PEER project - " Transboundary water management adaptation in the Amudarya basin to climate change uncertainties"

Research report

2. Research

2.2. Analysis of national development programs (Tajikistan)

2.5. Study HEPS operation regimes

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Introduction

The report describes the results of the research on assessment of hydropower development in Tajikistan, including potential options for balancing supply and demand, as well as alternative scenarios of operation of the Vakhsh hydropower cascade for 2016-2055. This work is a part of position 2.2 “Analysis of national development programs” and position 2.5 “Study HEPS operation regimes” of the second research stage under the PEER project.

The research work comprised:

- The analysis of existing national documents (e.g. Water Sector Development Strategy in Tajikistan, 2006), reviews and studies by international organizations (e.g. the World Bank: Daryl Fields, Artur Kochnakyan, Takhmina Mukhamedova, Gary Stuggins, and John Besant-Jones, 2013) expert assessments (e.g. Petrov G.N., 2009),
- The estimations by SIC ICWC to identify current trends in energy production and consumption,
- The determination of approaches to construct and assess scenarios of energy production and consumption by 2020 and 2050,
- The SIC ICWC’s assessments and analysis of scenarios of hydropower development in Tajikistan for 2016-2055,
- The determination of alternative scenarios of operation of the Vakhsh hydropower cascade for 2016-2055.

The report provides information on the energy sector of Tajikistan as a whole (HEPS, TPS) and for the Tajik part of the Amudarya basin (PEER research area), excluding the Sogd province (Syrdarya and Zeravshan River basins).

1. Hydropower development in Tajikistan

Development strategy

The main document that plans and guides the development process in Tajikistan is the National Development Strategy 2010-2015. The national energy sector is an important constituent of GDP in this National Strategy.

Tajikistan has set three main targets in energy development (CAREC, 2015):

- Availability of electricity (regular energy supply to the population),
- Energy efficiency (reduced energy losses),
- Renewable energy (its increased generation).

The following national programs could be marked as those addressing the hydropower development in the future:

- Water Sector Reform Program 2016-2025 for Tajikistan (Order No. 791 of the Government of the Republic of Tajikistan, December 30, 2015),
- State Environmental Program 2020,
- State Small Hydropower Program 2020.

In the Water Sector Reform Program 2016-2025, hydropower development is considered in context of energy provision to all economic sectors. The Program sets the following objectives:

- Eliminating energy shortage in winter,
- Reducing energy losses,
- Balancing energy production and irrigation needs.

The Ministry of Energy and Water Resources of the Republic of Tajikistan is responsible for policy development and management in the hydropower subsector, whereas the Bakhri Tojik Joint-Stock Company operates hydropower schemes and implements measures planned in the water and energy development programs.

According to the plan of actions for implementation of the reform, the development of draft National Water Strategy 2025 should be completed by 2018.

The water sector strategy of the Republic Tajikistan (2006) developed on the basis of the Tajikistan Economic Development Program until 2015, includes plans for reconstruction of old and construction of new HEPS; moreover, particular attention is paid to the issues related to interstate relations around water and energy resources:

- water allocation in low-water years,
- idle discharges and opportunity losses from the Nurek HEPS,
- sale of summer excess electricity.

The Water Sector Strategy mentions regular energy excess of 1.5 billion kilowatt-hours formed summer. However, currently this excess has been lacking demand on both internal and external markets. At the same time, due to energy shortage in winter (3-3.5 billion kilowatt-hour), restrictions on energy consumption are introduced in Tajikistan in winter time. In this context, the objective is established that the domestic energy needs should be met in full and the potential of energy export should be increased (up to 12 billion kilowatt-hour in 2015-2020, including 2-2.5 billion kilowatt-hour in summer) through the development of hydropower.

However, the Strategy does not show an assessment of winter and summer demand for electricity (in figures and by month for near- and long-term perspective).

Measures to reduce energy shortage

The analysis of available national documents, reviews and studies by international organizations reveals that by 2020 the current energy shortage in Tajikistan (caused by high demand and insufficient supply) is to be reduced by better balancing demand and supply, including the following measures:

- Decrease electricity demand through investments in energy efficiency (domestic sector, industry), tariff policy (reasonable increase of tariffs), and transition to alternative sources,
- Increase of electricity production by modernizing existing hydropower schemes, implementing thermal power projects and constructing small HEPS,
- Increase of energy import and export, mainly, through export opportunities of Tajikistan (e.g. CASA-1000 project).

Tendencies, estimations and assumptions

In order to construct scenarios of potential growth of electricity demand and the corresponding scenarios of power stations' capacities to cover this demand fully, partially or in excess, it is necessary to consider the existing programs on hydropower modernization and measures for energy saving and analyze:

- Current trends of energy production and consumption,
- Dynamics of population growth,
- Export potential and prospects of Tajikistan.

The analysis of dynamics of population growth over 2010-2015 (Fig.1.1) indicates to a downward trend of annual population growth in Tajikistan.

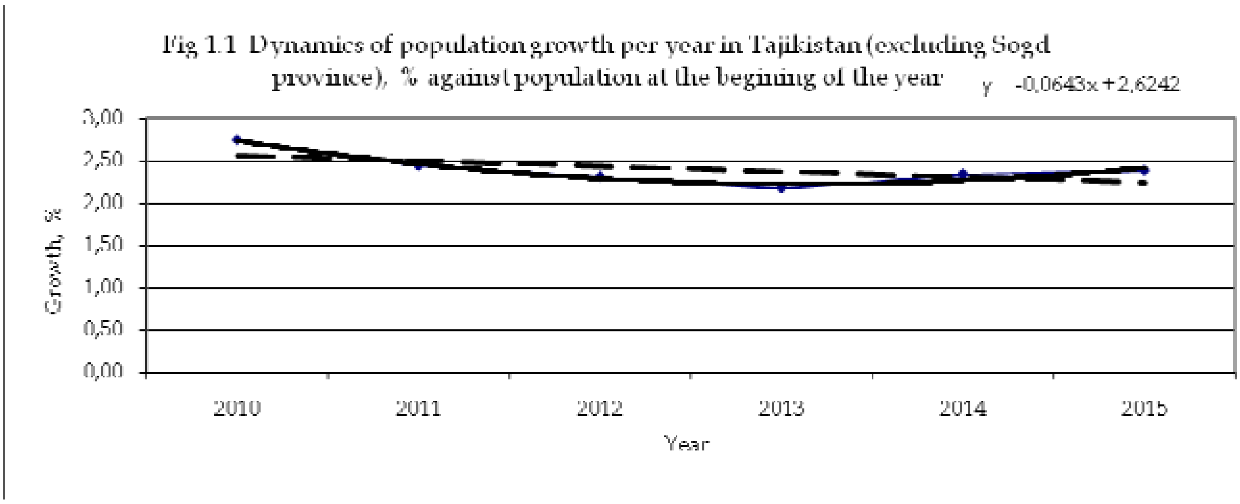

Fig.1.1. Dynamics of population growth per year in Tajikistan (excluding Sogd province)

It is assumed that this trend will remain and lead to 2.2% (2016) to 1.5% (2025) decrease in growth rates and further will be steady until 2050.

Energy demand in the residential sector is expected to depend mainly on demographic load (or population growth). Moreover, the rates of energy consumption growth in the residential sector will correspond to rates of population growth. Estimations of electricity demand in other sectors, including industry, are based on the World Bank studies (Daryl Fields et al, 2013).

Dynamics of energy production and consumption over 1991-2015 is presented in Fig.1.2. It shows that the production of electricity increased, while consumption decreased over this period of time.

In the future, this downward trend of electricity demand will continue until 2020 (through measures for the reduction of this demand, e.g. tariff policy, etc.). Thereafter the domestic demand for electricity will begin increasing, mainly at the expense of the residential sector.

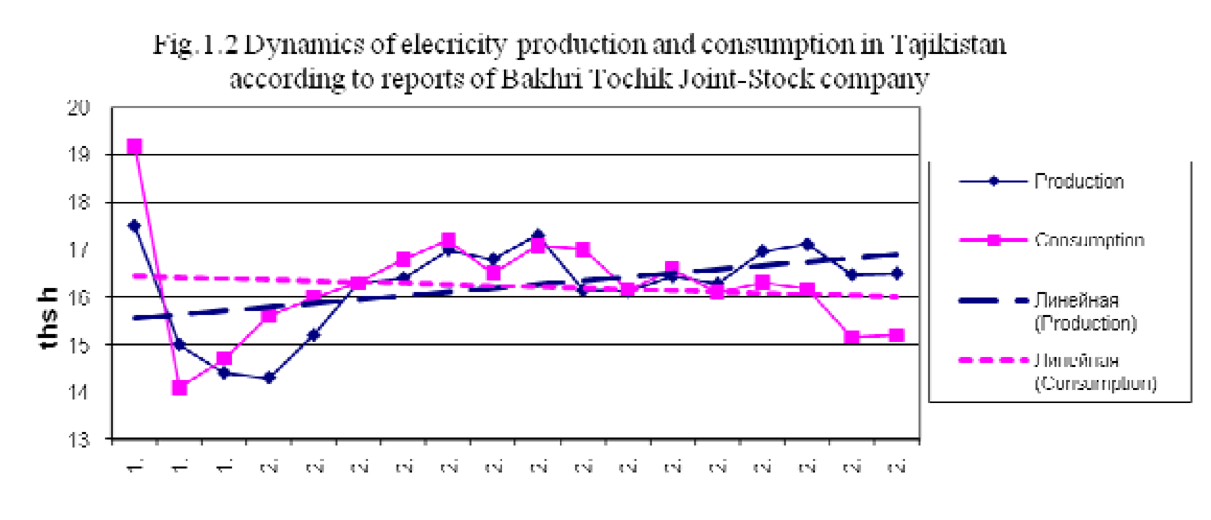

Fig.1.2. Dynamics of electricity production and consumption in Tajikistan

The analysis reveals that the upward trend of electricity production will continue because of putting into operation of new thermal stations, modernization of old HEPS and construction of small hydropower.

