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The Central Asian Economies of Water-energy security: The Future Role of Hydro and Fuel-based Systems

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ABSTRACT

This article provides an overview of the energy potential of Central Asian economies and in particular, the power sector of Tajikistan, with a special emphasis on the potential usage of coal since water availability for hydropower in the region depends on seasons and is already affected by climate change. With these restrictions, coal arises as to the economic alternative and coal-fired plants are considered in the country as a tool for development and new coal-fired plants are under construction and development of new coalmines is also proposed. The objective of this article is to achieve profitable capital investment in a 250 MW coal-fired thermal power plant situated in east part of Tajikistan. In this context, the article applies a mathematical model to estimate the quantitative advantages of coal alternatives. The cost analysis of the plant was carried out on the basis of total capital investment, operating cost (i.e. coal feedstock, maintenance and labour, and cost of pumping power) and revenue. Furthermore, the article discusses the main concerns of the government of Tajikistan in sustaining its economic development, and finally, describes the future role that hydro-coal power will play in this development.

Keywords: Energy Security, Energy Economics, Central Asia
JEL Classifications: 0130, Q400, Q430

1. INTRODUCTION

The water-energy problem in Central Asia (CA) is based on the contradiction between the energy needs of countries located in the upper (Tajikistan and Kyrgyzstan) and the irrigation needs of the countries located in the lower (Kazakhstan, Turkmenistan, and Uzbekistan). In winter, the countries located in the upper experience an increased need for heat and power service, and the water used to generate electricity flood the irrigated areas of the countries located in the lower (Stucki and Sojamo, 2012). In summer, the upper countries require less heat and energy, while the agriculture of the lower countries need abundant watering (Salnikov et al., 2015). The sovereign states of the region cannot find a balance of these needs. The plans of the upper countries related to the construction of new large energy facilities are not welcomed by Kazakhstan and are met with hostility by Uzbekistan (Dorian, 2006). This contradiction is reflected in the whole range of relations between the Central Asian countries.

Kazakhstan, Uzbekistan, and Turkmenistan have the opportunity to develop their economies through agriculture and the development of rich mineral resources including gas, oil, and coal (Movkebayeva et al., 2020). Tajikistan, which has the least land per capita (0.11 ha), of which 0.08 ha is irrigated, 93% of the territory is mountains, and where there are not enough hydrocarbon resources explored (Flammini et al., 2014). There is no other alternative than the development of hydropower as a strategic direction of their economy. Uzbekistan's claims to Tajikistan boil down to the fact that these projects allegedly do not consider their needs for land irrigation (Saiymova et al., 2020).

Another important aspect that forces Tajikistan to develop hydropower is due to the fact that in a country where almost 60% of the region's water resources are concentrated, 70% of the population receives electricity in the winter only a few hours per day, moreover, the situation in this the period is compounded by the fact that there is practically no gas in the republic (Dai et al., 2018). The paradox is that in winter, in order to save water for the countries located in the lower in the irrigated period, Tajikistan partially stops the work of hydropower production and at the same time country buys electricity from Uzbekistan at a high price (Boonstra, 2011). Thus, Tajikistan works at a loss, because by giving water, it provides Uzbekistan with electricity in the amount of 1.5 times more than it receives from it through gas supplies (Saiymova et al., 2018).

The problem of the resource supply of Central Asian countries is complex, covering water consumption, electricity, and gas supply (Nyussupova and Kalimurzina, 2016). It shows a high degree of integration of the economies of CA and Kazakhstan, which is tied to the problem of water supply (Bernauer and Siegfried, 2012). The solution to the water-energy problem in the region can be of universal significance. According to UN forecasts, by 2040, 60% of the world's population (approximately 5.5 billion people) will experience water shortages to varying degrees (Cotella et al., 2016). A positive solution to the water and energy problem in CA would serve as a contribution to the development of a methodology for resolving similar contradictions in other parts of the world.

2. FOSSIL FUEL POTENTIAL

The mineral base of almost all Central Asian countries is relatively rich (Auty and De Soysa, 2006; Dorian, 2006). The leader is Kazakhstan, its mineral resources base includes the most a wide range of minerals in the region (coal, oil, gas, uranium, metal, and non-metal), and the level of production is large enough (Demirbaş, 2002; Sheives, 2006; Baev, 2008). Uzbekistan has gas and gold, in Turkmenistan - gas, in Kyrgyzstan, and Tajikistan - gold and uranium (Bahgat, 2006; Karatayev et al., 2016). According to the BP Statistical Review of World Energy (2017), proven reserves of natural gas at the end of 2016 were as follows: Turkmenistan - 17.5 trillion cubic meters, Uzbekistan - 1.1 trillion cubic meters, Kazakhstan - 1 trillion cubic meters. As for oil, the numbers were as follows: Kazakhstan - 3.9 billion tons, Turkmenistan, and Uzbekistan - about 0.1 billion tons (BP, 2016; Rahman, 2011).

