of Kazakhstan and Russia at the end of 2009 signed an agreement that determined the rules for monitoring hourly power flow deviations, arrangement of daily power exchanges, and reconciliation of commercial metering data. Mutual services, such as frequency (capacity) regulation provided by Voljskaya HPP (Russia) and electricity transit through the Kazakh grid, that were previously based on barter, switched to a commercial foundation. Further in 2010 Kazakhstan signed an agreement with Russia for parallel operations. In the agreement the volume of allowed hourly deviations is stated[7]:

- 250.718 MW for the period: May 1, 2010 – September 30, 2010;
- 300.718 MW for the period: October 1, 2010 – April 30, 2011;
- 200.718 MW for the period: May 1, 2011 – September 30, 2011;
- 300.718 MW for the period: October 1, 2011 – December 31, 2011;
- 250.718 MW for the period: January 1, 2012 – April 30, 2011;
- 150.718 MW for the period May 1, 2012 – September 30, 2012;
- 250.718 MW for the period: October 1, 2012 – December 31, 2012;
- 150.718 MW starting from January 1, 2013.

Drawing from the Coordinating Dispatch Center (CDC Energy), the deviation volume should be shared between Kazakhstan and the rest of the Central Asian countries. It is expected that Kazakhstan can rely on half of this volume; the rest will be divided among the Kyrgyz Republic, Uzbekistan and Tajikistan. Kazakhstan pays to a Russian counterparty for the agreed deviations according to the balancing market price in Russia. As there is no market for electricity in the rest of the Central Asian region, hourly prices cannot be directly passed on. In order to facilitate the decision making process, it is expected that Kazakhstan will negotiate only with the Kyrgyz Republic, reaching agreement on the deviation volumes and prices with Uzbekistan and Tajikistan.

Currently, the secondary frequency control in the region is provided by Russia. However, power flow deviations from the agreed regime are not permitted. Therefore, to avoid assigning the whole task to Russia, CAPS countries intend to obtain required frequency regulation in the region by itself: those who are interested in regulating services are either contracting or negotiating with neighbors who have the ability to provide these services.

In addition to the agreements signed by the CAPS countries, each country aims to develop contractual relations with other countries in the region. In the case of Uzbekistan, the provision of regulating services for energy is based on an intergovernmental agreement with Tajikistan and a bilateral contract with the power system of the Kyrgyz Republic.

4.3 CURRENT OPERATIONAL COORDINATION IN THE CAPS

The operational coordination practices applied in the region have changed following the increasing level of disintegration. CDC Energy still maintains its main responsibilities. However, according to the opinions of the country representatives, its role has switched from direct operational coordination to an advisory role to the national dispatch centers in CAPS. Data exchange between dispatch centers is still functioning through CDC Energy; data from neighboring power systems are also collected. Trade still occurs even considering that presently there is no exchanged power between some CAPS countries, in addition to the significant decrease in import-export activities within the rest of the region.

A common feature of the Central Asian countries is the aging hardware (more than 20 years-old) and software equipment of the National Dispatch Centers and of CDC Energy. Only Kazakhstan is an exception – it has a new SCADA system, installed in 2005. The new SCADA monitors and collects the data. Monitoring is performed almost in real time (30 seconds of delay). The upgrading and/or changing of the technical systems in the region are currently under discussion in each country. However, decisions have been delayed due to the lack of financial resources.

[7] Deviations for Northern Kazakhstan, Aktyubinsk, Western Kazakhstan (Arytau, Aksay, Uralsk) are included.

4.4 CURRENT POWER EXCHANGES IN THE CAPS

Actual power flows in CAPS-5 in 2010 are summarized in the table presented below. These figures are based on the data provided by the countries' representatives. Discussed next are the intergovernmental developments concerning these power flows.

Table 2 - CAPS electricity power exchanges in 2010.

	Power Flows To (GWh)					
	2010	**Southern Kazakhstan**	**Kyrgyz Republic**	**Tajikistan**	**Turkmenistan**	**Uzbekistan**
Power Flows From (GWh)	**Southern Kazakhstan**	X	0	0	0	0
	Kyrgyz Republic	850	X	N/A	0	N/A
	Tajikistan	0	75*	X	0	0
	Turkmenistan	0	0	0	X	0
	Uzbekistan	0	0	360	0	X

*-data obtained for January-May 2010

Developments between Kazakhstan and the Kyrgyz Republic

- **Kazakhstan** and the **Kyrgyz Republic** have signed agreements on joint operations.
- The **Kyrgyz Republic** is now selling power to the South of **Kazakhstan** and providing frequency control services. According to the data provided by the Kazakh Ministry of Energy and New technologies, these services are paid.
- The price of energy exported from the **Kyrgyz Republic** to **Kazakhstan** also includes water supply for irrigation in Kazakhstan, according to the intergovernmental agreement.
- The price for frequency control services is not publically available.
- The power excess in 2010 in the **Kyrgyz Republic** is around 2.8 TWh, at lowest. The total agreed annual supply from the Kyrgyz Republic to Southern **Kazakhstan** is around 1.85 TWh/year as by contract for the current year. There are 7 GWh supplied daily. The 4 GWh supply of Kyzyl-Orda and Chimkent regions are currently under evaluation. Here, the transit issue with Uzbekistan still has to be solved. Additional 2 GWh of electricity are planned to supply to the Taldy-Kurgan region (close to Almaty). It is important to state the yearly amount supplied is not flat, but seasonal, with the average load factor of 0.4. Switching from power supplied by Northern Kazakhstan to the Kyrgyz power stations beneficially influences the power flow fluctuation at the Russian-Kazakh border.

Developments between the Kyrgyz Republic and other CAPS members

- Currently there is no transfer of electricity between **Kazakhstan** and **Turkmenistan**. However, it is expected that in January 2011 Turkmenistan will start to export power to Chimkent (Kazakhstan) through Uzbekistan (Serdar-Karakul substations). The general agreement has already been reached. The volumes provided and the price must still be agreed. It is stipulated that the energy should be sold on the Turkmen border – at the Serdar substation. All the negotiations and agreements related to the electricity transit through the Uzbekistan should be held by the Kazakh counterparty. It reflects one of the export principles for Turkmen power sector: to supply energy within its border and external buyers should solve the transit conditions with the other involved parties, if needed.
- The limited power flow from **Tajikistan** to the **Kyrgyz Republic** is caused by the reimbursement of unplanned power withdrawal from the Kyrgyz power system that took place in 2009.
- **Uzbekistan** provides transit services to the **Kyrgyz Republic** based on corresponding agreements. It allows transit power flows from the South to the North of the Kyrgyz Republic through Uzbek territory. From the other side, the Kyrgyz Republic is providing 160 MW of

Toktogul HPP capacity for frequency regulation purposes for free. The main issue remains to maintain the zero-net power flows at the end of each month.

- Currently there are no agreements between the **Kyrgyz Republic** and **Uzbekistan** on power supply. For instance, for July 2010 zero-net power balance has been maintained. It should be noted that there are small technical power exchanges between the two systems during the day. It should be considered that it is possible to offset the contracted and the actual supplied energy by the end of each month.
- Since November 2009 **Tajikistan** has been separated from the regional transmission system by the disconnection of both 500 kV lines, Guzar-Regar and Surkhan-Regar; although **Uzbekistan** still supplies Northern remote areas in Tajikistan. Annual supply to these country regions is about 360 GWh through 220kV and 110kV lines. The basic condition on the supply of those areas is the advance payment of ten days of supply.

Tajikistan and Uzbekistan disagreement

- As previously mentioned, water and electricity issues are very much interrelated in Central Asia. In April 2010, **Tajikistan** and **Uzbekistan** could not come to an agreement on the water management of the Kayrakum reservoir. At the time of writing, in June 2010 Tajikistan did not provide irrigation water to Uzbekistan. The main point of this disagreement was the free transit through the territory of Uzbekistan to Tajikistan in wintertime. There was no consensus on summer export from Tajikistan through the Uzbek network.

4.4.1 NEW TRADING OPPORTUNITIES.

It can be assessed that the situation for joint operations within CAPS is not stable. Countries are now looking for other opportunities to secure electricity supplies for consumers and to export the excess capacity. The main tendency in the region is to export to Southern countries, particularly to Afghanistan, Iran, Turkey, and possibly in the future – Pakistan.

Providing a full assessment, based on official sources, the export from **Uzbekistan** to **Afghanistan** of electricity is challenging. However, unofficially it is shown that Afghanistan currently receives more than 1 TWh from Uzbekistan. Afghanistan, according to information from Uzbekenergo, sometimes does not comply with the contractual terms for power delivery: it does not accept the agreed volumes. When this occurs, it creates instability on the Uzbek side. Searching for a nontechnical solution may involve bringing the matter to court with the possibility of penalties. However, to date the Uzbek side has not raised the issue.

Representatives from the Uzbek power sector have concerns over the ability of Afghan consumers to pay once subsidies from the financial institutions end. However, according to recent news, the financial aid to Afghanistan from the ADB funding will be increased from 350 million USD to 500 million USD.

Because of an excess of power production in the summer, **Tajikistan** is extremely interested to increase exports to **Afghanistan**. The Tajik part of a 220 kV line connecting the two countries is almost completed. However, the Afghan part of the line is still under construction and the completion date is unknown.

The **Afghanistan-Turkmenistan** connection is represented by two 110 kV lines that are currently overloaded. Those lines are used for the Turkmen power supply to Afghanistan.

Besides the enormous market of Afghanistan, Turkmenistan has discovered new export opportunities, such as the markets of Iran and Turkey.

Two 220 kV lines connect **Turkmenistan** with **Iran**. It allows Turkmenistan to export electricity. Iran, in turn, provides frequency regulation for Turkmen power system (250 MW). However the existing 220 kV lines are highly congested. Therefore the construction of a new 400 kV line from Mariyskaya TPP to the Iran border is planned.

70-80 MWh annually is exported from **Turkmenistan** to **Turkey** with the transit through Iran. The export volume defined in the contract with Turkey is the agreed base value, with possible deviation of 20% in both directions. Currently Turkmenistan is supplying power to the Turkish border. However, starting from 2011 electricity transmission will only be guaranteed to the Turkmen border with Iran. Turkey will need to negotiate the transit conditions through Iran.

To conclude, the Tajik and Turkmen power systems are disconnected from CAPS and are operating in an isolated mode. The longer the power systems operate in isolation, the more difficult it will be for the re-synchronization with CAPS. According to the opinion of Kuvvat experts (Turkmenistan), it is currently technically impossible for Turkmenistan to operate jointly with Uzbekistan and other CAPS countries. This is because the upgraded power system has significantly changed the properties of the lines connecting Turkmenistan to these other countries. The technical capacities of CAPS should be changed to meet these recent alterations; additional investments in transmission network are essential for this purpose. The reconnection of the two mentioned power systems will be a significant advantage for CAPS due to the large amount of reserve and frequency regulation available.

Matching the broader political situation in the Central Asian region, the countries are currently applying significant effort to secure their energy security, such as building their own national grids, and looking for new opportunities for electricity exports. International trade in electricity is targeted mainly at South-Asian countries.

Such unilateral grid development considerably complicates the ability to enhance and modernize the regional Central Asian power systems. It also complicates opportunities to reach bilateral agreements between the Central Asian countries over electricity and water resources.

5 STRENGTHS WEAKNESSES OPPORTUNITIES THREATS OF THE INTEGRATED OPERATION

SWOT analysis is the method used to evaluate Strength, Weaknesses, Opportunities and Threats of certain strategies or projects. In this section the SWOT diagram will be developed in order to provide a strategic evaluation of integrated operation in the CAPS. In this analysis regional and country perspectives are taken into consideration.

The main components of the SWOT analysis are:

- Strengths are those internal attributes of the system that are helpful to achieving integrated operations.
- Weaknesses are those internal attributes of the system that can be harmful if countries operate their power system jointly.
- Opportunities are those beneficial external conditions that could appear and could assist agreement on the integrated operations of CAPS countries.
- Threats are those external conditions, which could provide a negative impact on the collaboration between countries in the power sector decreasing the probability to reach joint operation in CAPS.

5.1 STRENGTHS OF THE INTEGRATED OPERATION

Strength of integrated operation for the CAPS region:

1. Optimal use of natural resources:
    a. Less water spillage
    b. Decrease in fuel consumption, especially in the countries with scarce hydro generation.
2. Optimal dispatch and balanced generation mix leads to the optimized operations.
3. Efficient thermal generation running.
4. Less need for investments.
5. Use of existing well developed regional network.
6. Decrease of disconnections from grid and decrease of economic loss from interruptions.
7. Security of supply improves in the region, as countries do not depend only on their own generation resources.
8. Less secondary reserve needed.
9. Favorable conditions for new investments. Facilitated electricity trading in the region leads to higher certainty that investments will be recovered.

Strength of integrated operation for each country in the CAPS.

From the countries' prospective the benefits of integrated operation are the following:

10. In the Kyrgyz Republic and the Tajikistan, electricity demand is mainly covered by hydropower. However, the cost could be optimized, if Uzbekistan or Southern Kazakhstan could use hydro generation in those countries in order to switch the majority of its generation to a base load regime (at the most optimal load level, even during the off-peak hours -in terms of fuel, each 4% of unit loading leads to 1% fuel consumption decrease).
11. From the other side, the Kyrgyz Republic and Tajikistan could increase the security of supply for their consumers. It is shown that the electricity price differences in CAPS makes parallel operations more advantageous
12. Kazakhstan and Uzbekistan have self-sufficient power systems in terms of total generating capacities. They will be able to solve problems relating to the optimization of power flows, coverage of peak loads during morning and evening hours, re-distribution of capacity reserves, etc.
13. Tajikistan and the Kyrgyz Republic:
    a. More export opportunities: possibility to export to Kazakh and Uzbek markets. More efficient water management, no water spillage.

   b. No energy deficiency during the dry period. Winter maximum will be covered.
   c. Reduction in the need for immediate investment in generation and transmission

14. Tajikistan:
    a. No power deficit in remote areas as far as those regions can be supplied by Uzbekistan.
    b. Possibility to import energy from Turkmenistan.
    c. Opportunity to negotiate transit services payment with Uzbekistan.
    d. New power export opportunities to Kazakhstan and Russia.
15. Kyrgyz Republic:
    a. Ability to supply consumers in the Southern regions
    b. Covering of power deficit in the North
16. Uzbekistan:
    a. Less need for investment in generation and transmission
    b. Regulation services provided by Kyrgyz Republic and Tajikistan
    c. Decrease gas losses and TPP equipment wear while covering the daily peak relying on Kyrgyz Republic and Tajikistan generation.
    d. Solution of the frequency regulation issue.
    e. Less need for fossil fuel.
17. Southern Kazakhstan:
    a. Possibility to obtain regulation services and energy from the Kyrgyz Republic.
    b. No congestion problems and overloading of 500 kV North-South connection. Decrease of losses.