The PEER research does not include in its analysis the Rogun Hydroproject as it is currently analyzed in detail by a number of relevant experts and decision makers, including its design parameters (dam height, normal maximum operating level, dead storage level, etc.), operation regime of Rogun in the Vakhsh cascade, cost-effectiveness, technical safety, economic and social risks for all riparian states.

<u>Future electricity demand</u>

Figure 1.3 presents the results of calculation on annual domestic electricity demand in Tajikistan (generation, by sector until 2055); the graph shows dynamics of demand given that no measures are taken to reduce this demand.

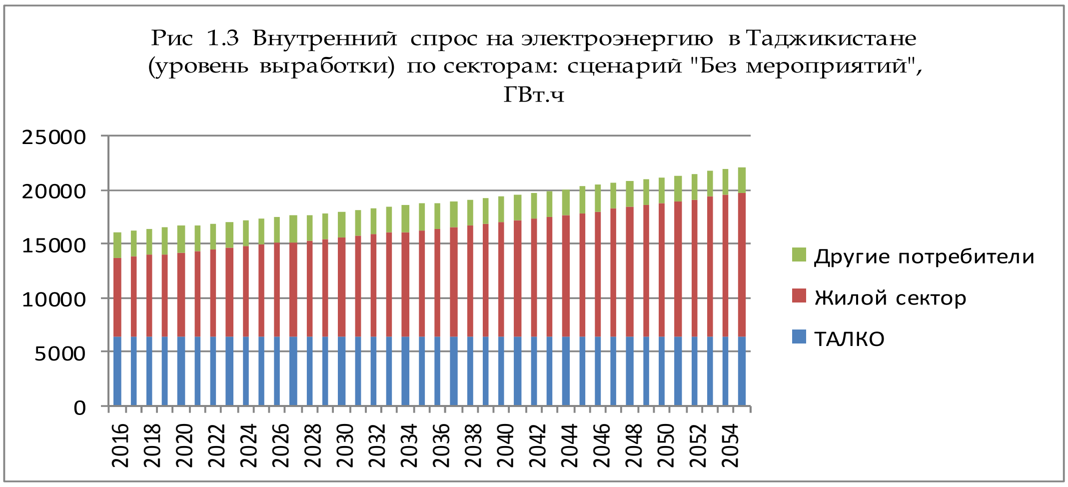

Fig.1.3. Domestic demand for electricity (generation) by sector, "No measures" scenario, GWh

Figure 1.4 shows the results of calculation of annual domestic demand for electricity in Tajikistan (no measures) for the Tajik part of the Amudarya basin, excluding the Sogd province (Syrdarya and Zeravshan basins).

According to this scenario calculations, by 2030 domestic demand in Tajikistan will be 17,952 gigawatt-hours (no measures for energy saving and energy shortage reduction) and 14,704 gigawatt-hours or 18% lower (after implementation of these measures). By 2055, the domestic demand may increase up to 22,080 gigawatt-hours (without measures) and to 18,830 gigawatt-hour (after implementation of these measures).

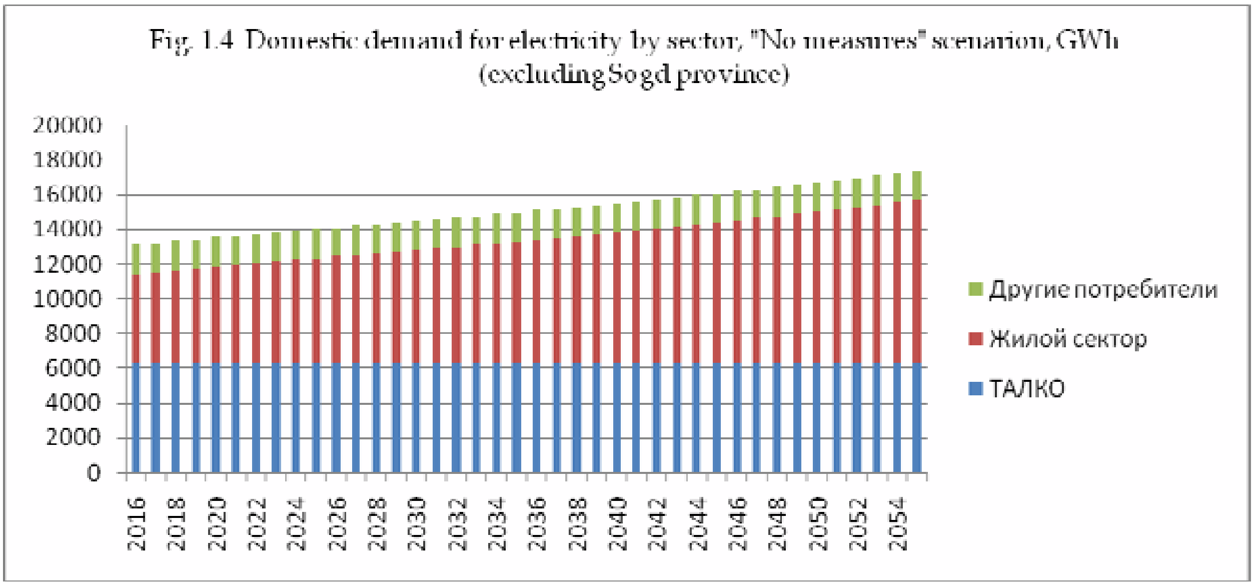

Fig.1.4. Domestic demand for electricity, by sector, "No measures" scenario, GWh (excluding Sogd province)

By 2030, in the Tajik part of the Amudarya basin the domestic demand will be 14,490 gigawatt-hours (no measures) and 11,240 gigawatt-hours (after implementation of these measures) or 22% lower. By 2055, the domestic demand may increase up to 17,376 gigawatt-hours (no measures) and 14,126 gigawatt-hours (after implementation of these measures).

2. Options for balancing supply and demand

Planned measures for energy saving and elimination of energy shortage include among others the increase of energy tariffs, reduction of energy losses during transportation, and transition to alternative sources. These would allow reducing winter electricity demand by 3,250 gigawatt-hours (addition to existing capacity of 1,108 megawatt) by 2020, as estimated by the World Bank (Daryl Fields et al, 2013). Moreover, these measures would fully cover the current energy shortage in winter (about 2,700 gigawatt-hours, 2012).

As alternatives to hydropower, by 2020 it is planned to increase available capacities by thermal power – Dushanbe-2 TPP, Shurob-1 TPP and Shurob-2 TPP with the total capacity of 800 MW - and additional winter energy of 3,308 gigawatt-hours. Another way to improve supply is to increase existing capacities through the projects on rehabilitation of the Nurek HEPS, the Vakhsh hydropower cascade, and the Varzob hydropower cascade; by 2050 the firm capacity of these HEPS will be increased by 65 megawatt and this will allow additional generation of 250 gigawatt-hours in winter.

Figure 2.1 shows the results of scenario calculations on energy generation in Tajikistan over 2016-2055; Figure 2.2 presents the results for the Tajik part of the Amudarya basin. This scenario accounts for an increase in capacities (HEPS, TPS) over 2016-2025; these capacities will not be increased over 2025-2055.