National statistics from these countries give other, more optimistic figures. According to Kazakh studies, natural gas reserves in Kazakhstan are about 2 trillion cubic meters, which is 2 times more than the figures given by British Petroleum (Pomfret, 2011; Koshim et al., 2018). According to the Minister of Energy of Kazakhstan, the country's oil reserves possesses about 5 billion tons, this figure is also significantly higher than the above (Allison, 2004; Bohr, 2004; Cooley, 2008; Singh, 2013; Zhiltsov, 2014). According to official Tashkent, potential oil resources in Uzbekistan more than 5.3 billion tons, natural gas - about 5 billion cubic meters (Saparaliyev et al., 2019). Numbers concerning Turkmenistan, much larger: the country has oil for 20.86 billion tons, gas - 50.34 trillion cubic meters. It is also important to note that the extraction of fuel and energy resources in two other Central Asian countries (Kyrgyzstan and Tajikistan) is insignificant, to the end, it cannot even satisfy domestic needs (Blank, 1995; Zakhidov, 2008; Akhmetov, 2015).

3. HYDROENERGY POTENTIAL

Water resources between the Central Asian states are divided unevenly. Over 90% of Central Asian water resources are concentrated in Kyrgyzstan and Tajikistan (Granit et al., 2012; Stucki and Sojamo, 2012). At the same time, the main consumers of water in the region are Uzbekistan and Kazakhstan, with Uzbekistan accounting for over 50% of the consumed water resources (Jalilov et al., 2013). The main source of water in the region is the flows of the Syr Darya and the Amu Darya, which form in the Pamir and Tien Shan mountains. The Syr Darya flows from Kyrgyzstan through Tajikistan to Uzbekistan (through the highly populated Ferghana Valley) and Kazakhstan, the Amu Darya flows from Tajikistan to Turkmenistan and Uzbekistan. Therefore, Kyrgyzstan and Tajikistan control the water resources that are required for other Central Asian states (Bakhtiar and Kadyrzhan, 2011). The upper reaches of the rivers and Kyrgyzstan and Kyrgyzstan view water as a strategic commodity because these countries are poor in other resources and use water to generate electricity for their own needs (Kiliç and Kaya, 2007). Energy-rich countries (Turkmenistan, Uzbekistan, and Kazakhstan) are in water dependence on Tajikistan and Kyrgyzstan, which form a schedule for lowering water down (Georgi, 2010).

The volume of water use in Central Asian countries is very uneven. The average annual volume of freshwater use per capita varies from 2.1 thousand m^3 in Tajikistan to 4.9 thousand m^3 in Turkmenistan. In the countries of CA, water is used in agriculture for irrigation and the production of electricity (Mamatkanov, 2008). In the former USSR in the mid-80s of the last century, the share of hydroelectric power plants of the combined energy systems of CA and Kazakhstan accounted for 24% of the total hydroelectric power generated, with the installed capacity of hydroelectric power plants in CA taking second place after the same indicator in Siberia. Vakhsh (installed capacity of 3.4 million kW) and Naryn-Syrdarya (2.7 million kW) cascades of hydroelectric power stations were among the five largest cascade-hydropower complexes of the USSR (Zhang et al., 2018). Political and economic crises that covered almost the entire Central Asian region in the 90s of the 20th century led to a decrease in the use of existing hydropower capacities and a freeze on the construction of the designed cascades of hydropower plants (Wegerich, 2011). However, nowadays, hydroelectric power plants make up a significant role (on average, about 20-30%) in the structure of electricity production in Central Asian countries (Karatayev et al., 2017).

Currently, the economically feasible hydropower potential of Central Asian countries is estimated at 173 billion kWh per year, of which 84% total energy demand of Central Asian countries (Valeyev et al., 2019). The development of hydropower potential is especially promising for these countries. The economically feasible hydropower potential in this region is 1.7 times higher than the total electricity production at all types of power plants in Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan combined. Despite the fact that hydropower plants have been created on many rivers, the energy potential of the river flow of CA has been used to a small extent. The actual use of hydropower potential is approximately 18% in CA and 14% in Kazakhstan (Zhang et al., 2018). For comparison, in the Central regions of the European part of Russia, the Volga region, and in the Urals, the corresponding level of development is 70%. In the mountainous regions of CA, there are favorable conditions for the creation of cascades of hydroelectric power stations, the most efficient energy development of watercourses both during construction and during operation (Yerkin et al., 2019).

