



# The Water-Energy-Food Nexus in Tajikistan: The Role of Water User Associations in improving Energy and Food Security

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## Abstract

*Tajikistan's agricultural sector suffers from a highly inefficient use of water and energy resources. As a country that is heavily dependent on energy-intensive pumping irrigation, wastage of water and electricity has severe impact on the country's energy and food security. The recent opening of potential energy exports further highlights these practises. Water User Associations (WUAs) can mitigate the delicate balance between water, energy and food in Tajikistan. Although they are often still underdeveloped, WUAs can address challenges that hinder agricultural energy efficiency. This paper suggests some low and no-cost technical and policy solutions.*

**Keywords:** water user associations, pumping irrigation, food security, energy efficiency.

## 1. Introduction

In the landlocked country of Tajikistan, energy, water and food are inextricably connected. About half of Tajikistan's territory is located above an altitude of 3,000 meters, with mountains covering 93% of the country [1]. The mountainous terrain forms an enormous challenge to the country's agriculture. Farming can only be practiced in plains situated in lowland areas. Due to the differences in altitude, 44% of agriculture is dependent on irrigation pumps– the highest percentage in Central Asia [2]. Irrigation pumping requires a steady energy supply to ensure proper functioning and makes the agricultural sector into the third largest energy consumer in the country, accounting for 21% of Tajikistan's total electricity consumption [3].

In order to meet the country's high energy needs, Tajikistan has resorted to tapping its rivers and streams for energy. The country currently covers 90% of its electricity demand through hydropower plants (HPPs) [2]. However, it faces a serious problem of inefficient use of water and energy resources. Following the country's independence in 1991, a devastating civil war and an economic collapse, water and energy infrastructure has been neglected and has fallen into disrepair. Ageing infrastructure, out-dated irrigation methods and unsustainable management practices have led to both water and energy being used highly inefficiently. Due

to these problems, only an estimated 30% of the total irrigation water ultimately reaches cultivated lands [2].

Literature on Central Asian water and energy has mainly focused on the balance of resource allocation between upstream and downstream riparian countries. However, publications on the connection between water, energy and food have been scarce. For Tajikistan, and to some extent for Kyrgyzstan and Uzbekistan, the current situation could have severe consequences for energy and food security. Already Tajikistan's energy supply cannot meet energy demand throughout the year, and food and energy demands are predicted to grow as the population rises. Food production is limited by the inefficient practises as well as by lacking electricity. Rural communities depending on subsistence agriculture for their livelihoods are especially vulnerable. If nothing is done, these communities could be severely affected. This situation can have consequences not only for the wellbeing of many, but also for the socio-political stability in the country and the wider region [4].

Recent developments have further highlighted the issue of energy efficiency. The signing of electricity trading agreements with Tajikistan's neighbours has opened up new possibilities for exporting electricity. It will soon be possible to export summer hydropower surplus, which is currently still largely wasted, at lucrative prices to Afghanistan and Pakistan. This prospect highlights wasteful practises more than ever: while electricity can now be a source of large revenue, it is currently largely spent on wasteful irrigation pumps.

Structural reforms demand significant investments in rehabilitation and maintenance of irrigation and energy facilities, for which funds are presently limited. This paper will therefore suggest low or no-cost technical and policy interventions on both local and national level. The role of Water User Associations (WUAs) as a suitable mean to balance the water-energy-food gridlock is especially emphasized. Legislative reforms will expand the responsibilities of WUAs in the near future [5]. WUAs currently face limited financial resources and knowledge capacity, and struggle to operate and maintain irrigation systems. However, they could have an important role in improving energy efficiency by and maintaining sustainable water and energy practises.

The first part of this paper sheds light on Tajikistan's energy and food security, focusing on the country's precarious situation. This is followed by an overview of the past and current agricultural water management in the country, focusing on pumping irrigation. The third and last part is dedicated to the role of WUAs in addressing energy efficiency. Low-cost measures are suggested to enable WUAs to tackle wasteful practises, focusing on both small-scale technical solutions and policies on a national level. The concluding remarks synopsise the current situation in Tajikistan, stressing the need for the enhancement of the role of WUAs and the impact of energy export on the food and energy situation.