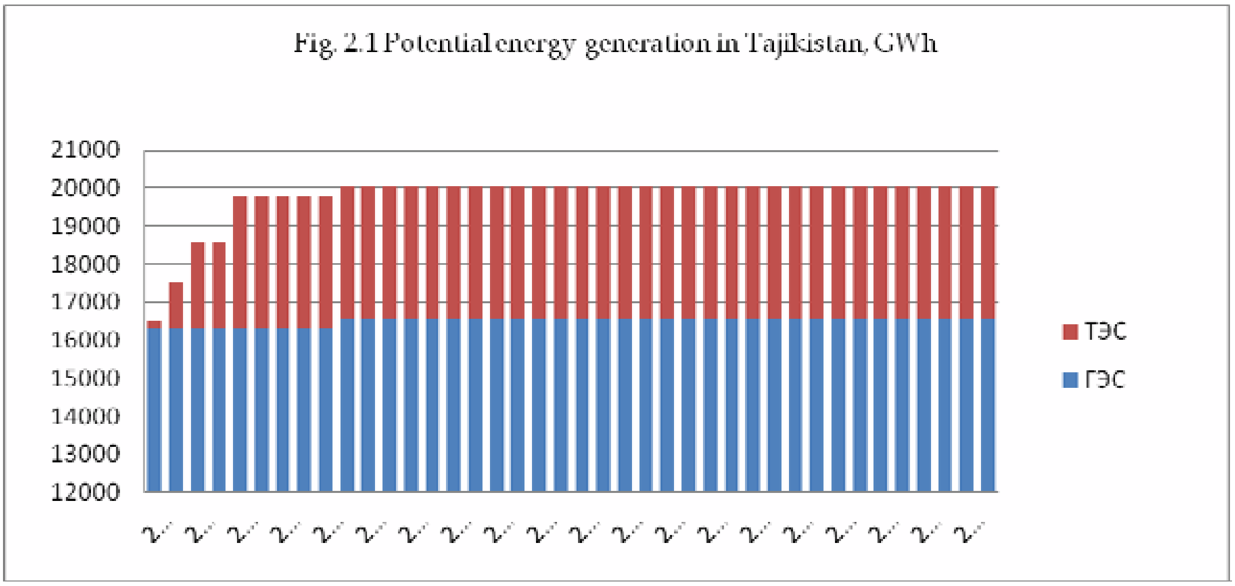

Fig.2.1. Potential energy generation in Tajikistan, GWh

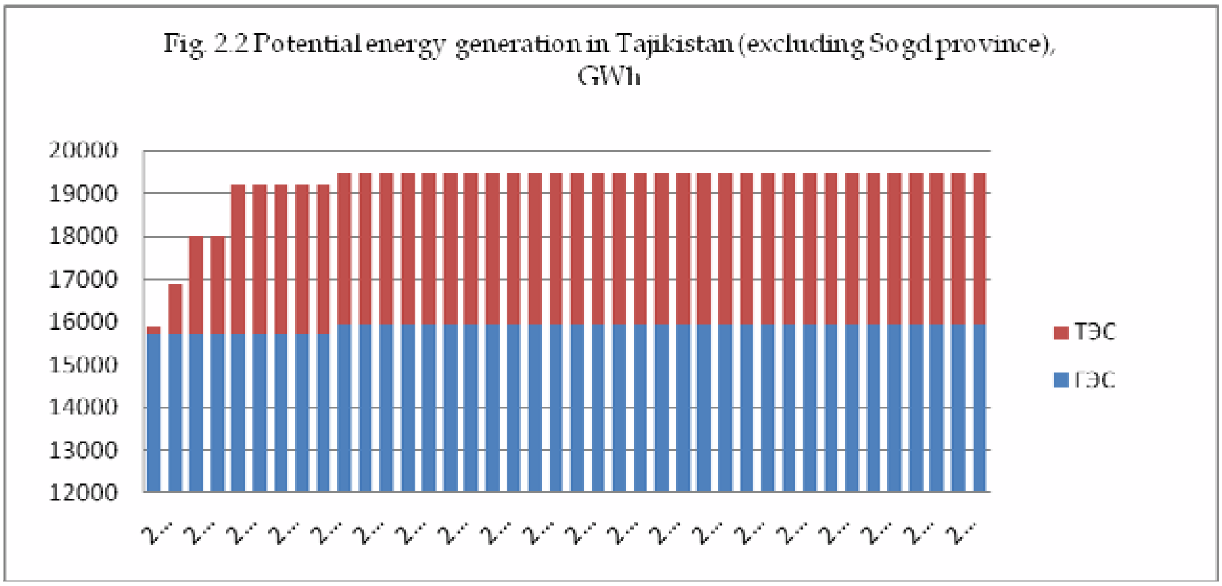

Fig.2.2. Potential energy generation in Tajikistan (excluding Sogd province), GWh

Figures 2.3 and 2.4 show the results of calculations on the balance of annual electricity demand and supply for Tajikistan as a whole and its part in the Amudarya basin. Figures 2.5 and 2.6 present the data on potential meeting of annual electricity demand through hydropower.

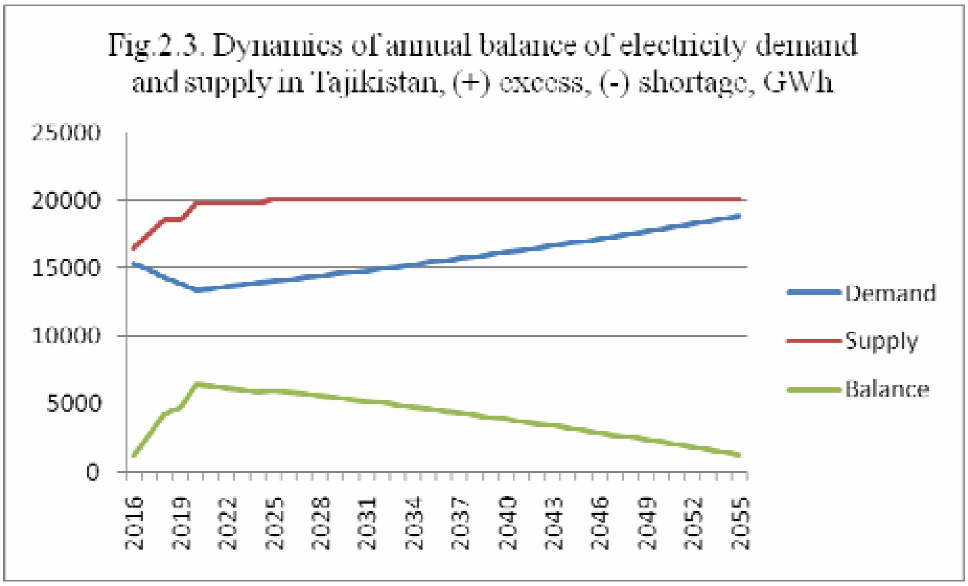

Fig.2.3. Dynamics of annual balance of electricity demand and supply in Tajikistan, (+) excess, (-) shortage, GWh

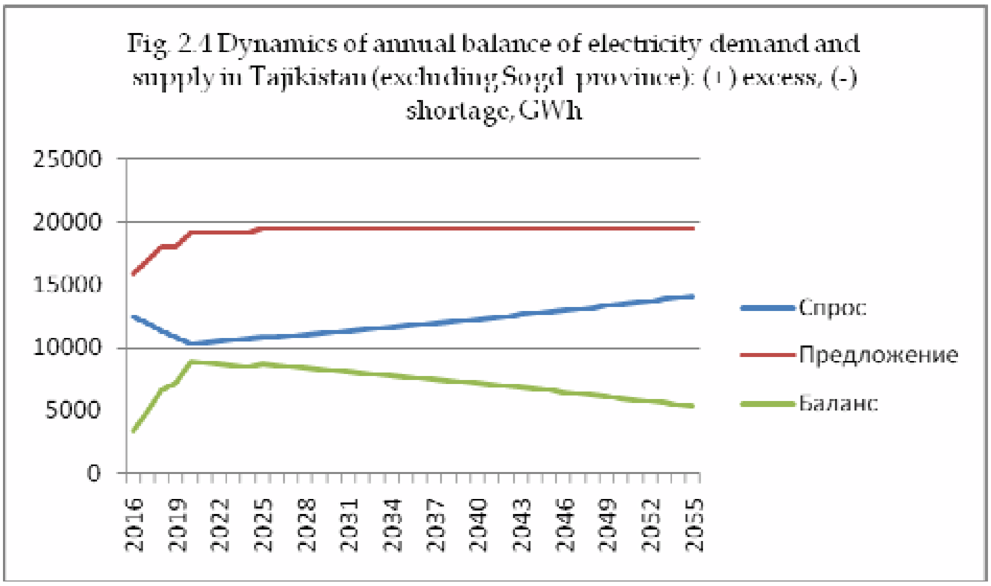

Fig.2.4. Dynamics of annual balance of electricity demand and supply in Tajikistan (excluding Sogd province), GWh

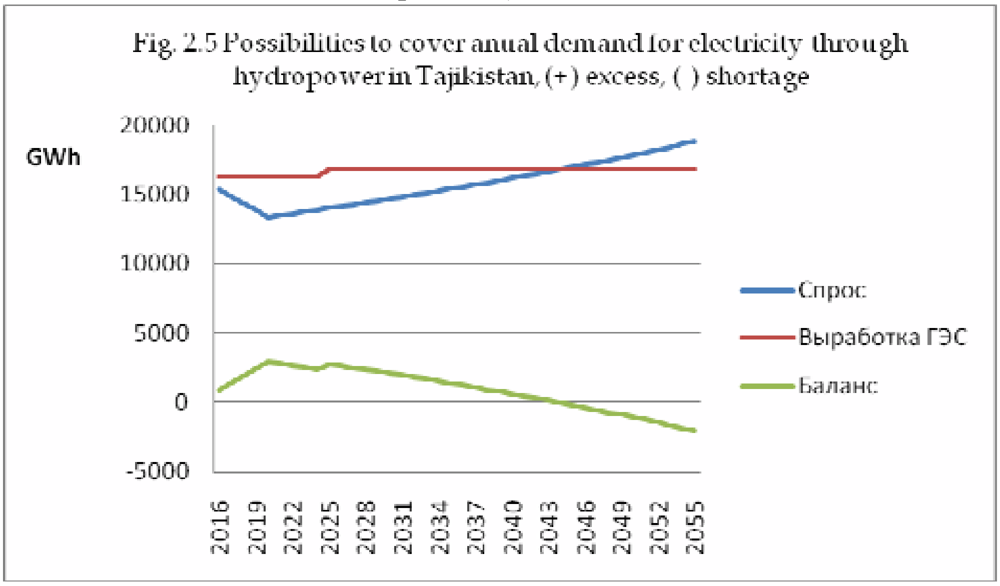

Fig.2.5. Possibilities to cover annual demand for electricity through hydropower in Tajikistan