However, there are barriers to the development of hydropower. For example, since 1998 there is an agreement between Kyrgyzstan, Kazakhstan, Uzbekistan, and Tajikistan on the use of water and energy resources of the Syr Darya river basin, which includes the Naryn River. Under this agreement, Uzbekistan and Kazakhstan should regularly buy electricity generated annually during the summer releases of water from the Toktogul reservoir. According to the agreement, Kazakhstan and Uzbekistan must buy 2.2 billion kWh of electricity from Kyrgyzstan at a cost of 1.1 cents within 6 months. During the growing season, Kyrgyzstan is forced to release from 6 to 7 km^3 of water, generating 4.9 billion kWh of electricity including 2.7 billion kWh for own needs and 2.2 billion kWh for sale (Stucki and Sojamo, 2012). However, nowadays Uzbekistan has not been buying electricity, so the country has actually withdrawn from this agreement. Kazakhstan also does not regularly buy electricity.

Added to this is the problem of imbalance in gas and electricity prices. The price of electricity in Uzbekistan and Kazakhstan is 3.5 U.S. cents on consumer meters. Therefore, Kyrgyzstan would like to sell its electricity for at least 2 U.S. cents (Kozhukhova et al., 2019). In 1996, the government of Kyrgyzstan made a concession to Kazakhstan and decided to sell electricity at 1 U.S. cent (it used to cost 3 U.S. cents). In response, the Kazakhstan promised Kyrgyzstan to supply Karaganda coal to Bishkek CHP at a cost of 16 USD per ton (Karatayev et al., 2018). Then Kazakhstan refused this, and Kyrgyzstan prices remained unchanged. Therefore, if earlier it was said about the brilliance of the Kyrgyzstan electric power industry, today it is said about its poverty and decline. Similar problems exist in Tajikistan.

4. CASE OF TAJIKISTAN

The Republic of Tajikistan (Tajikistan) is located in CA, bordered by Afghanistan to the south, Kyrgyzstan to the north, Uzbekistan to the west and China to the east. The country is approximately 143 000 km^2 in size with a population of 9 million (Figure 1). Tajikistan's economy performed strongly in the decade following the civil war that ended in 1997. The agricultural sector is the largest sector of the economy and employs more than 65% of workers. Real gross domestic product (GDP), measured in USD with purchasing power parity (PPP) was USD 20.6 billion in 2018, which is an increase of 110% compared to 1996. Relatively strong economic growth came from favourable prices in the country's main export items of cotton and aluminium. There was also significant growth in remittances from Tajik labourers working abroad. The global financial crisis hit Tajikistan through a drop in exports and remittances; however, the economy has stabilised since through help from the international community (World Bank, 2020).

Nowadays, Tajikistan faces a set of tasks that are interconnected, with their ultimate goal of economic growth of the country to a world average level and its inclusion in the international market, while improving the life of the population and protecting the environment. To solve these tasks, the priority development of the energy sector seems necessary. Energy resources in Tajikistan are represented by small oil and gas reserves, rather significant coal reserves in numerous deposits located mainly in mountainous, inaccessible areas (Hoeck et al., 2007; Wegerich et al., 2007. The country also has a huge, unique hydropower resources, the total potential of which is 527 billion kWh in year (Laldjebaev, 2010). International calculations show that in order to achieve the global average level of economic development, the total production and consumption of electricity in Tajikistan should increase three times. At the same time, nowadays and for the nearest future, hydropower will be the basis of all energy in Tajikistan (Umarov and Hanmadshoev, 2001; Doukas, 2012). And the outstripping development of Tajikistan's energy sector, which is necessary for reaching the world average economic level, is quite real (Shvedov et al., 2018). These are the parameters for the construction of hydropower plants that were provided for the republic during the Soviet time. In recent years, after the crisis of the 1990s of the last century, the development of hydropower in Tajikistan has resumed (Abazov, 2008). The Sangtuda hydropower plants 1 and 2 were built, the construction of the Rogun hydropower plant was resumed, on which the first two units have already been commissioned, and the program for the construction of small hydropower plants is being implemented.

At the same time, it is necessary to consider the shortcomings and very significant, objectively inherent in hydropower. Firstly, this is the unevenness of the river flow used to generate electricity - even for values such as average annual costs, the flow unevenness is very large - the extreme values differ almost twice. A greater non-uniformity of flow occurs during the year. The extreme values of average monthly expenses in the context of the average year differ by almost 10 times. Given the years of different water availability, this difference will be even greater. Thus, hydropower uses a resource to generate electricity, even the average monthly volume of which in its natural state fluctuates 20 or more times. This leads to a sharp decrease in production in the winter due to low-water spending in rivers - a fact well known to government of Tajikistan. Furthermore, the irregularity of flow can be reduced and even completely eliminated by regulating river flow by dams. But for this it is necessary to build a very large number of such dams. More simply and efficiently, this problem of river flow unevenness is solved by including a certain percentage of thermal power production in the general energy system along with hydroelectric power stations.