5.2 WEAKNESSES OF THE INTEGRATED OPERATION

From the perspective of the particular countries, weaknesses of the integrated operation are related to the assumed risk in neighboring countries:

1. Potential risk related to the failure of other parties to comply with agreements.
2. Potential risk caused by emergencies in the neighbor countries (but compensated by the possibility to be supported by other countries).

The drawback of the mentioned situations will be the possible loss of energy supply resulting in negative social impacts and economic losses.

5.3 OPPORTUNITIES FOR THE INTEGRATED OPERATION

Three important issues could significantly assist in reaching the agreement of joint operation in the CAPS. These issues are:

1. Transit/custom office issues;
2. Import/export issues.
3. Electricity and water issues (a comprehensive solution is needed). Leveraged solutions can be found where the Kyrgyz Republic and Tajikistan can adjust power production so as to satisfy irrigation needs of Kazakhstan and Uzbekistan.

Power exchanges in the region will be facilitated if the mentioned issues are solved. It will lead to the strengthening of the links between countries favoring the integrated operation in the CAPS.

5.4 THREATS FOR THE INTEGRATED OPERATION

1. National energy security, mainly independence from external sources. With no possibility to rely on neighboring countries' generation will place energy independence at the front.

6 ESTIMATING BENEFITS OF JOINT CAPS OPERATION.

The CAPS regional infrastructure was developed as an integrated system using distributed resources in an optimized manner. Power sector representatives, from the Central Asian countries, agree that from a technical prospective there is no difficulty for the countries to reconnect their national power systems. Technically, integrated operations provide significant benefits and opportunities for all members.

Representatives from the Central Asian power sector provide extensive information on the benefits stemming from joint operation of the regional network, such as:

1. **Optimal use of primary resources**:
   a. decrease natural gas/coal consumption and
   b. prevents unnecessary water releases during seasons with the potential for extra hydropower.

   Each summer day Tajikistan is losing about 50 GWh that can be sold at the price 0.02 USD/kWh for 1 million USD.

   Thermal efficiency of gas power stations is considered to be 2 839.2 Mcal/MWh with availability equal to a maximum of 70%. Importing hydro electricity from Tajikistan can save significant volumes of gas, which can be sold (e.g, at the reference Russian gas price equal to 0.01323 USD/Mcal). This means at least 2.7 million USD can be saved.

   During the summer months (based on 2010 data) joint operations, only in the case of Tajikistan-Uzbekistan, can lead to 1 million USD earnings for the Tajik side and 2.7 million USD savings for the Uzbek side. This is positive for both parties involved.

2. **Balanced generation mix and optimal dispatch,** this is directly related to the previous point. Integrated grid operation allows optimization of generation facilities and more efficient operations of thermal generation; this takes advantage of marginal cost differentials. In the future, a well-developed regional grid favors better renewable energy sources (RES) penetration and low-cost dispatch on the generation side. The operation of the intermittent RES will become more optimal, increasing benefits for exports of excess power.

3. An additional advantage in joint operations is the **optimization of load curve in the CAPS**. There are 2 time zones in the CAPS-4 region (4 GMT and 5 GMT). From the figures below (**Figure 7** and **Figure 8**) it can be seen that daily peaks fall on different hours in the CAPS-4 countries. Graphs are built for the 5 GMT time zone.

Figure 7 - Load profile in CAPS-4. Winter characteristic day.

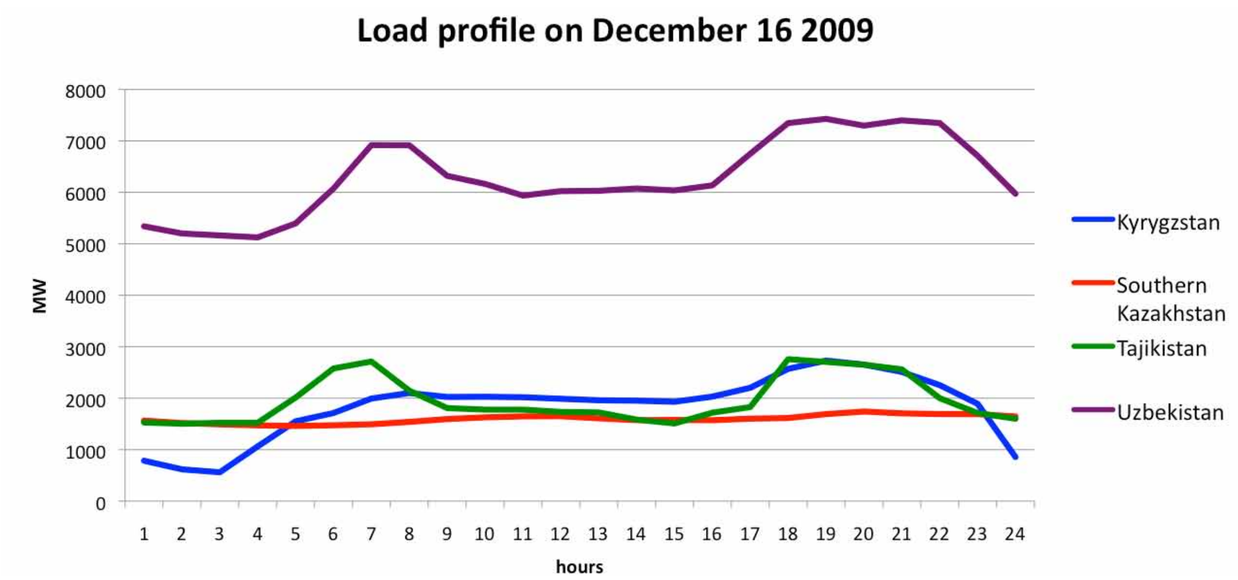


Figure 8 - Load profile in CAPS-4. Summer characteristic day.

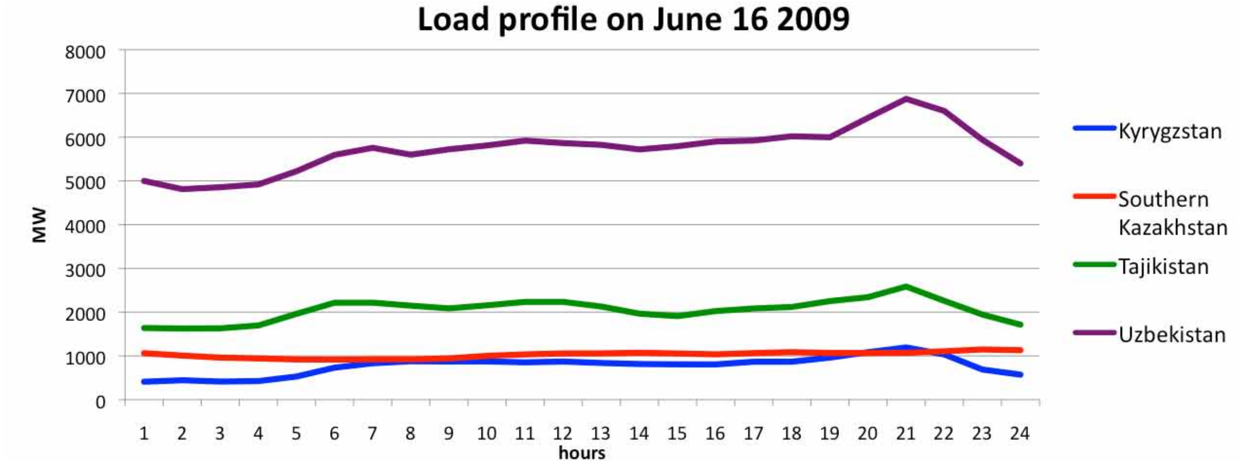


Figure 5 displays the aggregated load curve in the CAPS-4. Based on the data for the winter/summer characteristic days, in **Table 3** it can be seen that if countries operate in isolation, 14 658 and 11 800 MW of available capacity are needed in winter and in summer. However, if there is joint operation, the need for available capacity decreases to 14 527 and 11 598. From these results it can be stated that regional trade is beneficial for all participants.

Table 3 - Need for capacity to cover daily peak in the CAPS-4 countries.

	Kyrgyz Republic	Southern Kazakhstan	Tajikistan	Uzbekistan	CAPS-4 isolated	CAPS-4 in
Winter daily peak, MW	2 731	1 741	2 758	7 428	14 658	14 5
Summer daily peak, MW	1 193	1 147	2 585	6 875	11 800	11 5

4. Technically, joint grid operations can increase **RES development**, by allowing the export of surpluses, in particular from countries with high RES potential, such as:
   a. Hydropower from Tajikistan and the Kyrgyz Republic,
   b. Kazakhstan and Uzbekistan, in terms of wind and solar energy, can develop their potential while relying on the energy mix of their neighbors.

   Joint power system operation in the region provides additional incentives to invest in renewable generation.

5. **Security of supply increases** in the region as a whole and in each Central Asian country. Countries will not depend only on their own generation resources but also on their neighbors.

6. As the power system becomes larger, the **reliability parameters increase**. The number of disconnections of grid elements' decrease uniformly while also decreasing economic losses from interruptions. On the other side, the imbalances in the system can be more easily covered. Tajikistan and the Kyrgyz Republic are very small power systems with the advantage of having highly flexible hydropower. Uzbekistan, which is a comparably big system is strongly dependent on the unit of Talimarjan TPP, which if it cannot produce electricity, the frequency falls immediately. It represents about 10% of peak demand in Uzbekistan.

7. The **need for regulating facilities decreases** because countries can share reserves.

   For the development of the figures presented below, the CIS methodology was used to determine the required reserve for frequency and power-flow regulation. CIS countries approved this calculation in 2006.

   The minimum secondary reserves for isolated operations, in CAPS countries, are presented in **Table 4**. Plus and minus signs shows the need for the possibility to load and to unload the power stations at the stated value.

Table 4 - Need for secondary reserve if operated in isolation.

Country	Secondary reserve, MW
Southern Kazakhstan	±73
Kyrgyz Republic	±62
Tajikistan	±84
Turkmenistan	±47
Uzbekistan	±164

If the countries are operated jointly, the need for secondary reserves decrease. In the table below, figures are provided for the isolated and integrated operation of CAPS. Isolated operations are calculated as the total sum of the secondary reserve in each corresponding country-member of CAPS (see **Table 5**). In the case of joint operations, this is calculated based on the same methodology, considering that three, four or five countries represent one region.

Table 5 - Need for secondary reserve if operated jointly.

	Secondary reserve if Isolated operation, MW	Secondary reserve if Integrated operation, MW
CAPS-3	±299	**±234**
CAPS-4	±383	**±274**
CAPS-5	±430	**±293**

Where

- CAPS-3 includes Uzbekistan, Kyrgyz Republic and Southern Kazakhstan
- CAPS-4 includes Uzbekistan, Kyrgyz Republic, Southern Kazakhstan and Tajikistan
- CAPS-5 includes Uzbekistan, Kyrgyz Republic, Southern Kazakhstan, Tajikistan and Turkmenistan

From the comparison in the Table 2 it can be concluded that in the case of joint operations, the need for secondary reserve decreases 1.5 times.

8. The **need for regulation can be more easily covered** because of differences in generation mixes. For instance, Tajik and Kyrgyz hydropower can be regulated in order to maintain the most efficient regimes on the thermal power stations (regulation of 0.1 Hz costs 1 MW (frequency correction) in Tajikistan). In the case of Uzbekistan and Kazakhstan it will be more difficult to implement, and if implemented it would be associated with high costs.

   Members of an integrated grid can mutually support each other during emergencies. An increase in the level of security of supply can be reached at a least-cost basis when all the participants use lower priced power when it is available (possibly hydro or other RES), therefore, minimizing fuel consumption can lead to a low carbon economy.

9. **Less need for investments** due to the existing and well-developed regional network. The existing generation capacity in some countries could be used more efficiently. New investments in generation and transmission could also be optimized between those that import heavily and those with extra power for export.

10. Possibility to **develop regionally scaled projects**. Export opportunity prompts the decision to invest in large regional projects. Even if the local consumption is low, with a well developed transmission network and a stable economic and political environment in the region, there will always be opportunities for electricity export within or even outside the region.

7 ECONOMIC EVALUATION OF BENEFITS OF JOINT CAPS OPERATION.

Representatives of the CAPS agree on the qualitative benefits of joint operation in the region. Running the mathematical least-cost expansion model, where all the CAPS countries were considered as interconnected nodes with their electricity generation and consumption shows the advantage in regional cooperation.

From the modelling results it can be seen that if the CAPS countries operate their power systems jointly, around 1.6 billion USD can be saved in the first three years of operation. Optimal dispatch, with more efficient operation of thermal generation (comparing to the case of isolated operation) being the main source of these savings. The only condition to obtain these cost savings would be to allow cross border flows in the region. No additional investments are needed during the first three years of integrated operation.

Moreover, the security of supply will increase in the CAPS countries. It can be expressed in terms of non-supplied energy. According to the modelling results, in the case of joint operation, more than 0.5 billion USD can be additionally saved, if compared to the case of isolated grid operations.

It can be concluded that more than 2.1 billion USD can be saved during the period of 2010-2012 if the CAPS countries come to the agreement to operate their grids jointly.

7.1 METHODOLOGY

For estimation of the benefits of joint operation it is proposed to model and then to compare in terms of costs, grid operation for two different cases. The parameters will be:

- If the countries operate their network jointly;
- If there is no transmission interconnection between any of them.

It was decided to develop two cases mentioned above for CAPS-5 and CAPS-4 scenarios, where:

- CAPS-5 corresponds to the scenario when all five countries of the region are involved in the joint power system operation;
- CAPS-4 represents the scenario when Turkmenistan does not jointly operate with other countries of the region.

More cases could be developed depending on the level of disintegration in CAPS, however, two proposed scenarios are the most probable to happen and they provide (with estimation), accurate enough to conclude all participants benefit from integrated power operation in the region.

The methodology is comprised of the following phases:

- Data collection.
- Scenarios statement. The key variables to define scenarios for generation and transmission planning are: anticipated load growth, fuel costs, capital costs for generation and transmission facilities, discount rate, and performance standards.
- The optimal expansion planning phase, where through the use of a model, a candidate plan is selected. The input data are the variables that define the scenario, the set of all candidate plants and interconnections, and investment constraints such as earliest and latest decision dates, mandatory projects, mutually exclusive project constraints, and others. The output consists of the set of initial operation dates for all selected projects (power plants and interconnections). The model provides system performance and the present value of the system operational costs.