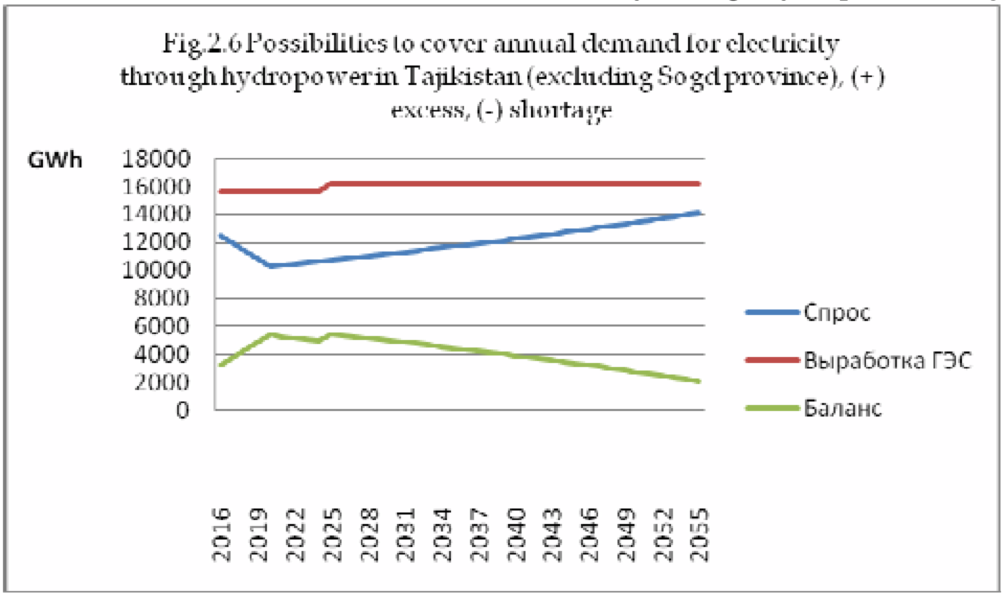

Fig.2.6. Possibilities to cover annual demand for electricity through hydropower in Tajikistan (excluding Sogd province)

According to calculations, in Tajikistan as a whole the annual energy supply (potential energy generation) will exceed demand by 5,353 gigawatt-hours by 2030 and by 1,225 gigawatt-hours (positive balance) by 2055, By 2030 the demand will be covered through hydropower (positive balance of 2,108 gigawatt-hours); however, by 2050, HEPS capacities will not be enough to cover the annual shortage (negative balance of 2,020 gigawatt-hours); therefore, thermal power generation will need to be increased.

The analysis of calculation results for the Tajik part of the Amudarya basin shows that the positive balance will be achieved both by 2030 and 2055 and HEPS' capacities will be enough to meet domestic and annual demand for electricity in Tajikistan.

Within-year demand for electricity and its meeting

The above mentioned calculations show the balance of demand and supply per year in general and do not account for within-year unevenness in both energy demand and generation.

Figure 2.7 shows minimum and maximum monthly energy generation from October to September – the data processed over 2005-2010, as well as the demand for electricity in Tajikistan (2009), while Figure 2.8 presents similar parameters but in progressive total (integral curves). Figure 2.9 shows the data on energy demand by sector (source: World Bank, Daryl Fields et al, 2013). Figure 2.10 shows the data on energy supply to consumers, energy losses and under-supply.

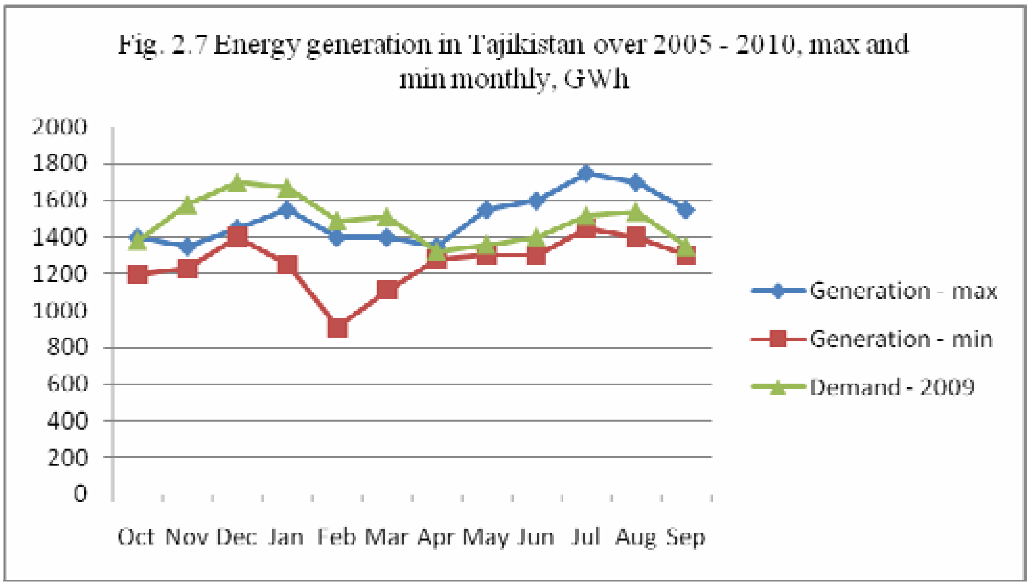

Fig.2.7. Energy generation in Tajikistan over 2005-2010, max and min monthly, GWh

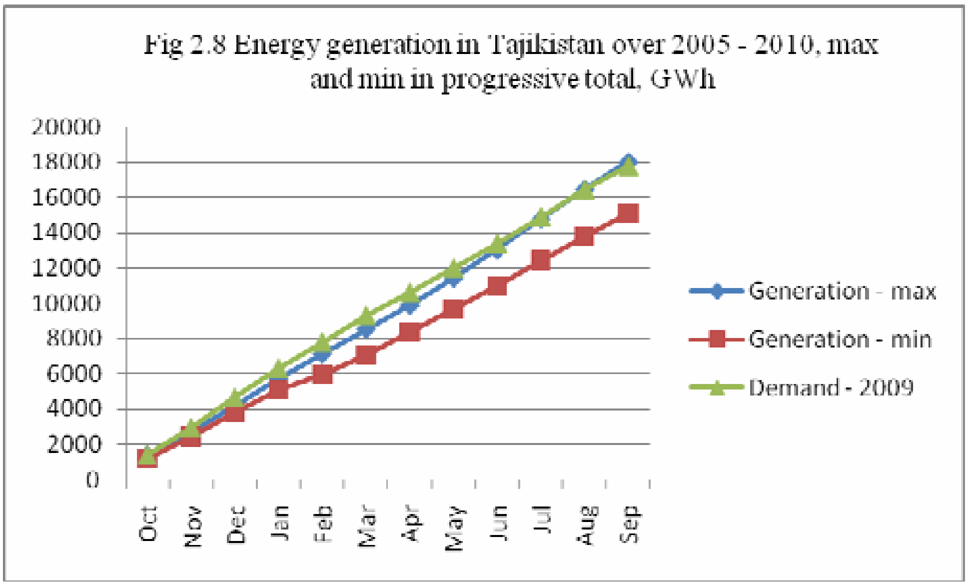

Fig.2.8. Energy generation in Tajikistan over 2005-2010, max and min in progressive total, GWh

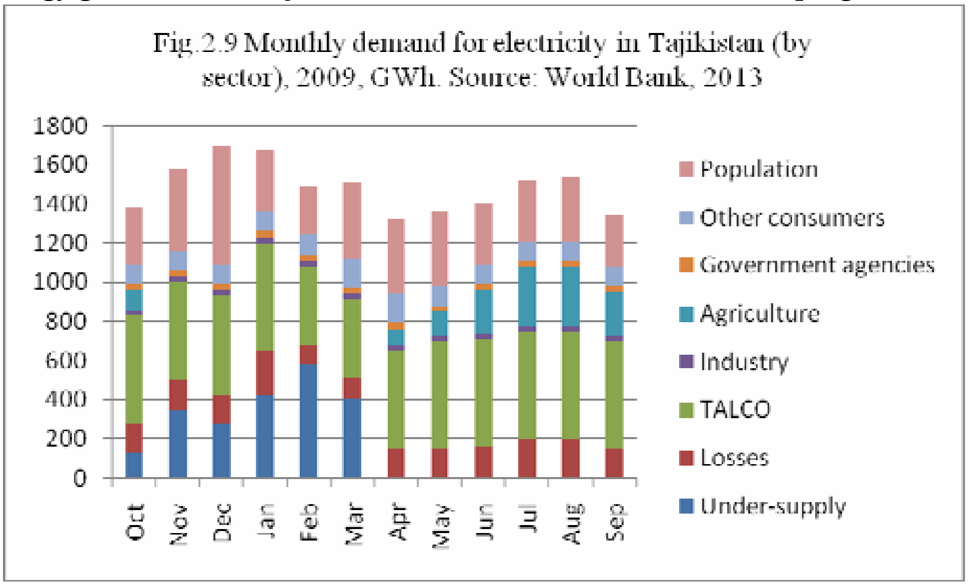

Fig.2.9. Monthly demand for electricity in Tajikistan (by sector), 2009, GWh Source: World Bank, 2013

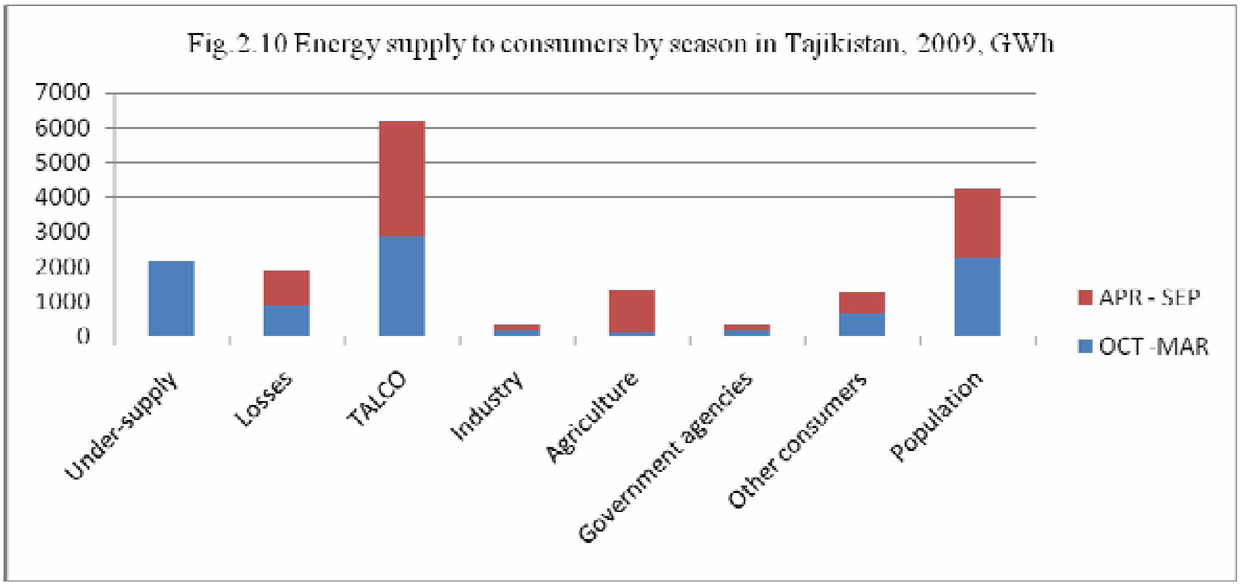

Fig.2.10. Energy supply to consumers by season in Tajikistan, 2009, GWh

The analysis of the data on within-year energy demand and generation over 2005-2010 allows assessing seasonal demand and potential of the energy sector in Tajikistan.