Total primary energy supply (TPES) in Tajikistan was 2.7 million tonnes of oil-equivalent (Mtoe) in 2018. The energy supply has increased by 6.5% since 1998, despite a contraction during the global financial crisis in 2008-09 (Figure 2). Hydropower is the main source of energy in Tajikistan. It accounted for 68% of TPES in 2018. Oil and coal represented 21.8% and 6% of TPES, respectively, while the remainder was accounted for by natural gas (4.2%). Over the past decade, gas supply in Tajikistan has declined by 72.2% while the supply of oil has increased by 78.7%. Coal use has surged over the same period, with the coal supply increased 100 times from negligible levels in 1998 to 0.2 Mtoe in 2018. Hydropower has increased by 11.4% from 2002 to 2018. Around 87% of total production is from hydro. The remainder comes from coal (10.7%), oil (1.8%) and natural gas (0.5%). Energy production has increased by 22.9% since 1998, which is a faster rate of growth than that of TPES. Coal production has boomed and is expected to continue to grow as Tajik industry switches from other fuels to coal use. The production of oil has increased by 87.5% while natural gas production declined by 64.9%.

Electricity generation in Tajikistan totalled 19 terawatt hours (TWh) in 2018, which is 10.9% higher compared to 1998 (Figure 3). The electricity supply has experienced volatility from one year to the next, with average generation of 16.6 TWh over the ten years from 1998 to 2018. Since the mid-1990s, the peak in electricity generation was 17.5 TWh in 2007, after which generation plateaued for four years before a 6.5% increase in 2018. Nearly all electricity is from hydropower, with only 0.4% from natural gas in 2018. Tajikistan produced around 0.4 petajoules (PJ) of heat in 2018, which is 88.1% lower compared to ten years ago. Heat was produced from natural gas before gas supplies from Uzbekistan were cut off in 2013. Since then, heat has been generated from coal in smaller volumes. Total heat supply in Tajikistan has been declining since 1990.

Tajikistan is reliant on imports of fossil fuels for around a quarter of its energy mix. Net imports were 0.8 Mtoe in 2018 or 35% of TPES. Imports are oil products (82.1%) and natural gas (15%), while Tajikistan's main export is electricity (70%), followed by oil products (23%). Tajikistan used to import gas from Uzbekistan, but Uzbekistan stopped delivering gas to Tajikistan in 2013. The second drawback of Tajikistan's hydropower is that its water