The optimal expansion plan was obtained using a proprietary model named ORDENA, which is a computational tool for determining the least-cost expansion (generation and interconnections) of a multi-regional hydrothermal system. The model considers system operation details, such as: river inflow uncertainties, emission constraints, and minimum capacity constraints, among other features.

It is important to note that the model-based methodology allows selection of the optimal set of generation of transmission expansions[8]. This is in contrast to other methodologies that are based on

[8] In this case, based on the candidate projects provided by the countries there are billions of expansion alternatives. Only through the use of a model it is possible to select the optimal one.

analysis of expansion alternatives, which are unable to ensure that an optional solution is achieved. It is possible to demonstrate that all the projects selected by the model have an internal rate of return greater or equal the discount rate used to calculate the net present value of cost to meet the load. Thus all projects selected by the ORDENA model are economically feasible.

The outputs of the ORDENA model, both generation and transmission should be technically feasible as well. ORDENA provides among other information, the energy balance, expected system reliability, expected short term and the long-term energy prices, air emissions, and the consumption of primary resources.

A description of the ORDENA model may be found in Annex II of this report.

7.2 MAIN ASSUMPTIONS AND DATA COLLECTION

7.2.1 CAPS MODELING

Five Central Asian countries are connected by the Syrdarya and Amudarya Rivers. They are the Kyrgyz Republic, Kazakhstan, Tajikistan, Turkmenistan and Uzbekistan. The goal of the analysis is to provide a least-cost generation and transmission expansion plan for CAPS, considering:

- Three operational possibilities: CAPS-5, CAPS-4 joint operation and the operation when all five countries operate their network separately.
- A time horizon from 2010 until 2031. Although among the objectives is the definition of investment decisions to be made in the next 2-3 years, it is necessary to consider a long-term horizon that allows the assessment of the performance plan during the life cycle of the identified investments. In order to limit the number of variables, not all the years of the period 2010-2031 are considered in the model. Eight years were considered to be representative of longer time intervals, as shown in the following table:

Table 6 - Time Intervals.

Year in the model	Represents the period
2010	2010
2011	2011
2012	2012
2013	2013
2014	2014
2015	2015
2016	2016
2017	2017
2018	2018
2019	2019
2020	2020
2022	2021-2023
2024	2024-2026
2029	2027-2031

- The actual power systems: internal demand, existing power generation and transmission facilities, cross-border transmission lines.
- Fuel cost forecast and availability.
- Load forecasts.
- Energy production from renewable sources for different scenarios (e.g. generation of hydro plants on average, wet, and dry hydrological conditions).
- Generation and transmission (G&T) expansion plans for each country (i.e. the national Master Plans). The regional optimisation model (ORDENA) identified additional facilities to those included in the expansion schedule provided by the countries.

- A set of candidate generation plants and cross-border transmission lines in order to obtain the least-cost additional expansion to meet demand at minimum cost[9].

It should be noted that the master plans developed in each of the CAPS countries cover a relevant part of the planning horizon. Therefore, during that period, the results of the master plans are mainly oriented to optimise the regional trading of energy, either by developing regional size generation projects, or by identifying the optimal expansion of the cross-border transmission capacity.

Figure 9 - Central Asian Power System.

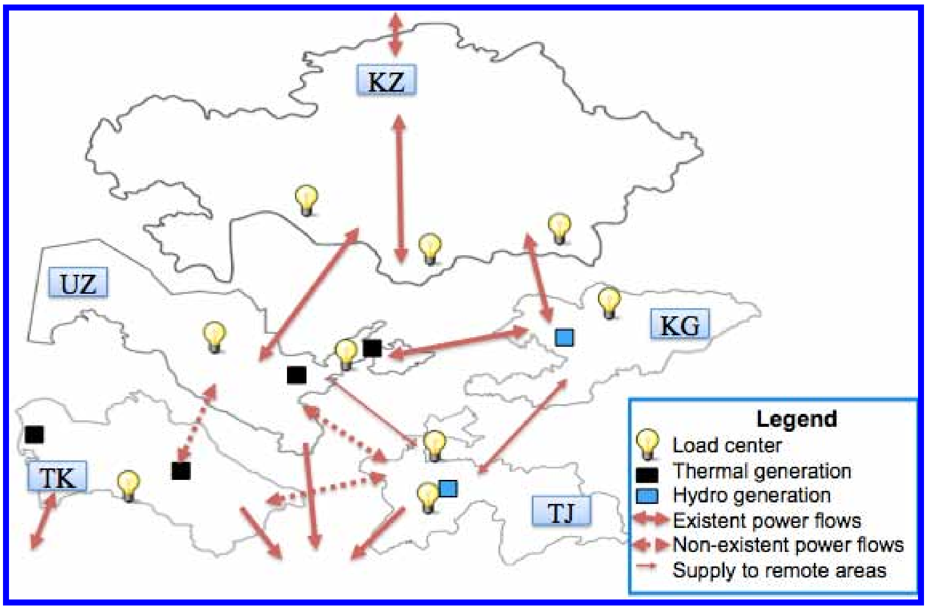


Figure 9 depicts the CAPS countries. Almost all countries provided the required data; with the exception of the fuel cost forecast and availability, load forecasts, different scenarios for renewable energy (hydro) production. The lack of data was covered by the introduction of the set of assumptions that can be found below.

Five nodes in the model correspond to the Central Asian countries (the Kyrgyz Republic, Southern Kazakhstan, Tajikistan, Turkmenistan and Uzbekistan) with their own power production and consumption. An additional node has been introduced to model Northern Kazakhstan. It was assumed that even in the case of isolated operation, Northern and Southern Kazakhstan would still operate their power systems jointly.

The type of fuel differentiates generation facilities in each node: coal, natural gas, heavy oil or mazut, hydro. Two sub-categories depending on the fuel efficiency were introduced within the gas-fuel category: combined-cycle gas turbines and open-cycle gas turbines. The 500 kV and 220 kV transmission lines connect country-nodes.

The transmission and generation facilities in the model have been classified into three categories:

- **Existing:** these are the facilities that are currently running, or under construction with a commissioning date before 2010.
- **Planned:** these are facilities included in the countries' master plans, which will be committed between 2010 and 2029. The model considered these facilities to be extant on account of the known commissioning date.
- **Candidate:** this is a portfolio of facilities that the model had to decide when and whether to install. The model evaluates candidates basing on:
  - Investment plus O&M costs provided,
  - Earliest commissioning date provided and,
  - Expected generation output of renewable resources.

  The model selected some of these facilities if they are part of the least cost expansion alternative[10].

[9] When a country did not provide enough candidate generation units (and power importations) to meet the internal demand, the consultants added standardised generation units of different technologies to the model.

Existing expansion plans are taken into account in order to construct the candidate expansion scenarios. In the cases when expansion plans are not available, there are assumed standard expansion candidates that depend on the fuel as available in each country.

The model provides the least-cost expansion plan from 2010 to 2031. Key issues that have a significant impact on the results are fuel prices and their availability throughout the planning horizon. Unfortunately, no reliable fuel price and/or availability forecasts are available for such a long time period. Any attempt to make such forecasts will lead to questionable and/or subjective results. Therefore, the proposed approach is to consider constant prices for the whole time horizon, and perform ex-post sensitivity analysis to assess the robustness of the results.

7.2.2 HYDROLOGY.

The Syrdarya River and hydrology play a decisive role in CAPS. Two of the five CAPS countries have a significant hydropower generation share.

Three hydro scenarios per season were considered: dry, average, and wet. The definition and the probabilities assigned to these scenarios have a significant impact on the candidate plans finally chosen by the model. The dry scenario is closely linked to the total installed capacity needed to meet peak demand, and the other scenarios play an important role in the selection of the cheapest generation mix to supply the total energy consumed. A more detailed description on these issues is discussed below.

Hydro scenarios and the historical data for the last 15 years have been obtained only from the Kyrgyz Republic. Because of the lack of the data and due to the fact that there are the same rivers in the CAPS countries, it was decided to use this data for all the countries, taking into account different volume of hydro generation in each of them.

7.2.3 LOAD PROFILE

Demand is considered to be uncorrelated to hydrology.

Load profiles represented in the **Figure 7** and **Figure 8** in Chapter 6 correspond to two characteristic days that happened during the last year: December 16 2009 and June 16 2010. It is supposed that during each day in a season, the shape of the load curve remains the same; only the height (maximum daily load) is changing correspondingly. Hereby should be noted that monthly distribution in energy consumption should coincide with the available historical data.

As far as there were no data obtained from Turkmenistan, for the modelling purposes the shape of load profile was assumed to be the same as in Uzbekistan, scaled down to the peak load level.

In the model, five demand blocks represent monthly load. The procedure designed to determine the demand blocks per country and season for 2010 is as follows:

- Add the hourly annual load profiles of all the CAPS countries to obtain the regional demand.
- Obtain the load duration curve for each country and month (differentiating between winter and summer periods).
- Determine the load blocks for each country and season as follows:
    - For each season, obtain the load blocks of the regional demand from its load duration curves.
    - The duration of the peak block is 1 hour and its power is the peak power times (1 + % of reserve margin). This reserve factor was initially set at 10%, and was iteratively adjusted in each country to achieve reliability target, takes into account the required medium term and spinning reserve.
    - The duration of the next four blocks is 119, 120, 240 and 240 hours. Note that the annual energy must coincide with the load forecasts.
    - For each season and country, obtain the load blocks and scale it vertically so that the addition of the demand blocks of each country matches the load blocks obtained at regional level.

The durations of the blocks B1, B2, B3, B4 and B5 are: 1, 119, 120, 240 and 240 hours respectively that correspond to 720 hours per month.

[10] When a country does not provide enough generation units to meet demand in either in their national plans or in the candidate set; standardized generation units of different technologies will be introduced in the model.

7.2.4 LOAD FORECAST

The total energy and peak demand per country is shown next. These figures were deduced from the Kyrgyz Republic forecast till 2025. Due to the lack of data in the rest of the CAPS countries, the growth of maximum load and total annual consumption was assumed to be the same in the Central Asian region.

Table 7 - Forecasted Energy Demand GWh / Year.

Year	Kyrgyz Republic, GWh	Northern Kazakhstan, GWh	Southern Kazakhstan, GWh	Tajikistan, GWh	Turkmenistan, GWh	Uzbekistan, GWh
2010	9 875	63 001	15 153	16 079	12 960	50 139
2011	10 629	67 809	16 309	17 306	13 949	53 966
2012	11 383	72 618	17 466	18 533	14 938	57 792
2013	12 136	77 426	18 622	19 760	15 928	61 619
2014	12 890	82 234	19 779	20 987	16 917	65 445
2015	13 644	87 043	20 935	22 215	17 906	69 272
2016	14 115	90 048	21 658	22 982	18 524	71 664
2017	14 586	93 054	22 381	23 749	19 142	74 056
2018	15 057	96 060	23 104	24 516	19 761	76 448
2019	15 528	99 065	23 827	25 283	20 379	78 840
2020	15 999	102 071	24 550	26 050	20 997	81 232
2022	51 591	329 137	79 162	84 000	67 708	261 940
2025	57 001	363 647	87 463	92 808	74 807	289 405
2029	108 065	689 418	165 816	175 949	141 822	548 667

Table 8 - - CAPS Forecasted Peak Demand MW.

Year	Kyrgyz Republic, MW	Northern Kazakhstan, MW	Southern Kazakhstan, MW	Tajikistan, MW	Turkmenistan, MW	Uzbekistan, MW
2010	2 236	9 625	2 721	3 223	2 182	7 598
2011	2 406	10 359	2 928	3 469	2 348	8 178
2012	2 577	11 094	3 136	3 715	2 515	8 758
2013	2 747	11 829	3 344	3 961	2 681	9 337
2014	2 918	12 563	3 551	4 207	2 848	9 917
2015	3 089	13 298	3 759	4 453	3 014	10 497
2016	3 195	13 757	3 889	4 607	3 118	10 860
2017	3 302	14 216	4 019	4 760	3 222	11 222
2018	3 409	14 675	4 148	4 914	3 326	11 585
2019	3 515	15 134	4 278	5 068	3 430	11 947
2020	3 622	15 594	4 408	5 222	3 535	12 310
2022	3 893	16 761	4 738	5 613	3 799	13 231
2025	4 301	18 519	5 235	6 201	4 198	14 618
2029	4 893	21 065	5 955	7 054	4 775	16 629

7.2.5 EXISTING AND PLANNED GENERATION UNITS

As it was previously described, the existing and planned generation is 'bulky' represented by technology for each country in the region.

Table 9 - Existing generation in CAPS countries.

Country-node	Coal, MW	Gas, MW	CCGT, MW	Fuel-oil, MW	Hydro, MW
Kyrgyz Republic	340	340	0	0	2 910
Northern Kazakhstan	13 618	846	0	0	1 734
Southern Kazakhstan	2 314	0	143	0	530
Tajikistan	0	198	0	198	4 706
Turkmenistan	0	4 536	0	0	9
Uzbekistan	480	9 659	0	480	1 420

Among the main planned facilities during the period 2010-2013 are:

- Moinak HPP (300 MW) in the Southern Kazakhstan;
- 2nd unit of Kambarata-2 HPP (120 MW) in the Kyrgyz Republic; and
- Sanktuda-2 (220 MW) in Tajikistan.

The ORDENA model assumes that these units will be installed and available the year they are scheduled in the national Master Plans. The ORDENA model estimates the optimal dispatch of these plants.

It was assumed that Rogun HPP (3600MW) in Tajikistan, Kambarata-1 (1900 MW) and the 3rd unit of Kambarata-2 (120 MW) in the Kyrgyz Republic would be commissioned after 2014.

7.2.6 CANDIDATE PROJECTS

Among the candidate projects countries provided this data. The model takes investment, fuel, and O&M costs into consideration to decide whether, and when, to install them.

In order to meet demand until 2029, additional standardized candidate units of different technologies (aside from the candidate units provided) were included in the model. The technology being used in each country is depicted in the next table.

Table 10 - Standard Candidate Plants for Country.

Country-node	Coal, MW	Gas, MW	CCGT, MW	Fuel-oil, MW	Hydro, MW
Kyrgyz Republic		X	X		X
Northern Kazakhstan	X	X	X		
Southern Kazakhstan	X	X	X		
Tajikistan		X	X		X
Turkmenistan		X	X		
Uzbekistan		X	X		

Mainly standard candidate power plants are expected to enter in use after 2013.

7.2.7 FUEL COSTS AND AVAILABILITY

Fuel constraints were introduced in some countries of the region because of existing unequal distribution of natural resources.