- In October-March, 7,100-8,550 gigawatt-hours of energy is produced in Tajikistan, given the demand of 9,330 gigawatt-hours; undersupply is 800-2,230 gigawatt-houra, including 400 gigwatt-hours in January, 550 gigawatt-hours in February and 400 gigawatt-hours in March.
- In April-September, 8,030–9,500 gigawatt-hours of energy is generated in Tajikistan (11-13 % more than in October-March), given the demand of 8, 490 gigawatt-hours; the maximum energy excess is 1,010 gigawatt-hours, however, undersupply may occur in June (100 gigawatt-hours), July (70 gigawatt-hours), August (150 gigawatt-hours), and September (50 gigawatt-hours).
- The highest demand for electricity in winter is observed in December (1,700 gigawatt-hours) and January (1,650 gigawatt-hours) and for summer in July (1,520 gigawatt-hours) and August (1,540 gigawatt-hours).

As currently the main generator of energy in Tajikistan is the Nurek HEPS and the Vakhsh hydropower cascade located downstream, the within-year demand for electricity (shown above) can be considered as a reference for operation of the Nurek HEPS.

3. Alternative scenarios of operation of the Vakhsh hydropower cascade

A long-term regional water development strategy should determine mechanisms and criteria for water allocation in alignment with national hydropower and agrarian development strategies. In this context, it is important to study scenarios of operation of the Vakhsh hydropower cascade, including the Nurek HEPS.

In the future, there could be situations that would be caused by over-regulation of the current operation of the Nurek HEPS as undertaken for:

- Optimization of winter energy demand in Tajikistan – this may result in reduction of water releases from the reservoir in summer,
- Minimization of idle discharges – this will result in re-allocation of water releases in summer,
- Generation of additional summer energy for export – this will result in an increase of water releases in summer.

The option of Nurek HEPS operation, which would result in an increase of summer releases, is acceptable for Turkmenistan. This option will be acceptable for Uzbekistan only provided that this summer energy is not supplied to Kyrgyzstan in exchange (return to Tajikistan) for winter energy; such energy exchange will worsen the situation in the Syrdarya basin – summer releases from the Toktogul HEPS will decrease and winter releases will increase, leading to higher summer water shortage in the Fergana Valley and the middle reaches of the Syrdarya River and to floods in autumn and winter.

Taking into account future needs of Tajikistan for electricity, including potential energy export, the following regimes will be studied in numerical experiments (third research stage in the PEER Project):

- regime typical for 2010-2015, with different options of water availability;
- energy generation regime, with two options – maximization of winter generation and annual generation;
- energy-irrigation regime – additional generation in summer (export of summer energy).

Figure 3.1 shows monthly water discharge at the Nurek HEPS under two energy regimes, where maximum energy is generated in winter and annually. HEPS discharge for 2003-2004 is shown for comparison. The design energy regime with maximum generation in winter almost coincides with the regime of 2003-2004. This attests intentions of the Tajik energy sector to produce as much energy as possible in winter. HEPS discharge under the regime providing for maximum annual energy generation almost coincides with non-regulated flow in the Vakhsh River.

Figure 3.2 presents the integral curve of inflow and water releases (Mm³) over 2003-2004 as compared to design water releases through the Nurek HEPS for two options of energy regime.