Figure 1: Geographic position of Tajikistan

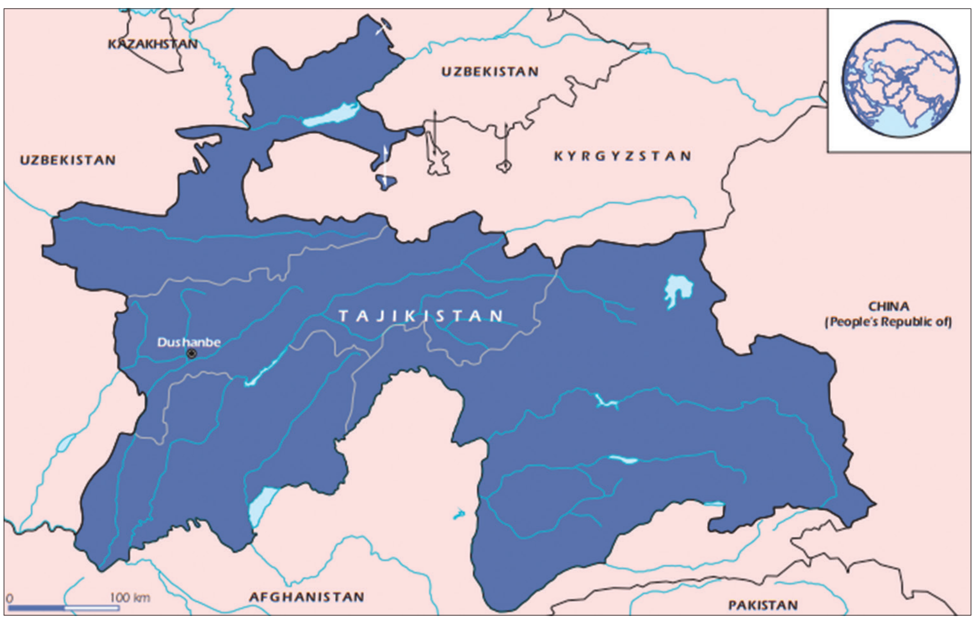


Figure 2: Total primary energy supply, Mtoe

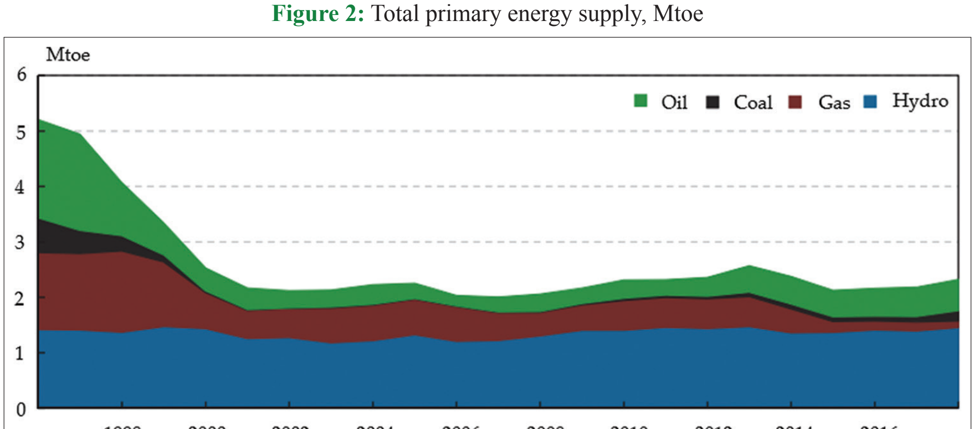
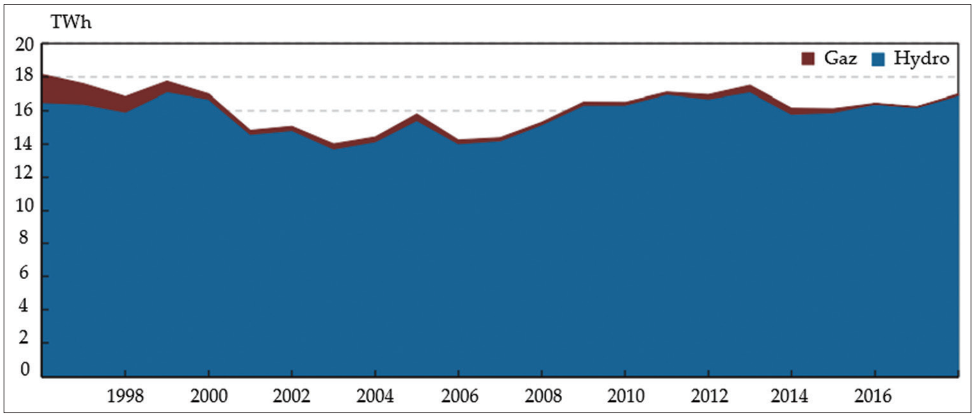


Figure 3: Electricity generation, TWh



resources are transboundary and are used by downstream countries mainly for irrigated agriculture. The inclusion in the general energy system of Tajikistan of a certain share of thermal energy solves this problem. All this shows not only the possibility, but even the need to develop coal energy in Tajikistan, as an addition to hydropower. As noted above, Tajikistan has large industrial coal reserves, of which only the accounted volumes are more than 700 million tons (Table 1). Therefore, the use of coal in the energy sector of Tajikistan is fully justified. The main task in this case is to determine the most optimal shares of hydropower and coal in the overall structure of energy.

Given the absence of water charges in the republic, the cost of electricity of a hydropower plant does not include a fuel component and consists only of the costs of operation and maintenance: for the actual production of electricity < 0.01 cent per kWh, and taking into account transportation and distribution ≈ 0.05 cent/kWh. At the same time, the fuel component at TPPs is quite significant. According to studies, coal prices for the period until 2030 will be about 200 USD per ton. Hydropower plant loses a thermal power plant in terms of the unit cost of construction: under current conditions it is equal to 1200 USD per kW, while 600 USD per kW at a thermal power plant. A disadvantage of a hydropower plant is its long construction time compared to a thermal power plant. On average, large power plants are built in 5, and thermal power plants in 3 years (Zhaxylykova et al., 2020). In addition, in order for the hydroelectric power station to be equal to the thermal power plant in terms of its economic effect, its installed capacity should be 1.5 times greater. Accordingly, there will be more construction costs, but the production of hydroelectric power plants will not increase. Finally, even if there is a regulatory reservoir, due to the sharp unevenness of the river flow, the number of hours of using a hydropower plant is on average 4000 hours per year, and at a TPP - 6000 h/year.

Total final consumption (TFC) of energy was 2 Mtoe in 2018. TFC has increased by 13.5% since 2002, with some annual volatility (Figure 4). Around 58% of TFC is electricity, while oil accounts for 27.3%. Coal, natural gas and heat represent 9.2%, 4.8% and 0.5% of TFC, respectively. Final consumption of natural gas and heat has contracted by 56.7% and 88.1%, respectively, over the ten years to 2018. Conversely, the use of coal and oil has increased by 992.2% and 78.6%, respectively. Demand for electricity has increased by a moderate 2.1% over the same period. Industry is the largest consuming sector and accounts for 26.7% of TFC, followed by agriculture at 16.1%, residential at 11.2%, transport at 5.4% and commercial and public services at 4.1%. However, the data include non-specified consumption, which is significant at 36.6%. Non-specified consumption includes all fuel use not elsewhere specified in data collection (Smagulova et al., 2018). Non-specified consumption is most likely in rural areas. The industry sector (mainly the aluminium industry), agriculture and the residential sectors are the main consumers of electricity, and coal, gas and oil are mainly consumed in commercial services and transport. Renewable energy in Tajikistan is in the form of hydropower, which accounts for 64.1% of TPES, 86.9% of energy produced and 99% of electricity generation. Tajikistan has the highest share of renewables in TPES among Eastern Europe, the Caucasus and CA countries, followed by Kyrgyzstan's similar energy mix (Smagulova et al., 2017). Hydropower generation has increased by 11.4% since 1998, increasing its share in TPES from 61.3% in 1998 to 64.1% in 2018 (Figure 5).