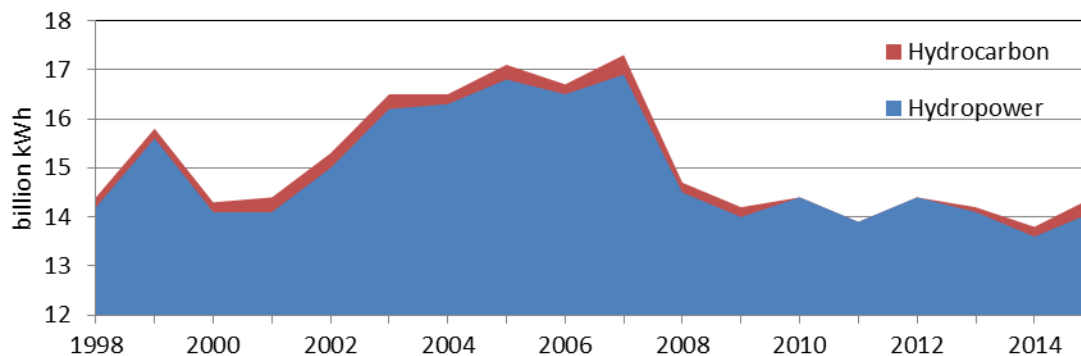
## **2. Energy and food security**

Before independence in 1991, the Central Asian energy network was regulated by a common regional energy system. The Central Asia Power System (CAPS) was established in the 1970s

and included all five former Central Asian Soviet republics into the internal market of the Soviet Union, where internal borders were disregarded and energy could be traded freely across the region. The CAPS helped mitigate the region's disproportional spread of resources: while the upstream countries of Tajikistan and Kyrgyzstan had large water supplies and almost no hydrocarbon resources, the downstream countries of Uzbekistan, Kazakhstan and Turkmenistan had large oil and gas reserves but suffered from water scarcity. In summer months, the water-rich upstream countries were, therefore, responsible for releasing agricultural water to downstream countries, while in winter months, fossil fuels and surplus electricity would flow the other way [6].

In the CAPS era, Central Asia was provided with sufficient power generation at low costs, enabling the modernization and development of the region's peripheral economy. The system was crucial for Tajikistan: over 60% of Tajikistan's electricity demand was covered by imports from other Soviet Republics [6]. However, after the dissolution of the Soviet Union this system gradually fell apart as international disputes arose. Each of the five newly independent states focused on their own national interests and aimed for energy independence. Since 2009 Tajikistan has been completely isolated from CAPS and its energy imports from both the Uzbekistan and Turkmenistan came almost to a complete halt. This isolation has made the problems of Tajikistan even more acute than before.

In this situation, the Government of Tajikistan (GOT) has focused on developing its hydropower potential. What Tajikistan is lacking in oil and gas, it makes up for it in water resources, ranking top in the world in hydropower potential per territorial unit [6]. Tajikistan is currently for over 90% dependent on hydropower for electricity production [2]. The government annually allocates more than USD 300 million (15% of the state budget) for hydropower rehabilitation [7]. Numerous hydropower plants (HPPs) supply this energy, the largest being Nurek, Kairakkum, Baipazin and Sangtuda I and II [8]. Over 75% of the country's electricity supply is generated by the Nurek HPP on the Vakhsh River – currently the largest dam in Central Asia at a height of 300m, with a capacity of 3000 megawatt (MW) and a reservoir of 10.5 billion m<sup>3</sup> of water. In October 2016 the construction commenced of the Roghun Dam, an ambitious USD 3.9 billion dollar project which once completed will overtake Nurek in height and become the tallest dam in the world at a height of 335m. The Roghun Dam will add another 3,600 MW of generation capacity, doubling Tajikistan's electricity production [28].