It was decided to use an opportunity costs based on netback of Russian prices for coal, oil by-products and natural gas. The lack of fuel price data provided by the countries and the opportunity to export to the neighboring Russian fuel market, led to the decision of taking Russian prices as a reference that as we consider is the best estimation of real fuel costs in the CAPS countries.

Table 11 - Fuel prices forecast in CAPS.

Year	Gas (USD/Mcal*)	Coal (USD/Mcal*)	Fuel Oil (USD/Mcal*)
2010	0.0133	0.0093	0.0160
2011	0.0168	0.0118	0.0202
2012	0.0178	0.0125	0.0214
2013	0.0191	0.0134	0.0229
2014	0.0203	0.0143	0.0245
2015	0.0247	0.0173	0.0297
2016	0.0259	0.0182	0.0311
2017	0.0263	0.0184	0.0316
2018	0.0266	0.0186	0.0320
2019	0.0270	0.0189	0.0324
2020	0.0314	0.0220	0.0377
2022	0.0314	0.0220	0.0377
2025	0.0314	0.0220	0.0377
2029	0.0314	0.0220	0.0377

* 1 Mcal is equal to 3 969 Btu

7.2.8 TRANSMISSION INFORMATION

The information about existing interconnections between the country-nodes is based on the information provided by the countries. Only the 220 and 500 kV interconnections are included in the model.

Regional integration requires the construction of more cross-border transmission lines in order to share resources and to maximize the social welfare of the entire region.

Costs for construction of new lines and substations are based on the international reference values.

Table 12 - Investment costs.

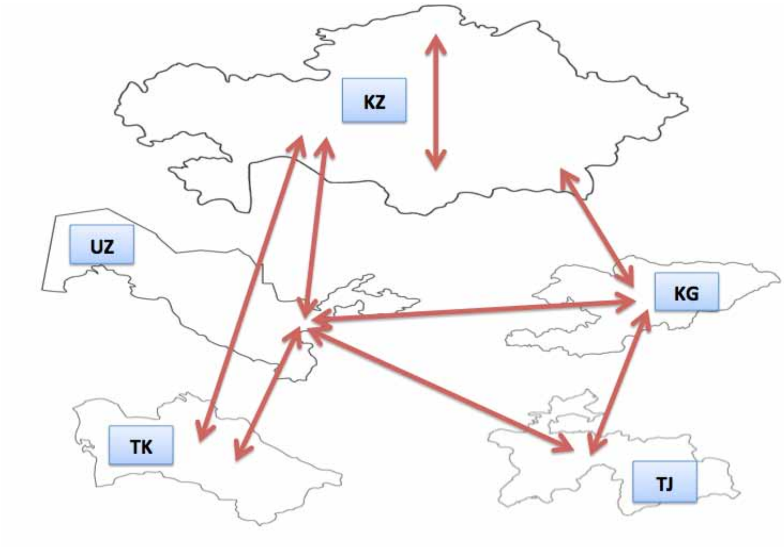
Lines (USD/Km)	
Voltage Level (KV)	**Investment Costs**
500	606 580
220	412 490
Substations (USD/Bay)	
Voltage Level (KV)	**Investment Costs**
500	1 414 920
220	932 620
Transformers (USD/MVA)	
Reference value	13 000

7.3 RESULTS

7.3.1 CAPS-5 INTERCONNECTED.

When modelling CAPS-5 as the interconnected power system, the power flows between the country-nodes exist, aiming at the cost minimization. The energy volume transmitted from one node to the other is represented in the table below.

Figure 10 – CAPS-5 Interconnected.



The tendency to export from Northern to Southern Kazakhstan, with the future re-export of electricity to the rest of the CAPS, can be observed. With the comissioning of new planned power plants in the CAPS, these volumes are replaced by the increasing power exchanges within the CAPS.

Uzbekistan and the Southern Kazakhstan become the major power importers that buy electricity from the Kyrgyz Republic, Tajikistan and Northern Kazakhstan.

Table 13 - Power flows in 2010, GWh.

		Power Flows To (GWh)					
	2010	Northern Kazakhstan	Southern Kazakhstan	Kyrgyz Republic	Tajikistan	Turkmenistan	Uzbekistan
Power Flows From (GWh)	Northern Kazakhstan	X	15 407	0.0	0.0	0.0	0.0
	Southern Kazakhstan	150	X	6 639	0.0	0.0	13 625
	Kyrgyz Republic	0.0	153	X	293	0.0	7 888
	Tajikistan	0.0	0.0	16	X	0.0	5 049
	Turkmenistan	0.0	0.0	0.0	0.0	X	0.0
	Uzbekistan	0.0	60	0.0	619	614	X

Table 14 - Power flows in 2011, GWh.

		Power Flows To (GWh)					
	2011	Northern Kazakhstan	Southern Kazakhstan	Kyrgyz Republic	Tajikistan	Turkmenistan	Uzbekistan
Power Flows From (GWh)	Northern Kazakhstan	X	14 479	0.0	0.0	0.0	0.0
	Southern Kazakhstan	118	X	5 260	0.0	0.0	13 167
	Kyrgyz Republic	0.0	156	X	343	0.0	6 976
	Tajikistan	0.0	0.0	10	X	0.0	4 831
	Turkmenistan	0.0	0.0	0.0	0.0	X	0.0
	Uzbekistan	0.0	38	0.0	728	711	X

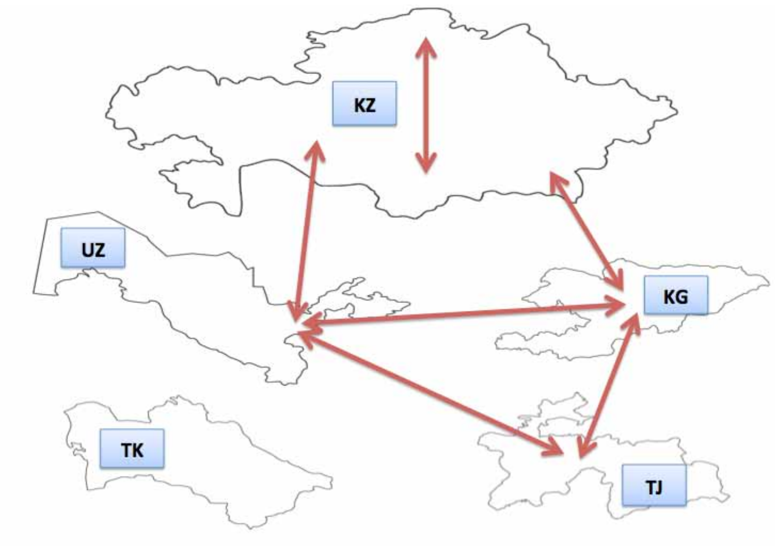
Table 15 - Power flows in 2012, GWh.

	2011	Power Flows To (GWh) Northern Kazakhstan	Southern Kazakhstan	Kyrgyz Republic	Tajikistan	Turkmenistan	Uzbekistan
Power Flows From (GWh)	Northern Kazakhstan	X	12 562	0.0	0.0	0.0	0.0
	Southern Kazakhstan	265	X	4 504	0.0	0.0	11 937
	Kyrgyz Republic	0.0	170	X	301	0.0	5 937
	Tajikistan	0.0	0.0	12	X	0.0	4 829
	Turkmenistan	0.0	0.0	0.0	0.0	X	0.0
	Uzbekistan	0.0	73	0.0	710	740	X

7.3.2 CAPS-4 INTERCONNECTED.

When modelling CAPS-4 as the interconnected power system, there are no power exchanges with the Turkmen power system; however, the power flows between other country-nodes exist, focused on cost minimization. The energy volume transmitted from one node to the other, depending on the year, is represented in the tables below.

Figure 11 - CAPS-4 interconnected.



Comparing to the CAPS-5 scenario, power exchanges volumes become lower, as far as Turkmenistan are not participating in the joint power system operation in the region. Uzbekistan and Southern Kazakhstan remain to be the main power importers, while the Kyrgyz Republic, Tajikistan and Northern Kazakhstan hold the exporters' position in the CAPS.

Table 16 - Power flows in 2010, GWh.

	2010	Power Flows To (GWh) Northern Kazakhstan	Southern Kazakhstan	Kyrgyz Republic	Tajikistan	Turkmenistan	Uzbekistan
Power Flows From (GWh)	Northern Kazakhstan	X	15 040	0.0	0.0	0.0	0.0
	Southern Kazakhstan	175	X	6 493	0.0	0.0	13 238
	Kyrgyz Republic	0.0	162	X	293	0.0	7 743
	Tajikistan	0.0	0.0	40	X	0.0	4 994
	Turkmenistan	0.0	0.0	0.0	0.0	X	0.0
	Uzbekistan	0.0	83	0.0	619	0.0	X

Table 17 - Power flows in 2011, GWh.

		Power Flows To (GWh)					
	2011	Northern Kazakhstan	Southern Kazakhstan	Kyrgyz Republic	Tajikistan	Turkmenistan	Uzbekistan
Power Flows From (GWh)	Northern Kazakhstan	X	13 958	0.0	0.0	0.0	0.0
	Southern Kazakhstan	157	X	5 202	0.0	0.0	12 591
	Kyrgyz Republic	0.0	171	X	343	0.0	6 902
	Tajikistan	0.0	0.0	12	X	0.0	4 814
	Turkmenistan	0.0	0.0	0.0	0.0	X	0.0
	Uzbekistan	0.0	70	0.0	728	0.0	X

Table 18 - Power flows in 2012, GWh.

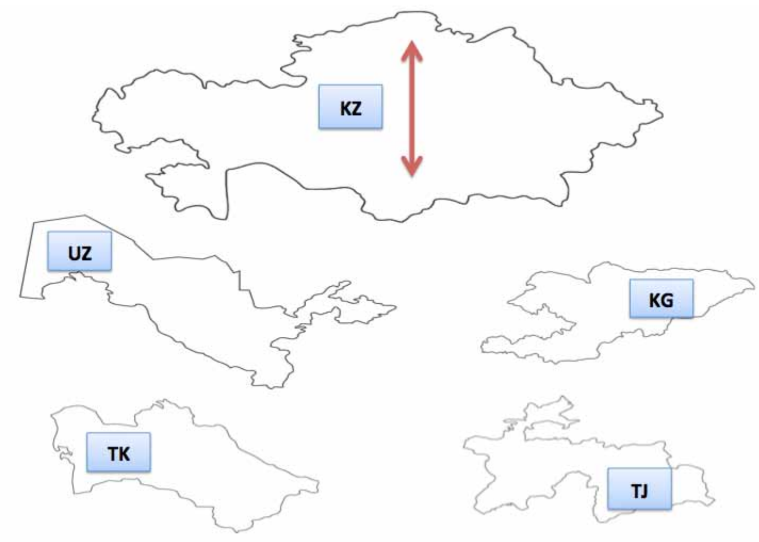
		Power Flows To (GWh)					
	2012	Northern Kazakhstan	Southern Kazakhstan	Kyrgyz Republic	Tajikistan	Turkmenistan	Uzbekistan
Power Flows From (GWh)	Northern Kazakhstan	X	12 239	0.0	0.0	0.0	0.0
	Southern Kazakhstan	311	X	4 467	0.0	0.0	11 384
	Kyrgyz Republic	0.0	217	X	299	0.0	5 836
	Tajikistan	0.0	0.0	12	X	0.0	4 829
	Turkmenistan	0.0	0.0	0.0	0.0	X	0.0
	Uzbekistan	0.0	120	0.0	712	0.0	X

7.3.3 CAPS-5 AND CAPS-4 NOT INTERCONNECTED.

In the case of no interconnected system, all the transmission lines are considered disconnected. And countries invest more in the power sector in order to have good security of supply levels.

However, the internal connection between the Northern and the Southern part of Kazakhstan stays in operation.

Figure 12 - CAPS not interconnected.



7.3.4 COMPARISON: BENEFITS OF JOINT OPERATION.

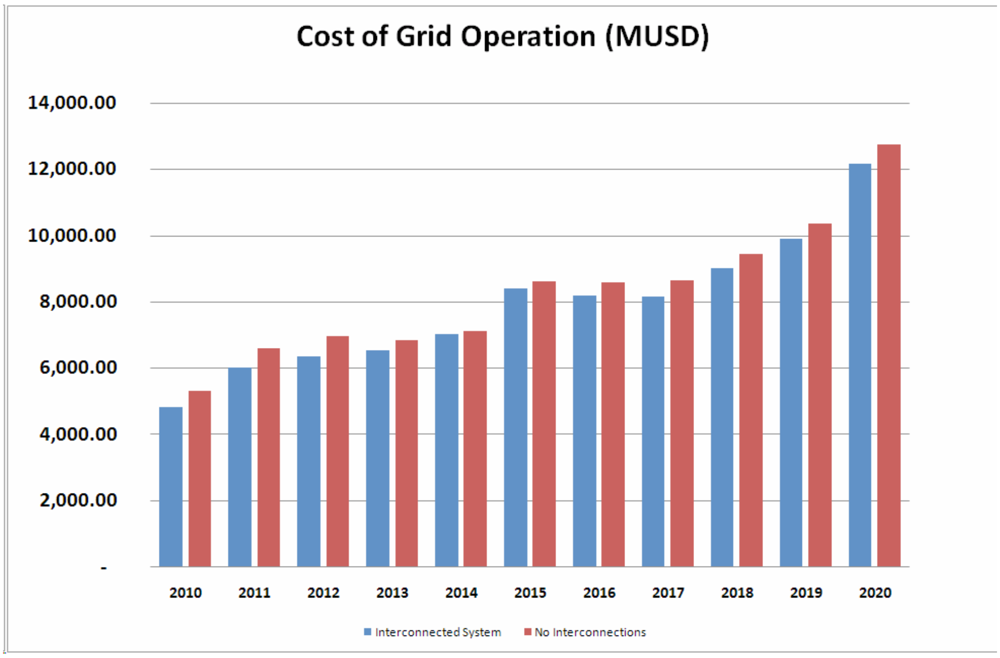
Grid operational cost savings.

The estimations of the costs are provided below. Total system cost includes cost of grid operation and cost for investment in new facilities. Cost of grid operation represent the backbone of the total cost and provides the majority of savings that could be obtained in the CAPS – if operated jointly:

- CAPS-5: 1,682 billion USD;
- CAPS-4: 1,640 billion USD.

From the figures below it can be seen that during the first years the cost of grid operations increase and in 2016 a cost decrease is expected. This trend can be explained by new investments in generation and transmission facilities that will happen by 2016.

Figure 13 - Trend of Total Costs of Grid Operation in CAPS-5.