Table 1: Coal reserves in Tajikistan, mln.t

Location	Accounted	Forecasted	Total	In operation
Shurab	130.0	170.0	300.0	-
Fan-Yagnob	428.9	923.7	1352.6	-
Nazar-Ailok	37.1	300.0	337.1	3.3
Ziddi	46.0	44.0	90.0	1.0
Saimeri	-	1.0	1.0	0.3
Mienadu	8.0	11.0	19.0	0.2
Ravnau	-	179.2	179.2	0.04
Shurobod	0.1	294.0	294.1	0.03
Magian	39.0	165.9	204.9	0.02
Khahimi	-	42.0	42.0	0.06
Guzn	0.1	34.0	34.1	0.01
Zauran	-	186.4	186.4	0.01
Chashma-Zang	-	1.5	1.5	0.05
Suffa	-	33.5	33.5	0.02
Others	24.6	502.5	527.1	
Total	713.8	2887.7	3601.5	

5. METHODOLOGY

In order to find out in more detail those conditions under which all the advantages and disadvantages of hydropower plants and thermal power plants in the general structure of energy system are

Figure 4: Total final consumption by sector, Mtoe

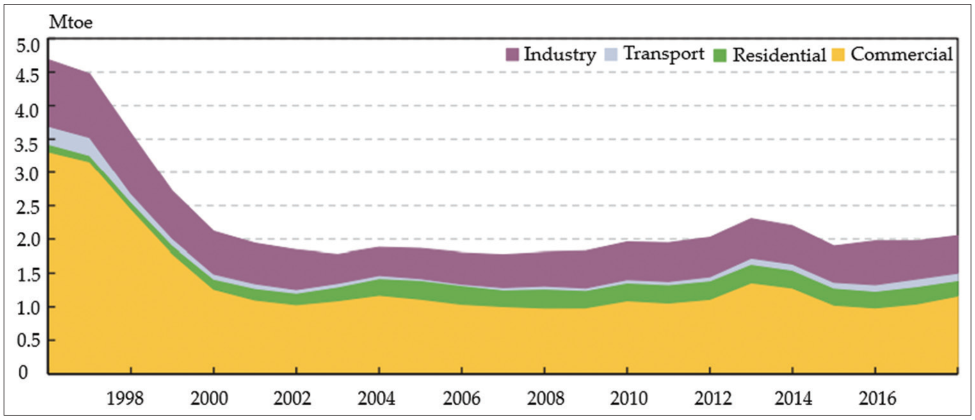
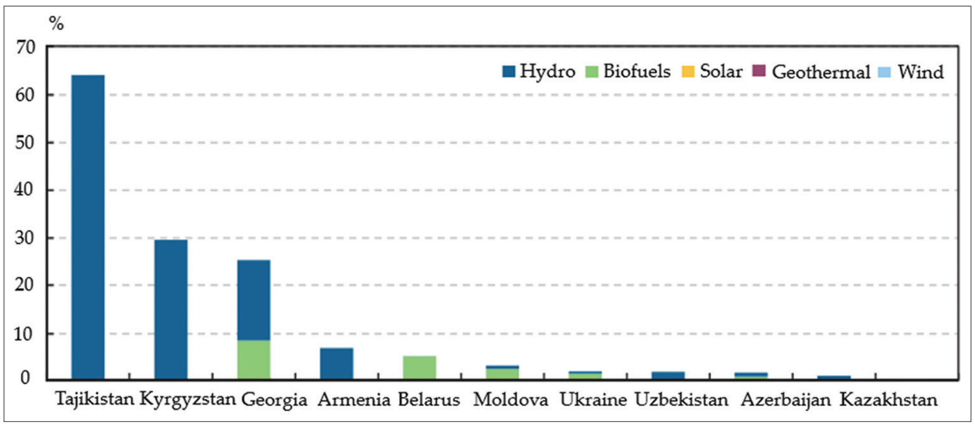