**Figure 1.** Energy generation in Tajikistan 1998-2015 [9, 29]

However, this high hydropower dependence has come with significant challenges. Until now, rehabilitation of hydropower facilities have not enabled Tajikistan to surpass the 1990 production levels of 18.2 billion kilowatt hour (kWh) of electricity per year [10]. Production has been decreasing ever since 2007 (see Figure 1). Tajikistan's HPPs cannot sustain energy supply in winter, when heating demands are highest and river flows the lowest due to decreased release of glacial water. Most of the country's HPPs are run-off-river plants without reservoirs and vulnerable to variations in precipitation, climate change and the whims of river flows. At the same time, the Tajik Aluminium Company (TALCO) reaches its peak production in winter, consuming almost 40% of the country's total energy supply, aggravating the situation. As a result, winter electricity production in Tajikistan is only around 70% of summer levels, and can be as low as 40% in some run-off-river HPPs [6].

The current deteriorating power system is increasingly vulnerable to a major breakdown that could cause enormous damages to Tajikistan's economy and food production [2]. Most of Tajikistan's HPPs have been in operation for an average of 45–50 years without major upgrade and maintenance. Many hydropower plants are now producing well below their potential output. The ageing electricity network often fails to transfer power to large parts of the country throughout the year. Insufficient energy supply currently has a grave impact on Tajikistan's economic development, forcing the closure of around 850 small and medium enterprises annually, costing an estimated 3% to the GDP [7]. This leads to severe power shortages during the freezing winters. Long electricity cuts especially affect rural communities.<sup>1</sup> Continued ageing of power facilities will further worsen shortages throughout the year. Winter shortages were still estimated at 2,700 MW in 2012, but if current trends continue, these deficits are estimated to rise to 6,800 MW by 2020 [6].

<sup>1</sup> Electricity rationing was upheld from October 1 until February 27 during the winter of 2014-2015 and from October 18 until February 23 in the winter of 2015-2016. Electricity supply was limited to around 10 hours per day – five hours in the morning (from 5:00 am to 10:00 pm) and five hours in the evening (from 5:00 pm to 10:00 pm). This is not applied to the capital Dushanbe, or the other major cities of the country.

## ***2.1 Export opportunities***

Summer hydropower is profiting from high river flows and produces an electricity surplus from July to September. Previously the lacking exporting capacity has meant that this surplus has been largely wasted. However, recent rehabilitation of major power lines has enabled Tajikistan to significantly increase its summer energy exports to Kyrgyzstan and Afghanistan.<sup>2</sup> Exports are expected to further increase with the CASA-1000 project. This USD 1.16 billion project, which saw the inauguration of its first construction phase May 2016, will connect Central Asia with South Asia through massive transmission lines. The electricity network will have the capacity to annually supply up to 5 billion kWh of Tajikistan's summer electricity to Afghanistan and Pakistan, possibly multiplying electricity exports fourfold [11, 8].

The government of Tajikistan will be able to gain large revenues by exporting hydropower up to USD 0.05 per kWh, which is significantly higher than the USD 0.0030 per kWh currently charged by the government for the pumping irrigation sector.<sup>3</sup> However, while promising, this prospect has also put summer hydropower wastage in the spotlight. Low energy efficiency in the agricultural sector will soon directly limit lucrative income for the state. The World Bank stated that "Energy use in Tajikistan during summer, previously not recognized as a concern because of the excess energy availability in summer, has been propelled on the national agenda, as energy wastage now comes at a high opportunity cost" [2]. These developments could aggravate the already existing pressures on agriculture and food production.