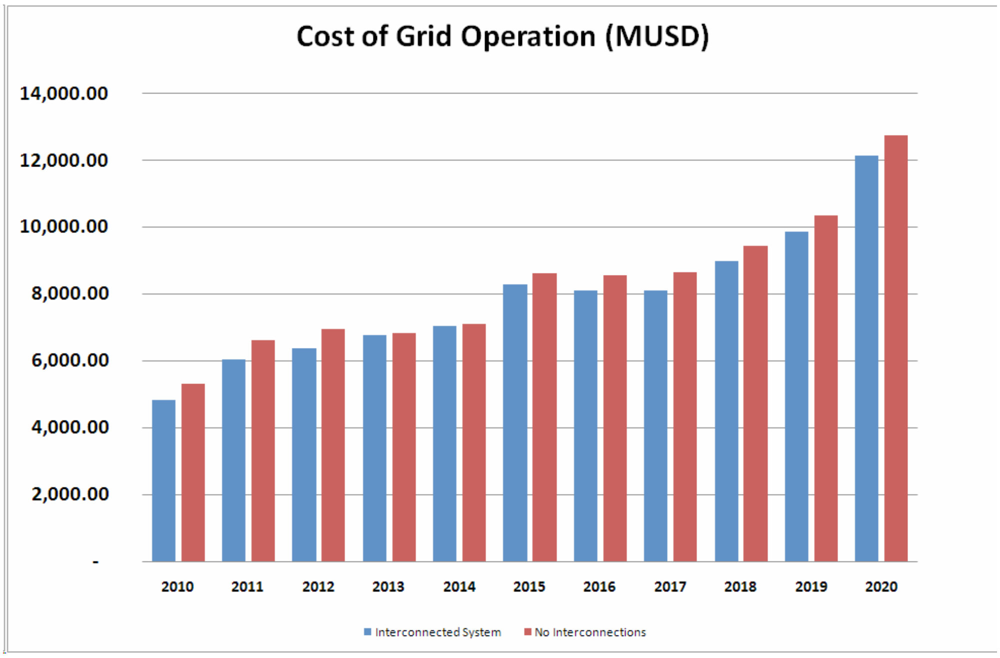
The next table provides, with cost comparisons, the difference between interconnected and isolated CAPS-5. Aggregated amount of cost savings during the first three years equals to 1.682 billion USD.

Table 19 – Costs of grid operation in CAPS-5 case.

Year	Interconnected System,	No Interconnection, MUSD	Savings, MUSD
2010	4 835	5 327	492
2011	6 022	6 612	590
2012	6 369	6 969	600

In the case of CAPS-4 the integrated grid operation, the general tendency remains the same as in the CAPS-5 case. With the commissioning of the projects-candidates, the regional dispatch becomes more optimal if the power interchanges are feasible.

Figure 14 - Trend of Total Costs of Grid Operation in CAPS-4.



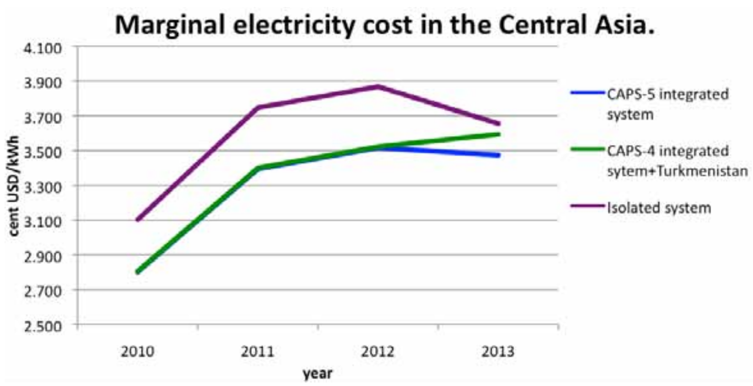
Due to the absence of power exchanges with Turkmenistan, the grid operation cost for the joint CAPS-4 operation appears to be slightly higher, if comparing with costs in the CAPS-4 scenarios. Aggregated amount of cost savings during the first three years is equal to 1.640 billion USD.

Table 20 - Costs of grid operation in CAPS-4 case.

Year	Interconnected System,	No Interconnection, MUSD	Savings, MUSD
2010	5 824	6 307	483
2011	6 657	7 234	577
2012	8 527	9 107	580

The savings are conditioned by the more efficient use of resources (fuel and hydro). This fact is clearly illustrated by the next figure, where average marginal cost of electricity in the first years is 10% lower in the case of joint operation than in the case of isolated operation.

Figure 15 - Tendency of average marginal electricity cost in CAPS.



The marginal electricity cost is growing together with the expected growth of electricity demand and of the fuel prices (see modeling assumptions), taken into consideration with the fact that no new capacities will be commissioned during 2010-2013.

It can be seen that in the beginning, the relative savings are growing over time. The increased trade volumes between the countries and the possibility to optimize the generation mix can explain this and the fact that in 2012 the electricity marginal cost decreases in the CAPS-5 compared to the CAPS-4 scenario. The regional generation mix, in this case, can be optimized in a more efficient way.

In 2013 the marginal cost is decreasing because new planned hydro capacity is commissioned, this leads to less thermal generation use. Therefore, the cost decrease is expected to happen in that year.

Increase in security of supply.

Savings benefits are possible in joint grid operational costs for CAPS members, also security of supply increases in the region, in the case of joint operation (CAPS-5/CAPS-4). In order to express it in terms of numbers, quantity of non-supplied energy was calculated for all scenarios.

As far as there is an opportunity for cross-border trading in CAPS-4 and CAPS-5 scenarios, there is no non-supplied energy, and the countries can jointly cover regional demand.

If countries decide to operate independently, during the first years there is a non-served energy (see figures expressed below). The total amount of non-served energy during the first three years this volume is expected to be equal to 2 654 GWh. The main reason is that countries do not invest in new generation before 2014, except the projects planned in the National Master Plans (see modeling assumptions).

Table 21 - Non-served energy in isolated operation.

Year	Non-supplied energy (GWh)
2010	823
2011	908
2012	923

If the non-served energy is monetized (for instance, at the cost of 200 USD/MWh), then joint operation leads to the additional savings of 530.8 million USD during the first 3 years of isolated operation.

The figures above show that more than 1.6 billion USD can be saved during the first three years if the CAPS countries implement a 'do-nothing approach', that is – letting import and export to take place in the region. No major investments are needed in this case. The savings are conditioned by the more efficient use of resources (fuel and hydro). In addition, in the case of joint operation, the security of supply increases in the region. This leads to an additional savings estimated at the 0.5 billion USD in the first three years. It can be concluded that more than 2.1 billion USD can be saved during the period of 2010-2012, if the countries in CAPS come to an agreement to jointly operate their grids.

8 EXISTING PROBLEMS ON THE REGIONAL LEVEL

From a technical and from an economical perspective, joint operations in CAPS are beneficial for all participants. However, it is important to understand the reasons that keep countries away from a common agreement on integrated operations. Among them are obstacles related to water and fuel issues, unscheduled power withdrawals, lack of common agreement on transit mechanisms, customs issues, lack of transparency in the energy sectors in most of countries and limited financial resources.

The analysis of the technical parameters for the whole regional system indicates greater technical cooperation could work. However further non-technical analysis indicates that an important inhibitor to greater regional cooperation is a lack of political will. There are a number of reasons for this. Below are listed the issues identified in the region that inform this analysis:

1. **Difficulties in power supply** to some regions. This includes the Kyrgyz Republic power system, in the North of the country in the Almaty region and in some remote areas of Tajikistan. The 220-500 kV ring power grid (with partly implemented second ring) in the CAPS satisfies electricity consumption for most consumers; however the regions mentioned above still require more investment.
2. In the region there is a **fossil fuel problem** this leads to a decrease in available capacity. The Kyrgyz Republic and Tajikistan have to import fuel from their neighbors. Due to increasing fuel prices, these countries cannot meet all their needs. According to existing practices, fuel supply contracts constitute part of the intergovernmental agreements. These agreements include water, gas and electricity. Therefore, if there are difficulties with the agreement on water, it will be reflected on the conditions for fuel and electricity, and vice versa.

   Tajikistan and the Kyrgyz Republic should include separately the fuel price in the electricity cost. According to the opinion of CDC Energy experts, the generation side in the Kyrgyz Republic is able to manage fossil fuel supply issues without the assistance of the Kyrgyz TSO (NESK). Exclusion of the fuel component from the intergovernmental agreements may be an acceptable solution to enable an agreement to be made on joint operations in CAPS.
3. Unclear **customs office** issues. The document with the transit services calculation methodology proposal was ratified by all CAPS countries, excluding Uzbekistan. For the Uzbek government electricity is a good and certain imposts should be paid even for transit goods. However, they do not have a clear position on customs duty.
4. **Water issues**. Each of four countries in the region has different interests in the water from the rivers that are in common usage. Water constitutes key parts of the intergovernmental agreements; further efforts should produce a beneficial equilibrium for all parties.
5. **Construction of Rogun and Kambarata-1, 2 HPPs**. Construction of Kambarata-1 will give the possibility to control all the water in the Syrdarya River. The Kyrgyz Republic, in turn does not provide down-stream countries with commitments to avoid harming their economic and social interests. The do not commit to releasing water during summer months when irrigation is needed. Therefore, water agreements need to be reached.

   According to the opinion of Tajik neighbors, the construction of Rogun will lead to changes in the ecosystem of the region. The river flow will change, therefore more territories in Uzbekistan and Turkmenistan will need additional artificial irrigation. From the Tajik point of view, Rogun HPP construction is the only way to cover the existing energy deficit in the country. The only negative point regarding Rogun HPP, is the need to fill the reservoir for the first time. Then the river will be completely regulated. It would be advantageous to have agreement between the Central Asian countries beforehand.
6. The current **automatic protection system** is not adapted to the needs of the growing electricity network. Stemming from the initial design of the common regional network, strengthening the generation or transmission side in one country must take into account the altered flows and the need to modernize the automatic emergency system in the whole region. Current automatic protection systems in CAPS consist of old and outdated equipment.
7. **Lack of commercial metering system** decreases quality of system operations in CAPS. Metering devices currently in use are old-fashioned and do not correspond to international requirements.
8. **Failures to comply with the previously agreed daily schedules** in CAPS followed by the lack of payment. It happens frequently that the failed power system provider needs to pay for an unscheduled power withdrawal. If it is done during the same month, according to the

established agreements between countries, no penalty should be paid. If it is done later, the power system that failed should pay for more electricity than was consumed. Netting of debts and payment-in-kind are common practices in the Central Asia region. However, for the countries that have seasonal excess/deficit of power these contract conditions provide clear incentive to withdraw the electricity from the neighboring power system when they have a deficit and to pay it off in the period of excess power. In the past, these wrong incentives introduced more conflicts in CAPS. Another form of agreement should be proposed to reduce this practice.

9. **Lack of transparency** in the power sector of CAPS countries. Transparency of operations and third party access are important and necessary components for meaningful participation in any regional electricity market. Almost all the countries have vertically integrated power sector. Only Kazakhstan liberalized the sector and has recently introduced market mechanisms. In the rest of the CAPS countries, reforms in domestic regulation and industry (management, corporate governance), have been neglected or only recently attempted.

10. **Frequency and capacity regulation in CAPS.** As it was described in the section devoted to the operational and legal framework, Kazakhstan is operating in parallel regime with Russia. In the case of joint operation in CAPS, all the payments for regulated services provided by Russia to Central Asia should be transmitted to the rest of CAPS. Agreement on this point should be reached between Kazakhstan and other countries of the region.

11. In CIS countries there are **limited monetary and financial resources** for energy (fossil fuel and electricity) market development. Because of the lack of investments, significant hydro potential in Tajikistan and the Kyrgyz Republic is not used efficiently. The old and inefficient equipment in the thermal power station needs modernization and significant investments as well.

12. **Decrease of base load consumption**, caused by the collapse of industry in the post-Soviet period. Now, consumption is mostly based on household demand. This requires adequate regulated services, which must be imported to Uzbekistan and Southern Kazakhstan.

These are the major problems that were identified during discussions with representatives of each country’s power sector. Solutions to these issues are proposed next.

It should be stressed that none of the countries of the region will have any benefits from isolated operations. In the case of the breakdown of CAPS drastic consequences will touch every Central Asian country.

9 SOLUTIONS

One of the main issues is the lack of confidence of CAPS members on the benefits of joint operation. Rebuilding confidence requires mitigation of the negative effects of joint operations related to unscheduled flows, security of supply, and negative impact of transits. The range of measures can be proposed, depending on the costs and time needed for the implementation.

The proposed measures can be classified in three categories (stages):

1. Measures that can be implemented in the short term and with relatively low costs (1-2 million USD). The target is to increase regional power trading to a significant level that is compatible with existing cross border facilities. This should occur without introducing changes to CAPS members' internal regulation and organization. Changing the internal power structure of members is usually a disincentive to join a regional market. An important part of the benefits of cross border trading can be achieved without changes to internal regulation/organization. The only key issue to create a regional market is to obtain the willingness of the countries to participate.
2. Measures that involve medium term targets, and also intermediate costs (1-10 million USD). In this stage it would be necessary to achieve some level of regulatory harmonization, which does not involve changes to the organisation of the internal power sectors.
3. Reinforcement of the transmission and generation system, which involves long maturation times and relevant investments (hundred million USD). In order to optimise the use of the new facilities, CAPS members should increase the regulatory harmonization, aiming for the creation of an efficient regional energy market.

Stage 1, the main target is to address the problems that are encouraging CAPs members to leave. CDC Energy, with participation of representatives of all the CAPS members should implement these measures. These include the following:

1. Organise seminars aimed to identify the (perceived) drawbacks of joint operation. Identify the immediate measures to correct these drawbacks (probably most of them can be corrected in the first stage). Numerically show the benefits of joint operation.
2. Improve the regional control system, aiming to reduce unscheduled flows (deviations). Review primary frequency control and AGC coordination, in order to identify the reasons of high unscheduled flows and to implement corrective actions.
3. Establish a fair methodology to settle or compensate unintended deviations. Although a methodology based on compensations is reasonable, given the difficulties to establish a fair price for deviations, these compensations should aim to reflect the cost of energy production (actual generation costs, supply/demand balance, etc.). Unintended deviations should be priced hourly. Power should be compensated at the same time when the deviation occurred (for instance, deviations happening on peak hours of working days should be compensated during another peak period on a working day).
4. Review the protection coordination, to ensure that a failure in a system will not lead to outages in other CAPS countries.
5. There is a need for comprehensive load flow and stability analysis at country and regional level. Identify the existing problems and the appropriate solutions.
6. According to the latest regulations approved for CIS countries, each country has to maintain:
   a. Agreed net power flow
   b. Agreed reserve for frequency and capacity regulation.