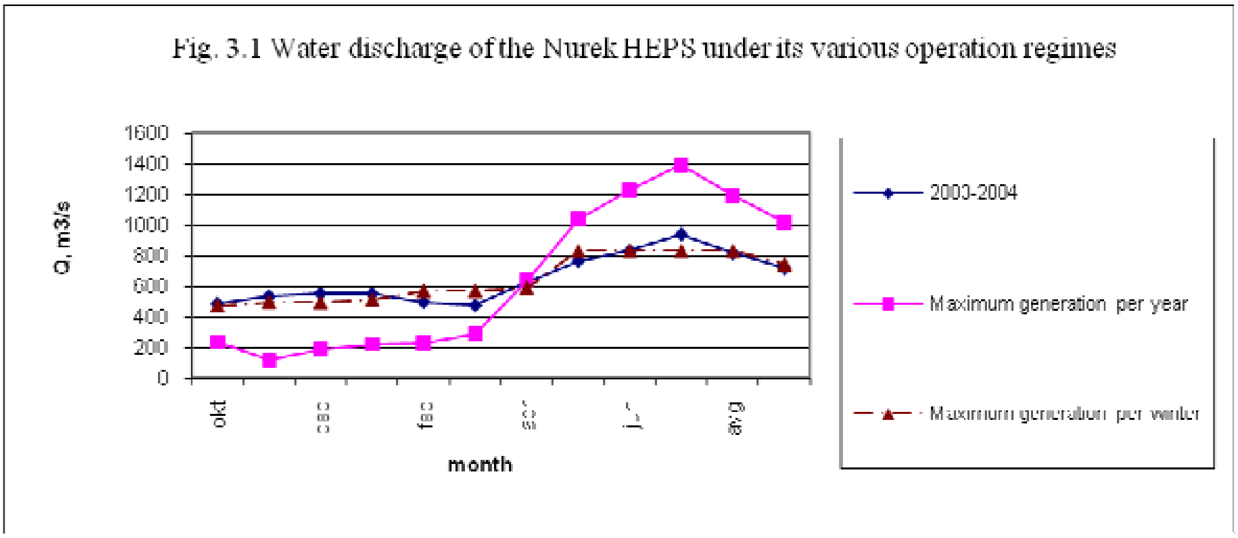

Fig.3.1. Water discharge of the Nurek HEPS under its various operation regimes

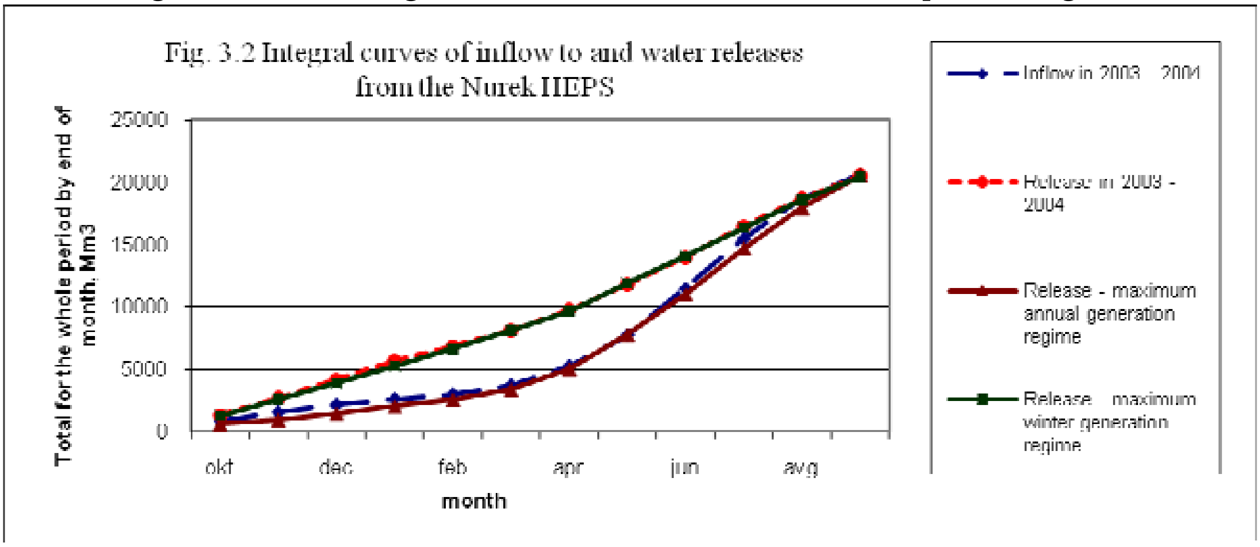

Fig.3.2. Integral curves of inflow to and water releases from the Nurek HEPS

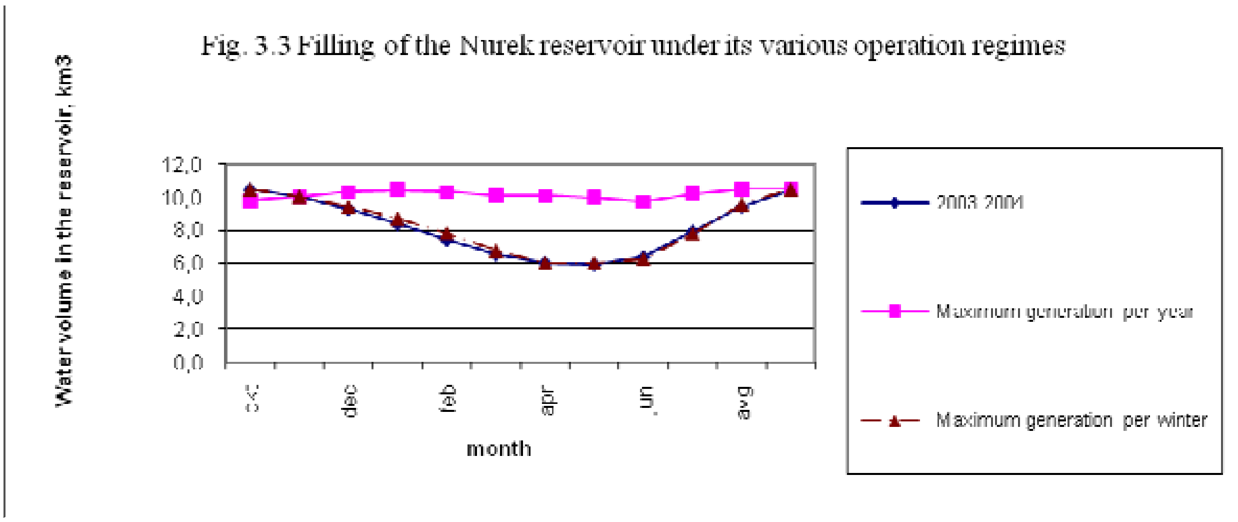

Fig.3.3. Filling of the Nurek reservoir under its various operation regimes

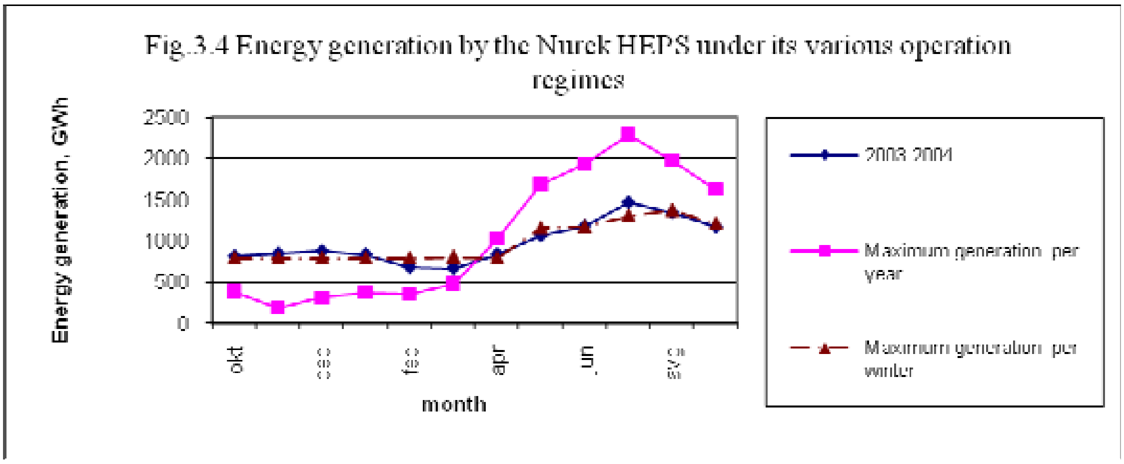

Fig.3.4. Energy generation by the Nurek HEPS under its various operation regimes

Comparison of the data reveals that the curve of inflow to the Nurek HEPS in 2003-2004 coincides with the curve of design water releases from the Nurek HEPS for the option of maximum annual energy generation, whereas the curve of water releases from the Nurek HEPS in 2003-2004 coincides with the curve of design water releases from the Nurek HEPS for the option of maximum winter energy generation.

Figure 3.3 shows dynamics of water volume in the reservoir of Nurek HEPS for 2003-2004 and design water volume under the two options of energy regime. Figure 3.4 demonstrates energy generation by the Nurek HEPS under its various operation regimes.

Annex 2 gives tables with the estimated data on operation regimes of the Nurek HEPS for 2010-2015, as well as the estimated energy generation by the Nurek HEPS and the Vakhsh hydropower cascade.

Conclusion

The conducted research allows starting numerical experiments on operation regimes of the Nurek HEPS for the long-term perspective (until 2055). The results of these experiments will provide the estimated water releases from the Nurek HEPS and energy generation that will be accounted from in the energy balance of Tajikistan and in the assessments of an impact of operation regimes on water availability for planning zones in the Amudarya basin in context of climate change.

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Annex 1, position 2.2 “Analysis of national development programs”

Table 1. Domestic demand for electricity in Tajikistan (excluding Sogd province), GWh					
Year	Total	TALCO	Residential sector	Other consumers	After implementation of measures
2016	13,120	6,400	5,040	1,680	12,470
2017	13,226	6,400	5,146	1,680	11,926
2018	13,332	6,400	5,252	1,680	11,382
2019	13,436	6,400	5,356	1,680	10,836
2020	13,538	6,400	5,458	1,680	10,288
2021	13,639	6,400	5,559	1,680	10,389
2022	13,739	6,400	5,659	1,680	10,489
2023	13,836	6,400	5,756	1,680	10,586
2024	13,932	6,400	5,852	1,680	10,682
2025	14,025	6,400	5,945	1,680	10,775
2026	14,116	6,400	6,036	1,680	10,866
2027	14,207	6,400	6,127	1,680	10,957
2028	14,299	6,400	6,219	1,680	11,049
2029	14,392	6,400	6,312	1,680	11,142
2030	14,487	6,400	6,407	1,680	11,237
2031	14,583	6,400	6,503	1,680	11,333
2032	14,680	6,400	6,600	1,680	11,430
2033	14,779	6,400	6,699	1,680	11,529
2034	14,880	6,400	6,800	1,680	11,630
2035	14,982	6,400	6,902	1,680	11,732
2036	15,085	6,400	7,005	1,680	11,835
2037	15,190	6,400	7,110	1,680	11,940
2038	15,297	6,400	7,217	1,680	12,047
2039	15,405	6,400	7,325	1,680	12,155
2040	15,515	6,400	7,435	1,680	12,265
2041	15,627	6,400	7,547	1,680	12,377
2042	15,740	6,400	7,660	1,680	12,490
2043	15,855	6,400	7,775	1,680	12,605
2044	15,972	6,400	7,892	1,680	12,722
2045	16,090	6,400	8,010	1,680	12,840
2046	16,210	6,400	8,130	1,680	12,960
2047	16,332	6,400	8,252	1,680	13,082
2048	16,456	6,400	8,376	1,680	13,206
2049	16,581	6,400	8,501	1,680	13,331
2050	16,709	6,400	8,629	1,680	13,459
2051	16,838	6,400	8,758	1,680	13,588
2052	16,970	6,400	8,890	1,680	13,720
2053	17,103	6,400	9,023	1,680	13,853

2054	17,238	6,400	9,158	1,680	13,988
2055	17,376	6,400	9,296	1,680	14,126

Table 2. Potential energy production in Tajikistan (excluding Sogd province), GWh			
Year	Total	HEPS	TPP
2016	15,900	15,700	200
2017	16,900	15,700	1,200
2018	18,000	15,700	2,300
2019	18,000	15,700	2,300
2020	19,200	15,700	3,500
2021	19,200	15,700	3,500
2022	19,200	15,700	3,500
2023	19,200	15,700	3,500
2024	19,200	15,700	3,500
2025	19,455	15,955	3,500
2026	19,455	15,955	3,500
2027	19,455	15,955	3,500
2028	19,455	15,955	3,500
2029	19,455	15,955	3,500
2030	19,455	15,955	3,500
2031	19,455	15,955	3,500
2032	19,455	15,955	3,500
2033	19,455	15,955	3,500
2034	19,455	15,955	3,500
2035	19,455	15,955	3,500
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2037	19,455	15,955	3,500
2038	19,455	15,955	3,500
2039	19,455	15,955	3,500
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2041	19,455	15,955	3,500
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2050	19,455	15,955	3,500
2051	19,455	15,955	3,500
2052	19,455	15,955	3,500
2053	19,455	15,955	3,500
2054	19,455	15,955	3,500
2055	19,455	15,955	3,500

Table 3. Growth of energy supply in Tajikistan (excluding Sogd province) through reconstruction projects, GWh				Table 4. Growth of thermal power supply in Tajikistan, GWh		
Year	Total	Nurek HEPS	Vakhsh cascade	Total	Dushanbe-2	Shurob-1,2
2016	0	0	0	0	0	0
2017	1,000	0	0	1,000	1,000	0
2018	2,100	0	0	2,100	1,000	1,100
2019	2,100	0	0	2,100	1,000	1,100
2020	3,200	0	0	3,200	1,000	2,200
2021	3,200	0	0	3,200	1,000	2,200
2022	3,200	0	0	3,200	1,000	2,200
2023	3,200	0	0	3,200	1,000	2,200
2024	3,200	0	0	3,200	1,000	2,200
2025	3,225	230	25	3,200	1,000	2,200
2026	3,225	230	25	3,200	1,000	2,200
2027	3,225	230	25	3,200	1,000	2,200
2028	3,225	230	25	3,200	1,000	2,200
2029	3,225	230	25	3,200	1,000	2,200
2030	3,225	230	25	3,200	1,000	2,200
2031	3,225	230	25	3,200	1,000	2,200
2032	3,225	230	25	3,200	1,000	2,200
2033	3,225	230	25	3,200	1,000	2,200
2034	3,225	230	25	3,200	1,000	2,200
2035	3,225	230	25	3,200	1,000	2,200
2036	3,225	230	25	3,200	1,000	2,200
2037	3,225	230	25	3,200	1,000	2,200
2038	3,225	230	25	3,200	1,000	2,200
2039	3,225	230	25	3,200	1,000	2,200
2040	3,225	230	25	3,200	1,000	2,200
2041	3,225	230	25	3,200	1,000	2,200
2042	3,225	230	25	3,200	1,000	2,200
2043	3,225	230	25	3,200	1,000	2,200
2044	3,225	230	25	3,200	1,000	2,200
2045	3,225	230	25	3,200	1,000	2,200
2046	3,225	230	25	3,200	1,000	2,200
2047	3,225	230	25	3,200	1,000	2,200
2048	3,225	230	25	3,200	1,000	2,200
2049	3,225	230	25	3,200	1,000	2,200
2050	3,225	230	25	3,200	1,000	2,200
2051	3,225	230	25	3,200	1,000	2,200
2052	3,225	230	25	3,200	1,000	2,200
2053	3,225	230	25	3,200	1,000	2,200
2054	3,225	230	25	3,200	1,000	2,200
2055	3,225	230	25	3,200	1,000	2,200