Figure 5: Renewable energy as a percentage of TPES, %



best manifested, an economic analysis is needed. The life cycle of a power plant is the same for both hydroelectric power plants and thermal power plants, and their financial flow or net present value of the project in this case is:

$$C_{direct} = C_{eqp} + C_{other} \quad (1)$$

The operating cost (includes the purchasing cost of coal feedstock, maintenance and labour, insurance and cost of power associated with boiler feedwater pumps and condensate extraction pumps for running the thermal power plant) is considered to be paid annually over the lifespan of the coal-fired power plant. It is likely to be changed in an economic climate (i.e. due to current interest rate and escalation rate in the prices of coal, maintenance, labour, insurance and pumping power). Therefore, to account for the influence of interest rate and the escalation rate for the total operating cost over plant life, the present worth factor (PWF) can be defined as:

$$PWF_k = \frac{1}{(1+i)^k} \quad (2)$$

Thus, the lifetime cost of coal or fuel, maintenance, labour, insurance and pumping power can be obtained in terms of PWF. Coal or fuel cost can be defined as:

$$C_{coal} = \sum_{k=1}^{pl} \left(PWF_k \times m_k \times C_{cc} \left(1+K\right)^{(k-1)} \right) \quad (3)$$

The maintenance cost is:

$$C_{maint} = \sum_{k=1}^{pl} \left(PWF_k \times C_{tci} (1+Q)^{(k-1)} \right) \quad (4)$$

The labour cost is:

$$C_{lab} = \sum_{k=1}^{pl} \left(PWF_k \times n_l \times C_s (1+J)^{(k-1)} \right) \quad (5)$$

The pumping cost is:

$$C_{pumping} = \sum_{k=1}^{pl} \left(PWF_k \times A_{overal} \times \left[\sum_{j=1}^{N} \frac{\left(\frac{m_j}{P_{water}}\right) \times P_j}{n\ pump,\ j} \right] C_{ep} (1+J)^{(k-1)} \right) \quad (6)$$

The maintenance and insurance costs are taken to be 1.5 and 1% of the total capital investment obtained from the literature. The coal storage, fuel handling system and fume treatment costs are neglected in the present work. The taxes and financial charges have been neglected in this work. The lifetime cost of purchasing cost of coal feedstock, maintenance and labour, insurance and cost of power associated with boiler feedwater pumps and condensate extraction pumps for running the thermal power plant can be calculated as:

$$C_o = C_{coal} + C_{maint} + C_{lab} + C_{pumping} \quad (7)$$

Likewise, the revenue over life span can be obtained from the sale of electricity in terms of PWF as:

$$R_{an} = f_{MW} \sum_{k=1}^{pl} (PWF_k \times MW \times A_{overal} \times C_{ep} (1+Q)^{(k-1)}) \quad (8)$$

It was reported that 10% of the total revenue is consumed in internal affairs of the plant, which includes the pumping cost itself. Since we have included the pumping cost in the operating cost itself, the necessary adjustment in the net electric output would be required. From a baseline run, it was observed that the pumping cost was hardly 1% of the total revenue. Therefore, the value of f MW was fixed at 91%. For assessment of the economic effectiveness of the investments, the NPV method is most frequently used. In the present work, therefore, the NPV method was employed. The expression of the net present value of plant on lifetime basis can be written as:

$$NPV_{lifetime} = R_{lifetime} - (C_o + C_{tci}) \quad (9)$$

The current interest rate is fixed at 9%. Plant life is assumed to be 50 years. Using the above mathematical models, the effect of various variables is investigated on plant operating cost (i.e. fuel cost, pumping cost, insurance and maintenance cost), total capital investment, revenue and net present value.

6. RESULTS

The effect of variation in total plant life has been highlighted on lifetime cost associated with plant operation (i.e. coal feedstock, maintenance and labour, and cost of pumping power due to feedwater pumps and boiler extraction pumps), total capital investment, revenue and net present value of plant. In Figure 6, the effect on lifetime cost components such as fuel, maintenance, insurance, labour and pumping has been plotted against plant life, which varies from 0 to 50 years with an interval of 5 years. The total fuel cost, maintenance, insurance, labour cost and pumping cost over the plant life increases with plant life, as expected. The fuel cost is observed to be highly sensitive, while pumping cost is observed to be least sensitive for the above range of plant life.

Figure 7 highlights the effect on total operating cost, total capital investment, revenue earned and net present value with plant life up to 50 years. Total operating cost, revenue and net present value of the plant also improve with plant life. Lifetime plant operating cost increases up to 3230.2 Tajikistani Somoni (TJS), while total revenue increases up to 6572.3 TJS by increasing plant life from 5 to 50 years and plant net present value improves from −2665.4 to 1850.8 TJS for encountering variation in plant life. At the present time frame, the total capital investment remains constant. It is observed from predictions that payback (or gestation period) of the plant is nearly 10 years. Beyond this period, the plant starts showing a profit.