   If it is unfeasible from a technical or economical perspective to provide reserves for regulation, the system operator can sign agreements with neighbouring countries on a provisional basis for primary frequency regulation. It is a widely used practice (e.g. in the Baltic countries).

   In the case of an unbundled power sector, such as in Kazakhstan, another solution would be to introduce the system of capacity requirements. This operates in the PJM market on the East Coast of the USA. In this system, the retail companies are required to purchase a certain percentage of reserve capacity. The percentage is determined by the regulator. This reveals the demand for reserve capacity. The cost of providing the reserve capacity is passed along to the consumers by the retail companies who contract the capacity. The reserve capacity is tradable and may consist of interruptible load.

7. Define the type of commercial transactions linked to effective agreements on the joint operation in the CAPS (or in the CIS in general) that will be scheduled by CDC Energy. Initially this should be bilateral contracts, but in the medium term it should allow short term transactions based on marginal costs in each country.
8. Define a timeline for transaction information to be provided to CDC Energy, which then would be included in CAPS members' daily dispatch,
9. Buy or develop state of the art software to prepare daily regional schedules
10. Define a scheme for mutual support during emergencies, including an appropriate price for supporting power. The electricity supplied or demanded in this situation, by the support system is to be valued at the same price of unintended deviations in order to cover the cost and for it to be paid to the affected power system. The settlement of this power should be part of the monthly account balance.
11. Agree on a sustainable transit compensation methodology. This methodology should compensate the additional losses produced by transits, and re-dispatch cost when transit produces congestion in the hosting country.
12. Training and strengthening of dispatch centers staff (CDC Energy and national dispatch centers).
13. Improve and/or implement:
    a. Regional Grid code (which should reflect agreement on the issues described in bullets 2-4)
    b. Balancing and settlement procedures (which should include the agreements on the issues described in bullets 3-5-6-7-10),
    c. Disputes resolution methodology

       Establish mechanisms and procedures to ensure a speedy, efficient and cost effective administration of disputes that facilitates and provides for expert advice and decisions, and adequate processes in dispute resolution within CAPS. This will help determine requisites and mechanisms that ensure non discriminatory and transparent dispute resolution procedures.
    d. Methodology to make decisions on regional issues
14. CDC Energy should be supported by all national dispatch centers and/or transmission system operators to allow it to perform generation and transmission adequacy assessment each year.

    Generation adequacy assessment describes how each country could satisfy its interior load with the available national capacity. Transmission adequacy assessment then investigates whether the transmission system is large enough to enable the potential imports and exports resulting from various national power balances, thus improving the reliability of CAPS.
15. For the liberalized power sectors (such as in Kazakhstan), the investment risk in peaking capacity could be greatly reduced by the use of long-term contracts. Moreover, long-term contracts would reveal the expected future demand for peaking capacity to generating companies, as the retail companies (who purchase power on behalf of their customers). This would reveal their peak supply demand when negotiating contracts. This would improve the availability of information for generation companies and therefore reduce their investment risk. Long-term contracts would remove much of the price volatility, which is a risk for generators and consumers alike. An important additional benefit of long-term contracts for consumers would be the removal of the incentive to withhold capacity during periods of scarcity.

The second stage should aim to improve the supervision and control hardware, install commercial metering, developing a regional database where the technical, economical and regulatory data would be stored, implement software for daily dispatch, real time re-dispatch, post operational calculations and settlement of deviations and transit compensations.

During this stage CDC Energy should develop a regional plan to identify expansions to the regional transmission system that would optimise joint operation of CAPS, including transactions with neighbouring countries. The planning may also identify generation projects at a regional scale. Members of CAPS should agree on the expansion plan and on an implementation action plan.

The third stage should aim to expand the transmission system based on the planning performed by CDC Energy.

ANNEX I.

CAPS DIAGNOSTIC BY COUNTRY.

Uzbekistan.

Primary resources.

Uzbekistan has large fuel reserves. According to the assessment of existent natural resources, Uzbekistan has a potential of:

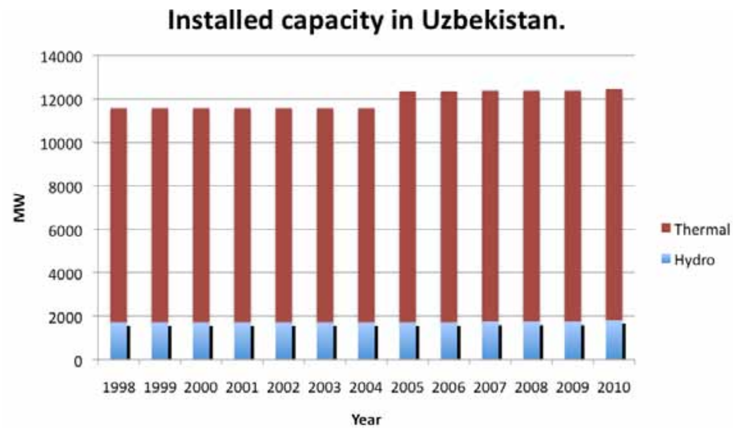
- 1,873 bln m3 of natural gas
- 4 bln tones of coal

During the last fifteen years oil and gas production has significantly grown comparing to the level of 1995, whereas the coal production has strongly decreased. Now Uzbekistan is one of ten biggest gas producers in the world. The pattern of primary resources consumption includes 12% of oil products, 84% of natural gas, 2% of coal, and 1% of hydro resources.

Generation side.

Uzbek power sector consists of 10 thermal and 28 hydro power stations with the total installed capacity of 12 453.7 MW, with 10 643 MW of thermal power plants and 1 810.7 MW of hydro units. The evolution of installed capacity in the country can be seen at the figure below.

Figure 16 - Installed capacity in Uzbekistan.



The Uzbek economy is fuel dependent. Among new objectives in the energy sector is the decrease in natural gas consumption. For this purpose, Novo-Angren TPP (with total installed capacity of 2100 MW distributed among 5 blocks) will be switched to the domestic coal and will become the power plant that operates during the whole year. It is expected that this step will decrease operational costs. However, it will force Novo-Angren TPP to operate constantly on a base load basis.

Transmission network.

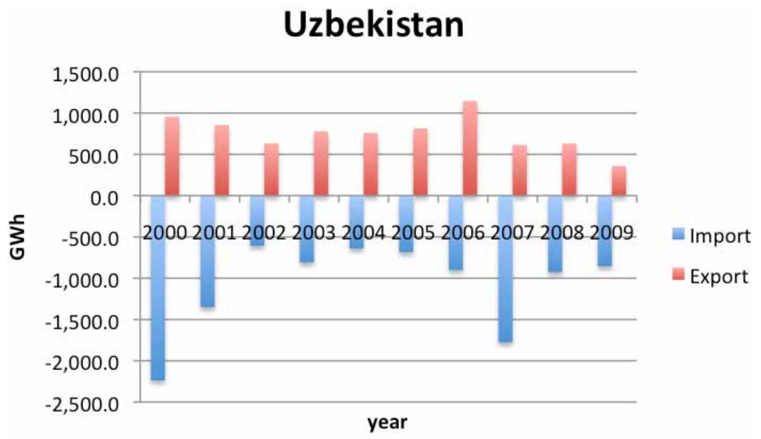
Transmission network in Uzbekistan was developed in the Soviet time as a part of regional grid in Central Asia. Up to the latest time, the design of the grid implied the need of the Kyrgyz transmission network to supply Fergana valley in Uzbekistan. Currently, with the construction of the second transmission ring, Uzbekistan can supply this location using its own facilities.

There are **line congestions** on the 500 kV lines: Sogdiana-Syrdarya TPP (the second line is under construction) and Regar-Guzar are the bottlenecks of the Uzbek power system. Uzbekistan is building the 500 kV line Angren – Uzbekistanskaya to establish its own 500 kV loop wholly within Uzbekistan. It is expected that with the commissioning of this line the congestion issue will be solved.

Import-export.

Looking at the retrospective of the import-export policy in Uzbekistan during the last ten years, the seasonality should be mentioned: Uzbek power system was importing the cheap hydropower from Kyrgyz Republic and Tajikistan during summer time, and exporting the excess of energy (around 1 TWh on average) in winter-time to Tajikistan.

Figure 17 - Import-export in Uzbekistan.



Since December 2009, Tajikistan is working in the isolation from the rest of the CAPS. Uzbekistan is supplying several remote areas located to the North of Tajikistan (360 GWh has to be supplied in 2010 according to the bilateral agreement between countries). Currently Uzbekistan is exporting to Afghanistan as well.

Critical issues.

Almost all the power is generated at thermal power stations using gas as a primary fuel. There is no large hydro potential to be developed and renewable energy sources are still very expensive for installation. Uzbekistan may suffer problems with **frequency regulations** and fossil fuel supply because of its higher reliance on expensive thermal generation.

As far as thermal generation operates more efficiently in the base-load, issue of capacity deficit for regulation purposes becomes of the first priority, especially if the cost optimization is one of the objectives). Out of the hydro power stations in Uzbekistan, only Charvakskaya (620 MW) and Hodjikentskaya (150 MW) can provide the regulation services as far as the needed capacity range is more than 2 500 MW. Normally the automatic protection system is activated 50-70 times per day leading to the load shedding. However during the last 9 months since Tajikistan had started to operate as an isolated regime, this number has increased.

According to the bilateral contract between Kyrgyz Republic and Kazakhstan, Toktogul HPP covers 160 MW capacity deficit in Uzbekistan. If the deficit is more than 160 MW, then this is covered by its own generation or by load shedding. Therefore there can be power exchanges between Uzbek and Kyrgyz power systems. According to the existent agreements, these energy imports should be returned back during the same month in order to comply with the agreed energy balance. If it is not complied, Uzbekistan should additionally pay for the energy consumed during the peak hours.

If Uzbekistan aims at covering the daily peak by its own generation, it leads to the considerable economic losses and strong wear of TPP equipment as far as TPPs should be loaded three hours in advance.

The installed capacity of Uzbek power system allows increasing the export volume that is currently restricted by the fuel availability and available generation. Therefore the most appropriate economic solution to deal with the frequency and capacity regulation issue would be to take advantage of well-developed interconnections with neighbors that have strong hydro potential, such as Kyrgyz Republic and Tajikistan.

Besides the lack of capacity for regulation purposes, there is another reason for load shedding – **scarce automatic protection systems**. According to the existing practices, the automatic protection system modernization is not always done when new generation and/or transmission facilities are constructed. For instance, there is a lack of an automatic protection facility on the existing 500 kV line in Uzbekistan. Therefore the system cannot operate efficiently.

Conclusions.

The analysis of the isolated Uzbek system shows that the installed capacity is enough to cover national needs and that the transmission and distribution system (including recently completed projects and the ones that are currently under development) is sufficiently developed for supplying Uzbek consumers. However there is a lack of generation that can meet peak demands. In the past, the Uzbek power system relied on Kyrgyz and Tajik hydro capacity to provide capacity regulation and to cover daily peak loads. If Uzbekistan must cover daily peak with its own generation then this will lead to considerable gas losses and extra wear on power stations. Existing TPPs are not suitable for dramatic load surge and dip. The experts from the CDC "Energy" noted that in order not to interrupt consumption during peak periods, TPPs have to be loaded at least three hours in advance.

It is important to state that Uzbekistan holds a strategic central location in the region and is connected to all the four CAPS countries. However, since the 500 kV lines with Tajikistan are switched off, and Turkmenistan connection is not available, the only transmission links with Kyrgyz Republic are currently used for Kyrgyz transit needs and for regulation purposes in Uzbekistan. Power system experts in Uzbekistan consider that upon completion of 500 kV line Angren-Uzbekistanskaya, Uzbekistan potentially can operate in isolation. The drawback of the Uzbek isolated operation is that it would not allow transmitting any output of hydropower plants in the Naryn Cascade downstream from Toktogul, thus limiting the power supply to the North of Kyrgyz Republic to the throughput of the sole 500 kV line Toktogul-Frunzenskaya.

Kazakhstan.

Primary resources.

Kazakhstan is rich in terms of primary resources. There is a potential of:

- 0.8-2.5 bln tones of oil;
- 1 840-1 980 billion m3 of natural gas;
- 185 bln tones of coal.

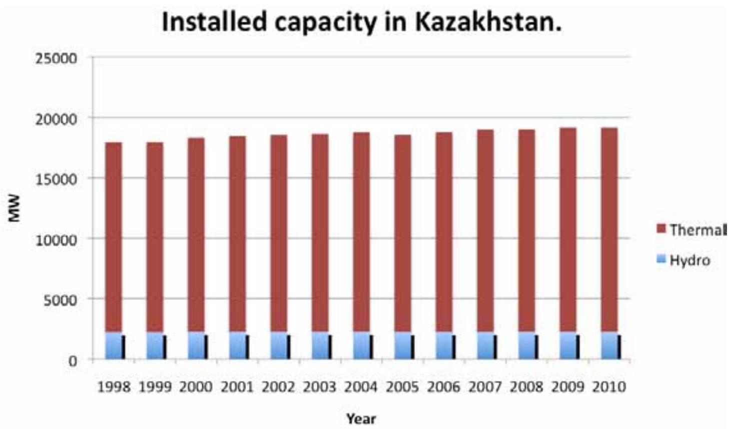
During the last fifteen years the gas production has grown comparing to the level in 1995. After the disintegration of the Soviet Union, the coal production had decreased from 127 mln tones in 1992 down to 58 mln tones in 1999. However, Kazakhstan still remained the main coal producer and exporter in the CIS, and in the beginning of 2000^{th} the country started to recover the previous coal production level. Now Kazakhstan is one of twenty biggest gas producers in the world. The primary resources consumption pattern includes 29% of oil products, 20% of natural gas, 49% of coal, and 2% of hydro resources.

The gas issue is important in the relations with Uzbekistan. Kazakhstan is interested in buying gas from Uzbekistan and then exporting it to Russia. However, price issues have not been solved yet. Winter restriction regarding the extraction and transportation of gas should be considered as well.

Generation side.

Kazakh power sector is characterized by the old, insufficient and expensive generation. The total installed capacity is 19 184.1 MW, with 16 920.1 MW of thermal power plants and 2 264 MW of hydro units. 70% of total generation in Kazakhstan is produced from nationally sourced coal. In the Southern Kazakhstan gas turbines are used.

Figure 18 - Installed capacity in Kazakhstan.



Currently there is a capacity deficit in Kazakhstan covered by the Russian Balancing market. In order to decrease and further eliminate this deficit new power plants are being constructed and the old ones are upgraded:

- Balkhash TPP (1320 MW) is under construction
- TPPs are being upgraded now – it will bring 1 500 MW additionally to the grid in 5 years

It is expected that due to the undertaken measures in five years the deficit will be covered.