Table 5. Annual balance of demand and supply in Tajikistan (excluding Sogd province): (+) excess, (-) shortage, GWh			
Year	Demand	Supply	Balance
2016	12,470	15,900	3,430
2017	11,926	16,900	4,974
2018	11,382	18,000	6,618
2019	10,836	18,000	7,164
2020	10,288	19,200	8,912
2021	10,389	19,200	8,811
2022	10,489	19,200	8,711
2023	10,586	19,200	8,614
2024	10,682	19,200	8,518
2025	10,775	19,455	8,680
2026	10,866	19,455	8,589
2027	10,957	19,455	8,498
2028	11,049	19,455	8,406
2029	11,142	19,455	8,313
2030	11,237	19,455	8,218
2031	11,333	19,455	8,122
2032	11,430	19,455	8,025
2033	11,529	19,455	7,926
2034	11,630	19,455	7,825
2035	11,732	19,455	7,723
2036	11,835	19,455	7,620
2037	11,940	19,455	7,515
2038	12,047	19,455	7,408
2039	12,155	19,455	7,300
2040	12,265	19,455	7,190
2041	12,377	19,455	7,078
2042	12,490	19,455	6,965
2043	12,605	19,455	6,850
2044	12,722	19,455	6,733
2045	12,840	19,455	6,615
2046	12,960	19,455	6,495
2047	13,082	19,455	6,373
2048	13,206	19,455	6,249
2049	13,331	19,455	6,124
2050	13,459	19,455	5,996
2051	13,588	19,455	5,867
2052	13,720	19,455	5,735
2053	13,853	19,455	5,602
2054	13,988	19,455	5,467
2055	14,126	19,455	5,329

Annex 2, position 2.5

“Study HEPS operation regimes” – Operation regimes of the Nurek HEPS

Definition of indicators

Inflow, mcm	Inflow to the reservoir of the Nurek HEPS, Mm^3/month
Res.vol. 1, mcm	Water volume in the reservoir by the beginning of the month, Mm^3
Res.vol. 2, mcm	Water volume in the reservoir at the end of the month, Mm^3
Avg.Res.vol, mcm	Average water volume in the reservoir, Mm^3
Avg.Res. H, m	Water level corresponding to average volume, m
Hmax, m	Maximum level, m
Hmin, m	Minimum level, m
Outflow, mcm	Releases from the reservoir of the Nurek HEPS, Mm^3
Outflow, m3/s	Water discharge in the tailwater of the Nurek reservoir, m^3/s
Hout, m	Water level in the Vakhsh River downstream of the reservoir, m
dH = H-Hout, m	Head, m
Qhpsmax, m3/s	Maximum discharge by HEPS, m^3/s
Qhps, m3/s	Discharge by HEPS,m^3/s
N, MWh	Nurek HEPS capacity, MW
T, h	Hours of HEPS operation, h
Enurek, mkwth	Energy produced by the Nurek HEPS, million kilowatt-hour
Evahsh, mkwth	Energy produced by the Vakhsh cascade, million kilowatt-hour

2009-2010	Oct	Nov	Dec	Jan	Feb	March	Apr	May	June	July	Aug	Sept	Oct-March	Apr-Sept	Oct-Sept
Inflow, mcm	1,008	645	555	490	425	553	1,898	3,316	3,815	4,891	4,796	2,127	**3,676**	**20,843**	**24,519**
Res.vol. 1, mcm	10,526	10,338	9,650	8,578	7,942	6,958	6,166	6,793	7,790	8,707	9,695	10,159	**8,999**	**8,218**	**8,608**
Res.vol. 2, mcm	10,338	9,650	8,578	7,942	6,958	6,166	6,793	7,790	8,707	9,695	10,159	10,507	**8,272**	**8,942**	**8,607**
Avg.Res.vol, mcm	10,432	9,994	9,114	8,260	7,450	6,562	6,480	7,292	8,249	9,201	9,927	10,333	**8,635**	**8,580**	**8,608**
Avg.Res. H, m	909	904	894	885	876	866	865	874	885	895	903	908	**889**	**888**	**889**
Hmax, m	910	910	910	910	910	910	910	910	910	910	910	910	**910**	**910**	**910**
Hmin, m	857	857	857	857	857	857	857	857	857	857	857	857	**857**	**857**	**857**
Outflow, mcm	1,156	1,373	1,674	1,476	1,417	1,436	1,469	2,191	2,927	3,929	4,317	2,166	**8,532**	**16,999**	**25,530**
Outflow, m3/s	432	530	625	551	586	536	567	818	1,129	1,467	1,612	835	**543**	**1,071**	**807**
Hout, m	645	646	646	646	646	646	646	647	647	648	648	647	**646**	**647**	**647**
dH = H-Hout, m	264	258	248	239	230	220	219	227	237	247	255	261	**243**	**241**	**242**
Qhpsmax, m3/s	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	**1,350**	**1,350**	**1,350**
Qhps, m3/s	432	530	625	551	586	536	567	818	1,129	1,350	1,350	835	**543**	**1,008**	**776**
N, MWh	980	1,183	1,351	1,154	1,188	1,049	1,105	1,645	2,353	2,911	2,987	1,881	**1,151**	**2,147**	**1,649**
T, h	744	720	744	744	672	744	720	744	720	744	744	720	**4,368**	**4,392**	**8,760**
Enurek, mkwth	729	852	1,005	859	798	781	796	1,224	1,694	2,165	2,222	1,354	**5,024**	**9,455**	**14,479**
Evahsh, mkwth	234	272	309	280	293	274	286	383	503	633	689	390	**1,662**	**2,885**	**4,546**

2010-2011	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct-March	Apr-Sept	Oct-Sept
Inflow, mcm	1,095	785	566	507	400	472	1,231	2,474	3,127	4,051	4,041	2047	**3824**	**16,972**	**20,796**
Res.vol. 1, mcm	10,507	10,469	9,965	9,025	7,945	6,800	6,000	6,364	7,066	8,469	10,088	10,517	**9,119**	**8,084**	**8,601**
Res.vol. 2, mcm	10,469	9,965	9,025	7,945	6,800	6,000	6,364	7,066	8,469	10,088	10,517	10,537	**8,367**	**8,840**	**8,604**
Avg.Res.vol, mcm	10,488	1,0217	9,495	8,485	7,373	6,400	6,182	6,715	7,767	9,278	10,302	10,527	**8,743**	**8,462**	**8,602**
Avg.Res. H, m	910	907	899	887	875	864	861	867	879	896	908	910	**890**	**887**	**889**
Hmax, m	910	910	910	910	910	910	910	910	910	910	910	910	**910**	**910**	**910**
Hmin, m	857	857	857	857	857	857	857	857	857	857	857	857	**857**	**857**	**857**
Outflow, mcm	1,166	1,289	1,506	1,587	1,544	1,271	868	1,772	1,724	2,432	3,612	2,027	**8,363**	**12,435**	**20,799**
Outflow, m3/s	435	497	562	593	638	474	335	662	665	908	1,348	782	**533**	**783**	**658**
Hout, m	645	646	646	646	646	646	645	646	646	647	648	647	**646**	**647**	**646**
dH = H-Hout, m	264	261	253	241	229	218	217	221	233	249	260	263	**244**	**240**	**242**
Qhpsmax, m3/s	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	**1,350**	**1,350**	**1,350**
Qhps, m3/s	435	497	562	593	638	474	335	662	665	908	1,348	782	**533**	**783**	**658**
N, MWh	990	1,119	1,233	1,252	1,290	923	647	1,301	1,365	1,969	3,000	1,773	**1,135**	**1,676**	**1,405**
T, h	744	720	744	744	672	744	720	744	720	744	744	720	**4,368**	**4,392**	**8,760**
Enurek, mkwth	737	806	917	931	867	687	466	968	983	1,465	2,232	1,277	**4,945**	**7,391**	**12,335**
Evahsh, mkwth	235	259	284	296	314	250	197	323	324	418	588	369	**1,639**	**2,218**	**3,857**