The economic attractiveness of coal energy increases with an increase in selling tariffs for electricity and a decrease in the internal rate of return for ongoing projects. That is, with an increase in the level of economic development of the country

Figure 6: The effect of plant lifetime on cost components

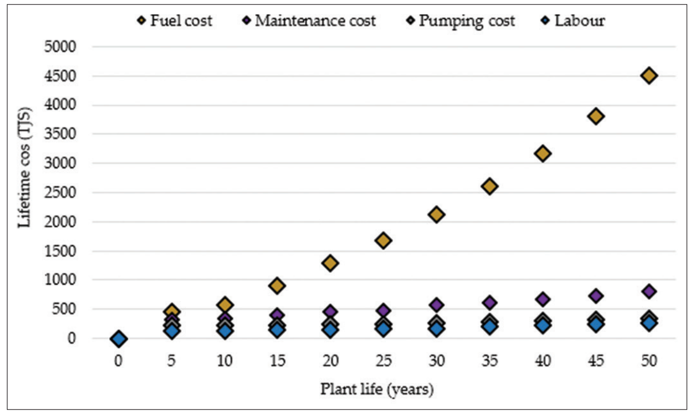
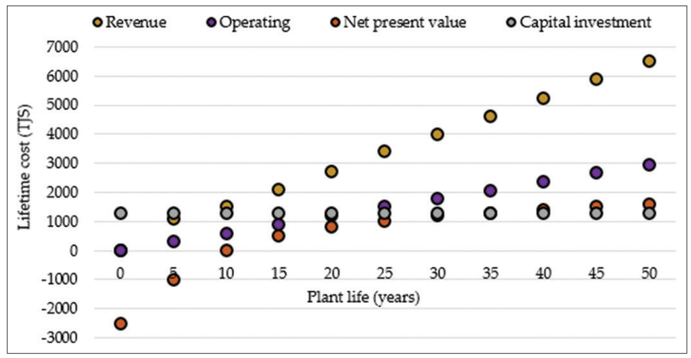


Figure 7: The effect of plant life on revenue and net present value



and its investment rating. The effect of variation in the number of labourers employed has been highlighted on the accumulated total fuel cost, pumping cost, insurance and maintenance cost, labour cost, fixed cost, operating cost, revenue and net present value of the plant. Since the contribution of labour cost to operating cost is very small, the variation in all trends of operating cost, revenue and net present value is marginal.

7. CONCLUSION AND DISCUSSION

The main priority of the Tajikistan government is to maintain social order while pushing ahead with economic development in a sustainable manner. The country looks for an opportunity to diversify its energy balance by increasing the usage of coal and hydropower resources. In spite of the government's push for a market economy, certain items are still under price control. Electric energy is one of those items. In the past, the energy price was determined by the need to repay the government's investment in the project, plus tax and interest. As a result, contrary to the claims of most environmental groups, hydropower ended up being the cheapest energy in Tajikistan. This low price for hydro has several adverse effects on the hydro industry: it is a disincentive to designing the generating plants for peaking, and it is a major obstacle to future investment in hydro (particularly by private investors in build, operate and transfer projects).

Hydro development requires large initial capital outlays. This is traditionally done at the government level. For most developing countries with uncertain economic futures and typically high internal interest rates (more than 20%), such large capital investments are usually difficult to arrange. Most developing countries, therefore, rely on financial institutes such as the World Bank and the Asian Development Bank, with lower interest rates to fund such large-scale projects. In the early days of market reform, Tajikistan was no exception. Loans from such institutes usually come with certain conditions attached, such as the requirement for international competitive bidding, the very strict and long environmental assessment, and even subjects like human rights. Most client countries consider these less than acceptable interference, forced on them by the rich countries.

As an alternative to government funding for such large-scale projects, Tajikistan is attempting to attract investments from China. Tajikistan is one of the countries most endowed with hydropower resources in the world and eighth in terms of absolute production potential reaching 300 billion kWh per year (Freeman, 2018). Tajikistan is second only to Russia in this indicator among all CIS countries. This colossal potential could not go unnoticed by Chinese companies. On August 31, 2017, a meeting between President of Tajikistan Emomali Rahmon and President of China Xi Jinping took place in Beijing, at which they discussed the prospects for cooperation between the countries in the field of hydropower (Karimov et al., 2013). According to Rahmon, his country is certainly interested in China increasing its investments in the country's hydropower, taking an active part in the construction of new hydropower plants. China, as you know, has extensive experience in building hydropower plants on its territory, and seeks to increase the share of hydropower in the country's energy basket (Kassenova, 2009). In 2016, China accounted for 28.9% of global hydropower production. The most striking example of the development of the hydropower industry in China is the project of the largest hydroelectric power station in the world - the Three Gorges hydroelectric power station with a capacity of 22.5 million kW. The Chinese, due to the negative environmental consequences of the development of their own water resources (erosion of the riverbed, increased seismic hazard, deterioration in water quality, etc.) are considering options for exporting electricity received by hydroelectric power plants located in neighboring countries.

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