However, new project are mainly developed in the Northern region of Kazakhstan. Currently there are no big projects in the South of the country (the part of the CAPS) where the generation side is not sufficient to cover the constantly growing demand: e.g., Jambyl GRES (1 230 MW) units run only in winter period because of lack of fuel and its high price.

Power sector of Southern Kazakhstan (incl. Almaty region) consists of 9 thermal and 4 hydro power stations. There are 4 small hydro power plants installed in Almaty region. The total installed capacity of 3 401.2 MW, with 2 457 MW of thermal power plants and 526 MW of hydro units.

Transmission network.

There are three main separated zones in Kazakhstan: Northern, Southern and Western. The Northern and the Southern are interconnected one with each other and with are linked as well to the Russian and Central Asian power systems. The Western part of the region is formed by four nodes: Aktyubink, Uralsk, Atyrau and Manghistau, where last two nodes have no connections with the Northern and the Southern Kazakhstan and are supplied by the Russian electricity company.

Supply opportunities from the Northern to the Southern Kazakh region previously had been restricted by the bandwidth of the North-South 500 kV line. Recent commissioning of the second 500 kV transmission connection between two parts of the region improved the situation significantly, however, the deficit in Almaty node still remains where the 500 kV congestions happen and the voltage level on the Substation A-A 500 is decreasing down to the emergency level of 475 kV.

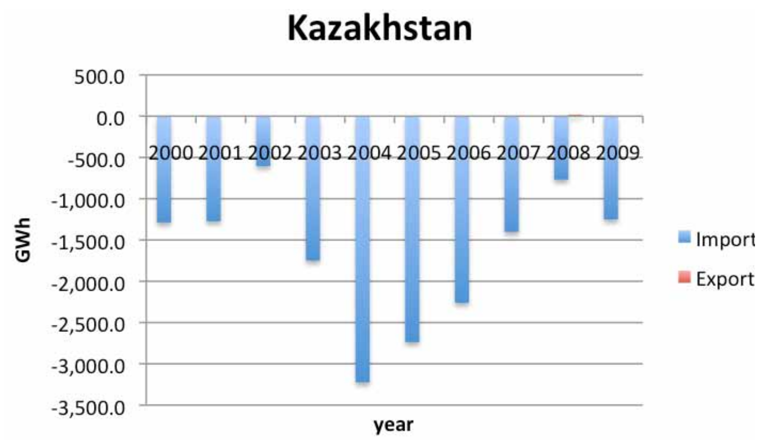
Import-export.

The Southern Kazakhstan power system is the deficit one. The ways to cover the existent power deficit are the next ones:

- by the electricity supplied from the Northern Kazakhstan;
- by the electricity supplied from the CAPS.

Southern Kazakh power system is importing one

Figure 19 - Import-export in Southern Kazakhstan.



According to the historical data, power system of the Southern Kazakhstan has been importing electricity, covering by this its existing deficit.

Existing agreements with Kyrgyz Republic are beneficial for the Kazakh side and are usually connected to fuel and electricity: Kyrgyz Republic is supplying Kazakhstan with the electricity, depending on Kazakhstan exports of coal to Kyrgyz Republic.

Critical issues.

As far as the generation side in the Southern Kazakhstan is mainly thermal, there is a lack of regulated capacity and **frequency and capacity regulation problems**. Currently frequency control in the South Kazakhstan is contracted through the regulatory services of Kyrgyz HPPs. In the hours of peak maximum (20-21pm) Kyrgyz Republic sells power to the South Kazakhstan and provides frequency control services as well. According to the data provided by the Kazakh Ministry of Energy and New technologies, Kyrgyz services are paid.

Conclusions.

The analysis of the Southern Kazakh power system shows that the installed capacity is not enough to cover national needs and that the transmission and distribution system still has to be strengthened to supply Kazakh consumers. There is a lack of hydro generation that can meet peak demands. Existing TPPs are not suitable for dramatic load surge and dip. The existent agreement between Kazakh and Kyrgyz government became an appropriate solution for the both counterparties, and makes it possible to cover energy and capacity deficit in the Southern part of Kazakhstan.

Kyrgyz Republic.

Primary resources.

Kyrgyz Republic has large hydro reserves. The estimated hydro potential of the country is higher than 163 TWh, while less than 10 % of this potential is currently used. The main focus now is to develop the strong hydro potential.

In terms of fuel resources, Kyrgyz Republic has relatively rich reserves of coal and according to the opinion of national experts, the mining in Kara-Kech could eliminate the coal import necessity. According to the assessment of existent fuel resources, Kyrgyz Republic has a potential of:

- 5.7 bln m3 of natural gas (but it is difficult to be reached)
- 5.7 mln tones of oil

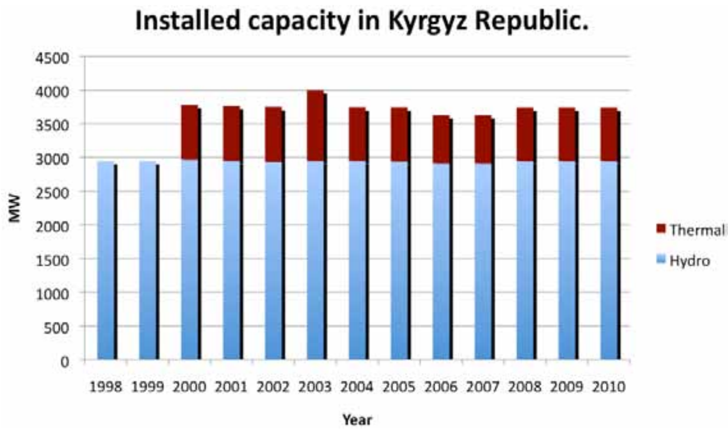
After the collapse of the Soviet Union, the coal production has significantly decreased from 2.2 mln tones in 1990 down to 0.41 mln tones in 1999 (80% lower). Currently, the oil and gas production is very low. Kyrgyz Republic became the pure importer of fossil fuel. The primary resources consumption pattern includes 25% of oil products, 21% of natural gas, 20% of coal, and 33% of hydro resources.

Generation side.

Total electricity generation in the country is about 14 TWh, 90% out of it is produced from hydro.

Total installed capacity in the Kyrgyz Republic is approximately 3 640 MW, where 2 910 MW are hydro power plants and 730 MW are thermal ones. Hydro power plants are mostly located at the Naryn cascade on the Southern part of the country, while the electricity in the Northern part is generated by the thermal power plant, with the major Bishkek power plant of 666 MW.

Figure 20 – Installed capacity in the Kyrgyz Republic.



About 2.5 TWh of electricity (corresponds to the 2.3 bln m3 of water) produced in the Kyrgyz Republic can be exported during the vegetation (summer) period. According to the opinion of specialists, year 2010 is wet one (the reservoir water level in Toktogul is growing by 30 sm daily). Basing on the very modest estimates, the existed power excess equals to 2.8 TWh.

During the last several years, fuel supply of the Bishkek TPP has become problematic. It is one of the reasons why Toktogul HPP has switched the mode of operation from the irrigation to electricity production.

Transmission network.

The major part of electricity production is concentrated in the Southern part of Kyrgyz Republic, while the main load centers are situated in the Northern region. The power supply from the South to the North is performed in the next manner: Kyrgyz Republic supplies consumers in Fergana valley in Uzbekistan, while power generated at the Uzbek CHPs (about 13 GWh) is transported to the Southern Kazakhstan and then to the Northern Kyrgyz Republic.

The North of Kyrgyz Republic is supplied via the sole 500 kV line Toktogul-Frunzenskaya. The line can transmit 1000-1100 MW while the total demand in the North of Kyrgyz Republic is 1600-1900 MW. The rest of the power needed to meet the load is transmitted from the Naryn cascade through the Central Asian 500 kV grid: Toktogul-Lochin (UZB) – Syrdarya (UZB) – Tashkent (UZB) – Chimkent (KAZ) – Jambul (KAZ) – Almata (KAZ) (From there the power goes to the North of Kyrgyztan through four 220 kV lines).

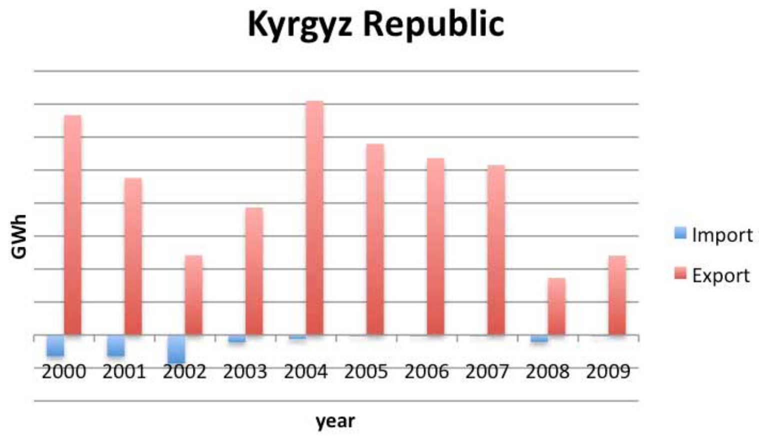
Uzbekistan is building the 500 kV line Angren – Uzbekistanskaya to establish its own 500 kV loop wholly within Uzbekistan. Upon completion of this line, Uzbekistan can potentially operation in isolation that will not allow transmitting any output of hydropower plants in the Naryn Cascade downstream from Toktogul, thus limiting the power supply to the North of Kyrgyz Republic to the throughput of the sole 500 kV line Toktogul-Frunzenskaya. It can result in substantial deterioration of reliability as well as in significant deficits (around 20-30%) in the Northern part of the Kyrgyz energy system.

The North-South link is of primary importance as well. Considering the existent network topology in Kyrgyz Republic, it would appear almost impossible to operate in the isolation of other CAPS countries: to supply consumers in the south and to cover a power deficit in the north. The South of Kyrgyz Republic (Osh and Batken region) is supplied by 220 kV lines from the Uzbek Grid and by electrical links via the 110 kV line from Jalal-Abad oblast. In order to facilitate the supply to the southern areas, the 500 kV Datka substation and associated 220 kV lines are to be built. An investment agreement with a Korean company to construct the Datka substation was signed in December 2008. The construction period is estimated to be 4 years.

Import-export.

The Kyrgyz Republic is an electricity exporting country. The main export flow from Kyrgyz Republic goes to Uzbekistan and Southern Kazakhstan. It corresponds to 15% of the total power produced within the country. The power export is based on the governmental irrigational agreements related to the exploitation of the Toktogul reservoir. Taking into account that the Toktogoul reservoir is used for long-term water storage for irrigation and agricultural purposes for the down-stream countries; its water usage is regulated by yearly international agreements. This leads to controlled water usage for irrigation and energy exports in the summer period and restricted water usage and energy in wintertime. Therefore, energy trading is the side product of the water usage agreements. A small share of the electricity export volume goes to Tajikistan as well.

Figure 21 - Import-export in the Kyrgyz Republic.



Currently the export volumes are comparably low and correspond basically to the technical power exchange in order to maintain stability and balance in the system.

Critical issues.

One of the main priorities in the Kyrgyz Republic is development of new hydro generation. The largest project that is planned to develop in the future is construction of the Kambarata-1 and 2 (1900 MW and 360 MW correspondingly). The construction will take place on Naryn River, in the part of the stream located higher than Toktogul reservoir. It is expected that these new hydro capacities will help to cover energy needs of the country and will increase the electricity export within the CAPS region, permitting Toktogul reservoir to switch back to the irrigation regime. Currently, Kambarata-2 is under construction.

However, **water issues** will become more sensitive. The Syrdarya-river will be controlled completely. In the case of isolated operations, Kyrgyz Republic, following the logic of security of supply, will save water for wintertime power production. Therefore in summer there will not be enough water for irrigation purposes. This issue should be addressed very carefully. With the commissioning of Kambarata-1, the importance of the joint power system operation will increase including the export issue which will be central.

Conclusions.

The main issue in Kyrgyz Republic that is the need for additional investment in power sector. Without commissioning of new generation and transmission capacities, after a while the Kyrgyz Republic power system might become a deficit one. As it was already mentioned, customers of Osh and Jalal-Abad economic regions currently are electricity dependent upon the grids of neighboring states. In winter Kyrgyz Republic has to purchase electricity from the neighboring countries or to pay them for transit services, while in summer there is electricity generation surplus in Kyrgyz Republic.

One more important issue to be mention is that during the last few years a critical situation exists in the electricity sector of Kyrgyz Republic in terms of general losses and accounts payable for consumed heat and electricity.

Tajikistan.

Primary resources.

The major primary energy resource in Tajikistan is its considerable hydro potential (more than 300 TWh). Currently around 5% of this potential has been used. Other fossil fuel natural resources are limited.

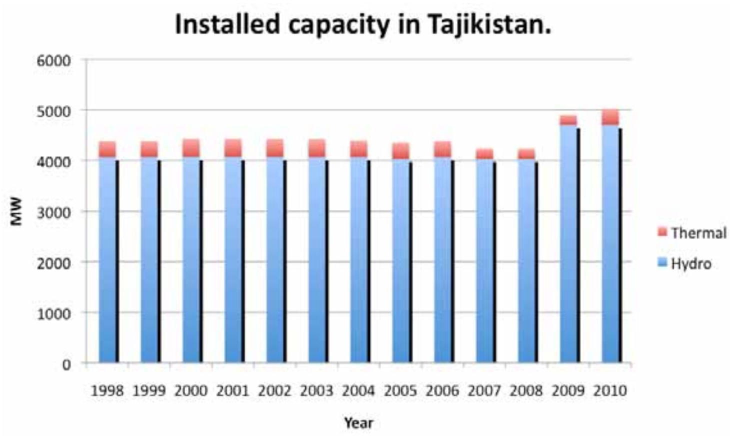
The consumption of oil and natural gas in the country exceeds in several times its production. Major part of fuel consumed in the country is imported from the neighboring countries. It should be mentioned that while the fuel consumption is increasing, its production is decreasing year by year.

The primary resources consumption patters includes 39% of oil products, 28% of natural gas, 2% of coal, and 32% of hydro resources.

Generation side.

Total installed capacity in the Tajikistan is approximately 5 025 MW, where 4 706 MW are hydro power plants and 319 MW are thermal ones. Hydro power plants are mostly located at the Vahsh cascade on the Southern part of the country, while in the Northern part only 126 MW of installed hydro capacity are located.

Figure 22 - Installed capacity in Tajikistan.



Tajik power sector is heavily dependent on the electricity generated from hydropower that constitutes more than 17 TWh (95% of total electricity generated in the country). This holds the possibility for the whole region to be supplied by low cost electricity. However, by analysis of the present situation, it can be stated that corresponding agreements and joint grid operations are necessary to take advantage of this potential.