## ***2.2 Food security***

Tajikistan still has the lowest GDP per capita in the Post-Soviet sphere and 49% of its rural population lives below the poverty line [30, 31]. Almost three quarters of the country's population resides in rural areas, where paid jobs are scarce [30]. Domestic food production is still insufficient to meet the national demand. Many poor households in rural areas rely solely on staple foods for their nutrition and suffer from a lack of dietary diversity. Although undernourishment has diminished since the 1990s, malnutrition still affected 20% of the population by 2007 [4]. A dramatic situation unfolded in 2008-2009 when a severe winter combined with high food prices and lacking energy supply exacerbated in national food shortages. About 32% of the entire rural population suffered from a lack of food, with 9% of the rural households being severely affected [12, 13].<sup>4</sup> The UN World Food Programme declared an emergency situation and established a humanitarian programme worth USD 25 million to help the tens of thousands of people who were malnourished [14]. Almost 25% of children still suffered from malnutrition in 2012 [15].

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<sup>2</sup> In 2011 the share of electricity exports in total revenue was only 0.1%, amounting to a mere 190.9 million kWh worth USD 4.3 million [1]. By 2016 almost 15% of the total summer-time electricity surplus, 1.3 billion kWh, was exported to mainly Afghanistan, with a total worth of USD 50 million [8].

<sup>3</sup> The rate of 1 USD was valued at 7,88 Tajik Somoni (TJS) as of 23 December 2016.

<sup>4</sup> According to the government of Tajikistan, in 2009 there were 1.4 million people suffering from food insecurity, of which 390,000 people were severely affected.

Tajikistan has to import a large part of its food from abroad to meet demands. Imports accounted for over 58% of Tajikistan's domestic wheat requirements and 81% of overall food consumption for 2012-2013 [15]. Due to a lack of arable land, a growing population and an insufficient domestic supply, dependence on food imports will continue to rise. Cotton, which remains an important exporting crop, has seen major price drops in recent years and has subsequently reduced the purchasing power of poor households employed in cotton farming. Many urban households are vulnerable to the world food price fluctuations. Even though the food situation has improved since 2009, global food price spikes led the government of Tajikistan to once again introduce tight price controls in Dushanbe in 2010 and 2011.

In coming years, electricity and food demands are predicted to increase as the population will continue to grow from 8.55 million in 2016 to 10 million by 2020 [2]. The Tajik government sees food security as a high priority to sustain national socioeconomic stability and prevent social unrest. Observers note that is essential for Tajikistan's socio-political stability to make substantial investments in the agro-food industry [4].

### **3. Agriculture: connecting water, energy and food**

Tajikistan is a highly agricultural country. About 46.5% of the overall population is employed in agriculture, while productivity in the agricultural sector represents 20% of the national GDP [16].<sup>5</sup> During the Soviet period, Tajikistan's agricultural systems were transformed into a modernized agricultural hub, tripling Tajikistan's agricultural output in between 1960 and 1988 and making the region into the "bread basket" and main cotton-production centre for the entire Soviet Union. After independence, however, the civil war followed by a liberalization of the agricultural sector caused a large decline in agricultural output. Agricultural production dropped by 55% between 1991 and 1997. Since the beginning of the twenty-first century, agricultural production has shown remarkable recovery and has surpassed the level of 1991 once again. While cotton used to be the most important cash crop for Tajikistan in the first decade after independence, it has since been surpassed by other crops such as potatoes, wheat, fruit and onions [15].

Due to geophysical and climatic constraints, arable land is limited and water is scarce in most areas of Tajikistan. Only 28% of Tajikistan's total territory is suitable for cultivation [10]. More than 90% of country's total annual volume of fresh and groundwater sources is diverted to supply irrigated lands [2].<sup>6</sup> The majority of cultivated land relies on either rain supply or gravitational irrigation. However, irrigation is significantly more profitable: the yield of wheat crops in irrigated areas are on average 4-6 times higher than in rain fed areas. Of the total arable land of 953,000 hectares (ha), 79% relies on irrigation. Currently, however, only 500,000 ha receives sufficient irrigation water due to poor conditions of the irrigation infrastructure [2].

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<sup>5</sup> Agriculture, including fisheries, hunting and forestry, accounted for 20.3% of total GDP in January-September 2016, compared to the combined 14.9% from industry and energy in the same period.

<sup>6</sup> The total volume of agricultural water abstracted is on average 8.0-10.0 km<sup>3</sup> per year [5].