2011-2012	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct-March	Apr-Sept	Oct-Sept
Inflow, mcm	895	830	623	452	323	444	2,341	2,644	4,038	4,724	4,018	2,232	**3,567**	**19,999**	**23,565**
Res.vol. 1, mcm	10,537	10,324	9,877	9,029	7,950	6,838	6,064	6,703	7,366	8,358	9,765	10,509	**9,092**	**8,128**	**8,610**
Res.vol. 2, mcm	10,324	9,877	9,029	7,950	6,838	6,064	6,703	7,366	8,358	9,765	10,509	10,543	**8,347**	**8,874**	**8,610**
Avg.Res.vol, mcm	10,430	10,100	9,453	8,489	7,394	6,451	6,384	7,034	7,862	9,062	10,137	10,526	**8,720**	**8,501**	**8,610**
Avg.Res. H, m	909	905	898	887	875	864	864	871	880	894	906	910	**890**	**887**	**889**
Hmax, m	910	910	910	910	910	910	910	910	910	910	910	910	**910**	**910**	**910**
Hmin, m	857	857	857	857	857	857	857	857	857	857	857	857	**857**	**857**	**857**
Outflow, mcm	1,108	1,278	1,470	1,532	1,434	1,217	1,703	1,981	3,046	3,317	3,274	2,198	**8,039**	**15,520**	**23,559**
Outflow, m3/s	414	493	549	572	593	454	657	740	1,175	1,238	1,222	848	**512**	**980**	**746**
Hout, m	645	646	646	646	646	645	646	647	648	648	648	647	**646**	**647**	**646**
dH = H-Hout, m	264	260	252	241	229	219	217	224	233	246	258	263	**244**	**240**	**242**
Qhpsmax, m3/s	1,350	1,350	1350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	**1,350**	**1,350**	**1,350**
Qhps, m3/s	414	493	549	572	593	454	657	740	1,175	1,238	1,222	848	**512**	**980**	**746**
N, MWh	939	1,105	1,202	1,208	1,200	886	1,274	1,473	2,411	2,659	2,727	1,922	**1,090**	**2,078**	**1,584**
T, h	744	720	744	744	672	744	720	744	720	744	744	720	**4,368**	**4,392**	**8,760**
Enurek, mkwth	699	796	894	899	806	659	917	1,096	1,736	1,978	2,029	1,384	**4,754**	**9,139**	**13,893**
Evahsh, mkwth	227	258	279	288	296	243	321	353	521	545	539	395	**1,590**	**2,674**	**4,264**

2012-2013	Oct	Nov	Dec	Jan	Feb	March	Apr	May	June	July	Aug	Sep	Oct-March	April-Sept	Oct-Sept
Inflow, mcm	881	675	525	504	408	628	1,193	2,282	3,712	3,765	3,865	2,002	**3,620**	**16,819**	**20,439**
Res.vol. 1, mcm	10,543	10,352	9,865	9,039	8,121	7,292	6,365	6,161	6,868	8,360	9,801	10,539	**9,202**	**8,016**	**8,609**
Res.vol. 2, mcm	10,352	9,865	9,039	8,121	7,292	6,365	6,161	6,868	8,360	9,801	10,539	10,561	**8,506**	**8,715**	**8,610**
Avg.Res.vol, mcm	10,447	10,109	9,452	8,580	7,707	6,829	6,263	6,514	7,614	9,081	10,170	10,550	**8,854**	**8,365**	**8,610**
Avg.Res. H, m	909	905	898	888	879	869	862	865	877	894	906	910	**891**	**886**	**889**
Hmax, m	910	910	910	910	910	910	910	910	910	910	910	910	**910**	**910**	**910**
Hmin, m	857	857	857	857	857	857	857	857	857	857	857	857	**857**	**857**	**857**
Outflow, mcm	1,139	1,157	1,390	1,423	1,237	1,581	1,397	1,575	2,219	2,325	3,127	1,980	**7,927**	**12,624**	**20,551**
Outflow, m3/s	425	447	519	531	511	590	539	588	856	868	1,168	764	**504**	**797**	**651**
Hout, m	645	645	646	646	646	646	646	646	647	647	648	647	**646**	**647**	**646**
dH = H-Hout, m	264	260	252	242	233	223	217	219	231	247	259	264	**246**	**239**	**242**
Qhpsmax, m3/s	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	**1,350**	**1,350**	**1,350**
Qhps, m3/s	425	447	519	531	511	590	539	588	856	868	1,168	764	**504**	**797**	**651**
N, MWh	966	1,002	1,137	1,127	1,049	1,167	1,041	1,148	1,743	1,869	2,609	1,734	**1,075**	**1,691**	**1,383**
T, h	744	720	744	744	672	744	720	744	720	744	744	720	**4,368**	**4,392**	**8,760**
Enurek, mkwth	718	721	846	838	705	868	750	854	1,255	1,391	1,941	1,248	**4,698**	**7,439**	**12,137**
Evahsh, mkwth	231	240	268	272	265	295	275	294	398	402	518	362	**1,571**	**2,250**	**3,820**

2013-2014	Oct	Nov	Dec	Jan	Feb	March	Apr	May	June	July	Aug	Sept	Oct-March	Apr-Sept	Oct-Sept
Inflow, mcm	1,095	641	574	477	364	398	1,064	2,777	3,412	4,464	3,182	1,909	**3,549**	**16,808**	**20,357**
Res.vol. 1, mcm	10,561	10,351	9,783	9,005	8,070	7,175	6,240	6,121	7,100	8,683	9,917	10,554	**9,157**	**8,103**	**8,630**
Res.vol. 2, mcm	10,351	9783	9,005	8,070	7,175	6,240	6,121	7,100	8,683	9,917	10,554	10,541	**8,437**	**8,819**	**8,628**
Avg.Res.vol, mcm	10,456	10,067	9,394	8,538	7,623	6,708	6,181	6,611	7,892	9,300	10,235	10,548	**8,797**	**8,461**	**8,629**
Avg.Res. H, m	909	905	897	888	878	867	861	866	881	896	907	910	**891**	**887**	**889**
Hmax, m	910	910	910	910	910	910	910	910	910	910	910	910	**910**	**910**	**910**
Hmin, m	857	857	857	857	857	857	857	857	857	857	857	857	**857**	**857**	**857**
Outflow, mcm	1,305	1,209	1,352	1,412	1,260	1,333	1,184	1,791	1,837	3,220	2,505	1,921	**7,870**	**12,459**	**20,328**
Outflow, m3/s	487	467	505	527	521	498	457	669	709	1,202	935	741	**501**	**785**	**643**
Hout, m	646	646	646	646	646	646	645	646	646	648	647	647	**646**	**647**	**646**
dH = H-Hout, m	264	259	252	242	232	222	216	220	234	249	260	264	**245**	**240**	**243**
Qhpsmax, m3/s	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	**1,350**	**1,350**	**1,350**
Qhps, m3/s	487	467	505	527	521	498	457	669	709	1,202	935	741	**501**	**785**	**643**
N, MWh	1,106	1,045	1,104	1,116	1,065	980	881	1,309	1,461	2,604	2,098	1,683	**1,069**	**1,672**	**1,371**
T, h	744	720	744	744	672	744	720	744	720	744	744	720	**4,368**	**4,392**	**8,760**
Enurek, mkwth	823	753	821	831	716	729	634	974	1,052	1,937	1,561	1,212	**4,672**	**7,369**	**12,041**
Evahsh, mkwth	255	247	262	271	268	259	244	325	341	531	428	353	**1,563**	**2,223**	**3,786**

2014-2015	**October**	**Nov**	**Dec**	**Jan**	**Feb**	**March**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct-March**	**Apr-Sept**	**Oct-Sep**
Inflow, mcm	905	662	556	522	496	679	1,458	2,783	3,692	5,839	4,049	1,522	**3,820**	**19,343**	**23,163**
Res.vol. 1, mcm	10,541	10,419	9,929	9,205	8,411	7,633	6,779	6,700	7,761	8,810	10,145	10,500	**9,356**	**8,449**	**8,903**
Res.vol. 2, mcm	10,419	9,929	9,205	8,411	7,633	6,779	6,700	7,761	8,810	10,145	10,500	10,500	**8,729**	**9,069**	**8,899**
Avg.Res.vol, mcm	10,480	10,174	9,567	8,808	8,022	7,206	6,740	7,231	8,286	9,478	10,323	10,500	**9,043**	**8,759**	**8,901**
Avg.Res. H, m	910	906	899	891	882	873	868	873	885	898	908	910	**893**	**890**	**892**
Hmax, m	910	910	910	910	910	910	910	910	910	910	910	910	**910**	**910**	**910**
Hmin, m	857	857	857	857	857	857	857	857	857	857	857	857	**857**	**857**	**857**
Outflow, mcm	1,029	1,170	1,259	1,317	1,275	1,535	1,562	1,722	2,651	4,508	3,668	1,528	**7,585**	**15,640**	**23,225**
Outflow, m3/s	384	451	470	492	527	573	603	643	1,023	1,683	1,370	590	**483**	**985**	**734**
Hout, m	645	645	646	646	646	646	646	646	647	648	648	646	**646**	**647**	**646**
dH = H-Hout, m	264	261	254	245	236	227	222	227	238	250	260	264	**248**	**243**	**246**
Qhpsmax, m3/s	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	**1,350**	**1,350**	**1,350**
Qhps, m3/s	384	451	470	492	527	573	603	643	1,023	1,350	1,350	590	**483**	**926**	**705**
N, MWh	874	1,015	1,035	1,053	1,094	1,152	1,187	1,292	2,135	2,939	3,000	1,338	**1,037**	**1,982**	**1,510**
T, h	744	720	744	744	672	744	720	744	720	744	744	720	**4,368**	**4,392**	**8,760**
Enurek, mkwth	650	731	770	783	736	857	855	961	1,537	2,186	2,232	964	**4,527**	**8,735**	**13,262**
Evahsh, mkwth	216	242	249	257	271	289	300	315	462	717	596	295	**1,522**	**2,685**	**4,207**