Power system of Tajikistan can be defined as the energy deficit one, with the dominating electricity production on the Vahsh river. Its annual generation is not able to cover the winter demand. Since October till the end of April each year there is a 4 TWh deficit in the country. Therefore the demand restrictions and load shedding are introduced in Tajikistan in winter period. From the other hand, there is power excess in summer. The variation interval depends on the hydrology and water content of the current year. In 2010 it has been too high, equal to 4.5 TWh. Being disconnected from the main grid, Tajikistan cannot export power and consequently spills water.

Transmission network.

The national power system is not developed enough to supply all the consumers with electricity. Therefore for Tajikistan there is a clear necessity for neighbors' assistance in supply issues. Recently 500 kV line North – South was commissioned. This line, which was recently commissioned by a Chinese company had to be improved partly to supply the North. Its carrying capacity is enough to supply the northern regions of the country. However, the substations have not been upgraded – there is only one transformer in place. Because of this it introduces restrictions on network operation: maintenance works are impossible to perform on the line. Moreover, it is possible to use only 1/5 of its transmission capacity (300 out of 1500 MW).

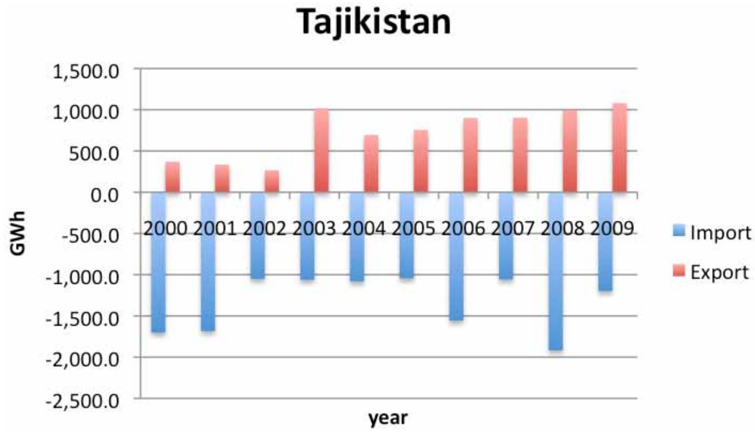
Even though, Uzbekistan decided not to continue with the parallel operation with Tajik power system, it still supplies the remote areas in the northern part of Tajikistan on the prepaid basis. In other words, currently Tajikistan cannot operate completely independently. Upgrading of the network is needed for that purpose.

One more point to mention in this Section is that the network equipment is very old and remains from the Soviet period, as in the majority of the CAPS installations. About 30% of the load shedding happens because of failures in transmission or distribution networks.

Import-Export.

Tajikistan is characterized by its seasonal hydro generation: with the energy excess in summer and deficit in summer. Previously Tajikistan was selling its surplus in summer time and buying power in winter. Since 2009, the new HPPs Sanktuda-1 (670MW) has been commissioned (Sanktuda-2 (270MW) is currently under construction) and now the summer surplus will increase up to 4.5 TWh annually. Just during May 2010, 100 mln m3 of water was spilled. If Uzbekistan were exporting all the electricity lost this summer by Tajikistan, natural gas could be saved and then beneficially sold.

Figure 23 - Import-export in Tajikistan.



Currently because of the absence of interconnections with the rest of the CAPS region, Tajikistan cannot take an advantage of its seasonal generation, as far as there is no possibility to export same energy volumes to their neighbors (the only export that is taking place now is the power flow to Afghanistan).

Critical issues.

As it has been already mentioned, the most important point to consider while characterizing the Tajik power system is its **seasonal power generation with deficit in winter and excess in summer**.

Compared to previous years, electricity production and consumption has declined significantly. This stems from political, commercial and technical problems, which have reduced, and almost eliminated import volumes. Also, power generation levels decreased due to operational difficulties in the hydro power stations (lack of financial resources for upgrading and rehabilitation). Consequently, there is a power deficit in the system, especially in the winter and spring.

Remote areas appeared to be without power supply from Tajik generation facilities. There is no reliable electricity supply for the most of regions and often equipment failures became the result of lower-than-rated voltage in the network.

In order to cover winter peaks, the vertically integrated electricity company in Tajikistan, Barki Tochik, previously agreed on import contracts with neighbors. At the beginning of December 2009 two 500 kV lines were disconnected, and Tajikistan started to operate as an isolated power system. It led to an increase of load shedding. Load shedding mostly happens during periods of deficits, in winter/spring, some regions do not receive more than 4 hours of power daily. It is estimated that around 70% of the total number of outages are caused by the lack of generation. However, because of the mild winter of 2009-2010 and adequate water levels in reservoirs, this increase was not crucial.

Related to this is the fact that excess water during the summer, and the lack of storage possibilities (seasonal water management), leads to the inefficient use of water, associated with spillages and enormous losses in economic terms.

If operating in an isolated regime, additional investments in the generation side are essential to provide a reasonable level of security of supply.

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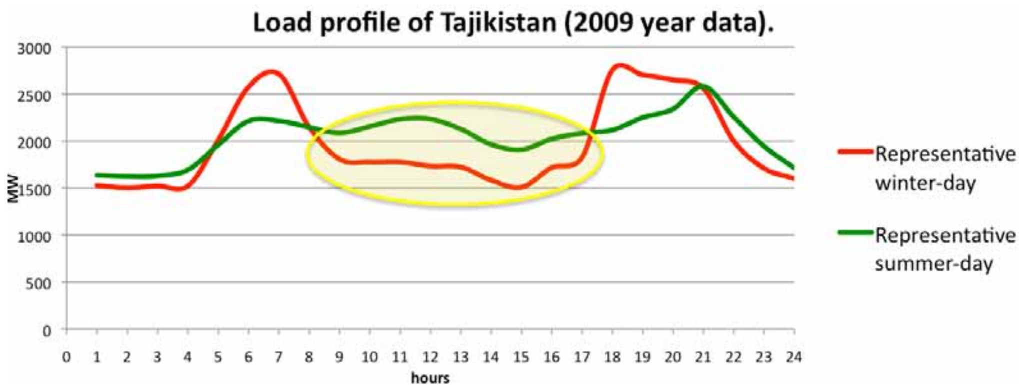
If operating in an isolated regime, additional investments in the generation side are essential to provide a reasonable level of security of supply. However, **water issues** will become more sensitive, as in the case of Kyrgyz Republic. Tajikistan is planning to construct the Rogun HPP (3600 MW). This power plant would become of the regional value. But from the other hand it might make collaboration in water sector in the Central Asia more complicated. It will need more willingness to cooperate and the give more importance of the joint power system operation.

Conclusions.

The analysis of the Tajik power system shows that there is energy deficit in winter and energy excess in summer. Previously energy deficit was covered by the export from the neighboring countries. Since the December 2009 Tajikistan has been operating in the isolation from the rest of the CAPS and therefore, cannot continuously supply consumers during winter months. It leads to the considerable amount of the non-supplied energy directly related to the social suffering and economic losses.

The figure below illustrates the rough estimation of the non-served energy in wintertime in Tajikistan. Statistical data used for these purposes is the satisfied demand in the country. It appears that power supplied to the consumers in winter is lower than in summer. However, the actual winter demand should be higher than in summer because of the necessity to provide heating services as well (due to the lack of fossil fuel, main heating source in Tajikistan is electricity). Therefore it could be conjectured that the area above of the load profile for representative winter-day and below the load profile for summer-day (mainly since 9am till 17 pm) in Tajikistan is the non-served energy.

Figure 24 - Load profile of Tajikistan.



From the other hand summer excess cannot be completely sold as well. Because of the seasonal water management at all the Tajik reservoirs, there is a lack of water storage capabilities, and it leads to the significant economic losses in terms of spilled water.

Now Tajikistan mainly aims at strengthening of its hydro generation side and at development of new transmission lines. It will increase security of supply in the countries and will open new export opportunities to Afghanistan and then probably to Pakistan.

Turkmenistan.

<u>Primary resources.</u>

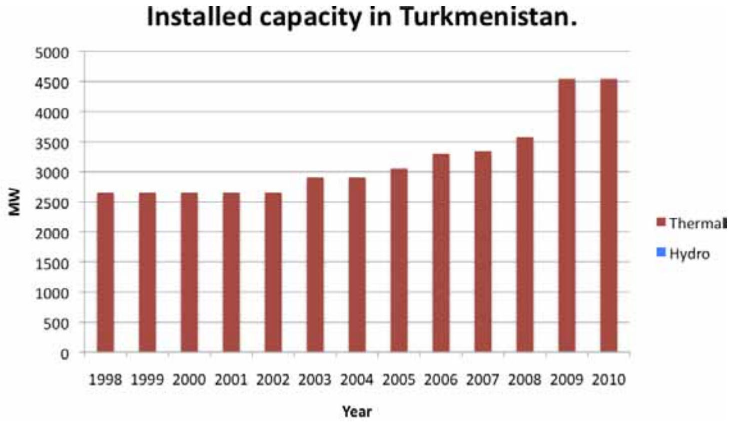
Turkmenistan has large fuel reserves, mainly natural gas. (2800 bln m3). There are almost no coal reserves in the country. The primary resources consumption pattern includes 11% of oil products, 89% of natural gas.

<u>Generation side.</u>

The generation mix is mostly (>95%) represented by TPPs that use natural gas as a primary fossil fuel. Turkmenistan has an excessive system in terms of capacity. However, the country currently is strengthening its generation side even more. Therefore, the use of network facilities and losses are decreasing.

According to the verbal data obtained from the representatives of the Ministry of Energy in Ashgabat, the installed capacity in Turkmenistan was equal to 4 545 MW, where 4 536 MW was thermal and 9 MW of hydro capacity.

Figure 25 - Installed capacity in Turkmenistan.



Due to the warm summer this year, the national consumption has almost reached the generation level. Normally, the summer maximum does not reach 70% of available generation.

<u>Transmission network.</u>

Commissioning of new generation units (CCGTs) has led to a decrease in network overloads. Power flows are low. On the contrary to other CAPS countries, there was no load shedding during the last 12 months.

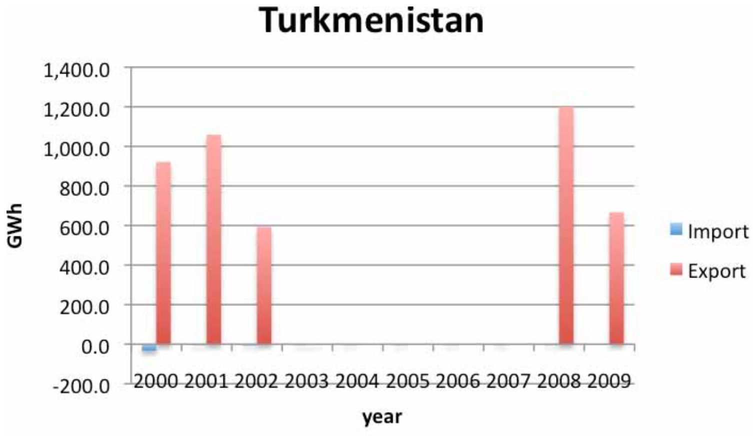
In the western part of the country new generation was commissioned. It allowed 250 MW power to be exported to Iran. In the case that this energy is not exported, the transmission link West – Centre becomes overloaded.

Commercial accounting is widely used for the border power flows. On the borders Turkmenistan has installed metering system, as well as Uzbek and Iran maintaining their own meters. However, the data metered is continuously compared and metered on the last day each month at 24pm. Auditing is performed once a year. 1-phase meters are audited once per 8 years, 3-phas meters – once each 4 years.

<u>Import-export.</u>

Turkmenistan is constantly strengthening its generation and transmission side. It allows exporting more power to neighbors. In 2009 it exported 2 680 GWh out of 15 608 GWh generated. Tajikistan, Turkey, Iran and Afghanistan are the main importers of Turkmen electricity. Currently there is no export to any CAPS countries, even to Tajikistan. CAPS represent a big potential market for Turkmenistan and now the country is looking forward to establishing new contracts with the countries of the region. It is expected that in January 2011 will start supplying South Kazakhstan.

Figure 26 - Import-export in Turkmenistan.



Before Turkmenistan left the CAPS (2003) it had 50% of excess power. In turn Kazakhstan had the opposite problem; there was a lack of power. It was agreed between the two countries to begin a trading relationship. However, the transit agreement through Uzbekistan could not been reached. This became one of the main reasons Turkmenistan has left CAPS.

<u>Critical issues.</u>

The most critical issue in Turkmenistan is the need for **capacity and frequency control**. In peak hours Iran provides frequency regulation services for Turkmen power system (250 MW). In its turn, Turkmenistan supplies Iran with the thermal power. Turkmen TPPs can be regulated in the diapason of 20-120 MW depending on the operational mode.

<u>Conclusions.</u>

Power system in Turkmenistan is characterized by the thermal generation that uses natural gas as a primary fuel. Turkmenistan is investing in the development of its generation and transmission side and looking forward to new export opportunities. Now there is export to Iran, Turkey and Afghanistan. It is planned to establish a new export channel to the Southern Kazakhstan.

ANNEX II.

DESCRIPTION OF THE ORDENA MODEL

The ORDENA model determines the optimal generation schedule (generation and transmission) required to supply the forecasted load in a multi-region or multi-country system. The objective is to minimize investment cost plus expected operation cost, composed of fuel cost plus cost of lost energy (VOLL) associated with supply reliability constraints. Supply options include hydro generation, thermal generation (coal, gas, oil, etc.), contracts and interconnections with other regions or countries. The model permits the detailed representation of hydro plants, the definition of hydrological scenarios' conditions, and renewable. The operation of thermal plants (for example, constraints on gas supply) and interconnections are also modelled in detail.

The ORDENA model allows an accurate representation of peak load, therefore the model's outputs are able to identify clearly the system's needs for generation suited to meet the peak load and select the alternative that optimally solves the trade-off between economy vs. reliability.

The aim of the model is to identify the expansions of generation and transmission that minimizes total incremental cost to meet the countries' demand, calculated as the net present value (NPV) of capital and fixed O&M costs of new generation and transmission facilities, plus the variable costs of existing and new generation facilities.

The demand is modelled as a load-duration curve that can be defined at quarter, season or yearly level. A load duration curve is necessary for each of the nodes of the transmission system.

Demand can be met with existing and new generation. Alternatives for new generation can be considered as integer or continuous variables. Normally, hydro plants, transmission expansions and major thermal plants are simulated as integer variables, and small thermal and renewable plants as continuous ones.

The model allows binding of the emissions, or to assume that emissions are penalized, in order to represent environmental constraints.