Due to high altitude differences in the country, many regions are dependent on pumping for irrigation. In total, 44% of irrigational agriculture in Tajikistan relies on water pumps for overcoming obstacles of higher elevated lands. This greatly varies throughout the country's geographical landscape: while only 21% of irrigational agriculture in the central Rasht Valley relies on pumps, in the northern Sughd this share reaches 85% (see Table 1) [2]. The pumping irrigation sector faces many challenges. The Soviet legacy left a system, which was accustomed to a collectivized economy in which all expenditures for maintaining irrigation systems were fully covered by the state. Highly educated personnel were equipped with excellent technical capacities and qualifications. Agricultural land was divided mainly among around 600 collective and state farms. After independence, land reforms reshaped the ownership of farmlands, and land use rights were gradually moved from collective farms to private (dehkan) farms and farmers associations through long-lease agreements [17].

In many Post-Soviet states the operation and maintenance responsibilities of irrigational systems were transferred to local or regional authorities. In Tajikistan, however, a lack of financial assets meant that these tasks could not be transferred to the state. Private farms became mostly responsible for the operation and maintenance of irrigation pumps, canals and drainage. This situation was further complicated by a lack of knowledge on how to operate these systems. Many people of different backgrounds started practising farming as a result of the economic collapse of the 1990s, most of whom had limited farming knowledge. New landholders often lacked insight in their rights and roles in the agricultural sector. As a result, the maintenance and operation of the existent irrigation and drainage systems were often largely ignored. Irrigation and drainage facilities were abandoned without clearly delegating a management body. Lacking state funding could not support the rehabilitation of irrigation and drainage systems. Subsequently, the agricultural sector deteriorated and issues like water use inefficiency, decreasing crop productivity and land degradation ensued. As a result, currently only 63% (473,022 ha) of potentially irrigable land is actually being supplied with sufficient water (see Table 1). Only 73% (280,850 ha) of land that is dependent on pumps still has operational pumping infrastructure [18, 2].<sup>7</sup>

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<sup>7</sup> The actual mix between pumped and gravitational irrigation is unknown, as many farms use both methods, and have inoperative pumps that make estimations unreliable. Out of a total of around 36 large, 450 inter-farm and 1,807 on-farm pumps, only 21 large, 286 inter-farm and 900 on-farm pumps are currently operational.

**Table 1.** Agricultural arable land and pumping irrigation (ha) [2]

<b>Region</b>	<b>Rain-fed land</b>	<b>Irrigable land</b>	<b>Irrigated land</b>	<b>Irrigable land with pumps</b>	<b>Irrigated land with pumps</b>	<b>Share of irrigated land with pumps</b>
Sughd	61,905	287,266	171,113	162,760	145,760	85%
Khatlon	95,688	338,087	230,359	102,911	93,911	41%
DRS <sup>1</sup>	45,451	106,079	63,425	15,085	13,585	21%
GBAO <sup>2</sup>	741	18,224	8,125	92	92	1%
<b>Total</b>	<b>203,785</b>	<b>749,656</b>	<b>473,022</b>	<b>280,850</b>	<b>253,348</b>	<b>54%</b>

<sup>1</sup> District of Republican Subordination

<sup>2</sup> Gorno-Badakhshan Autonomous Oblast

As presented in Table 2, in some areas of the country, only a small part of the water abstracted from rivers and groundwater is ultimately delivered to the crops. It is estimated that only 30% of the total water supplied by irrigation pumps ultimately reaches cultivated lands due to many leakages and inefficient functioning of pumping facilities [2].

**Table 2.** Water and energy consumption of pumping irrigation [18]

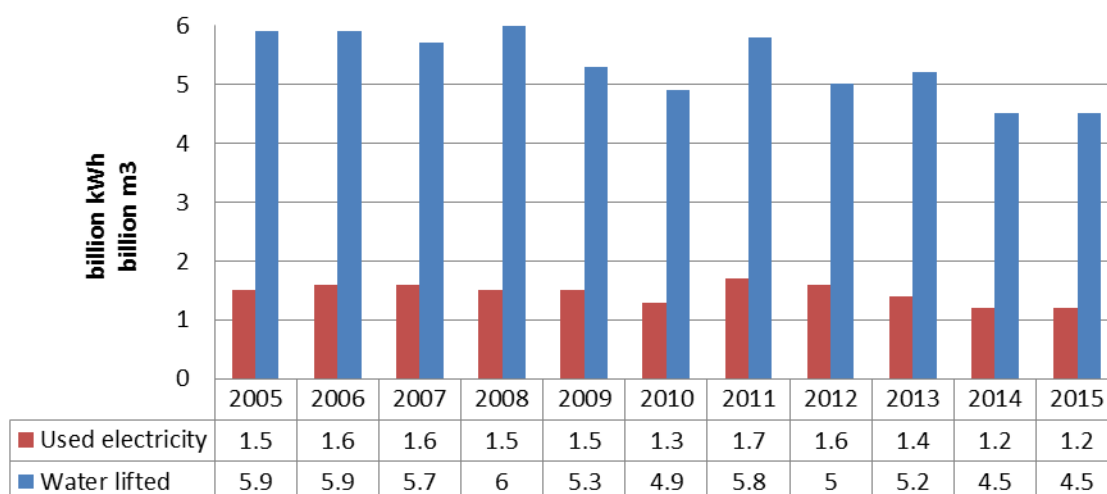
<b>District</b>	<b>Water abstracted (million m<sup>3</sup>)</b>	<b>Water delivered (million m<sup>3</sup>)</b>	<b>Electricity consumption (million kW/h)</b>
Zafarobod	810.8	323.4	287.8
Mastchoh	453.1	259.8	144.5
B. Ghafurov	618.4	214.2	177.2
Asht	479.6	162.9	168.2
Ayni	9.8	5.6	5.6
Farkhor	156	142.4	23.1
Vose	65.3	84.7	18.9
Yovon	202.2	199.7	49.2
Kulob	42.1	36.6	0.9
Rudaki	13.2	34.8	12.5

This highly wasteful use of water has severe consequences for both food and energy. In total, almost 80% of agricultural food production originates from irrigated areas and 35% from pumping irrigation. Deteriorating facilities and inefficient use of water resources, thus directly impact domestic food production. At the same time, pumping irrigation is interconnected with the energy sector. The high reliance on energy intensive pumps makes the agricultural sector the third largest consumer of electricity after industry and residences. In 2015 the sector was



good for 21% of the total energy consumption of Tajikistan [3].<sup>8</sup> Pumping irrigation has seen a gradual decrease of electricity consumption in recent years. As seen in Figure 2, in 2005 there was still 5.9 billion m<sup>3</sup> of water pumped up by using 1.5 billion kWh of electricity, while in 2015 this had dropped to 4.5 billion m<sup>3</sup> using 1.2 billion kWh. This decrease can be partly attributed to frequent power cuts and malfunctioning electricity grids, but mostly to the ageing pumping facilities and irrigation canals that limit the water intake and distribution.

Lacking energy supply to farms has a severe impact on agricultural output. Due to the unreliable power supply to pump stations, many pumps shut down erratically. Voltage fluctuations and complete power outages may occur on a daily or weekly basis. Unpredictable water supply makes it impossible for farmers to adhere to good irrigation schedules. According to estimates, the average annual loss to agricultural production in rural areas resulting from this stands at 30% per year [1, 7].



**Figure 2.** Electricity consumption for water lifted in Tajikistan [18]

#### 4. Water User Associations

In 2011 the government of Tajikistan adopted the “Programme for the efficient use of hydropower resources and energy 2012-2016”, aiming to improve energy efficiency and energy saving measures as a means to reduce energy losses [9]. The government’s main objective herein has been to eliminate the country’s dependence on energy imports and become completely energy independent through the elimination of energy inefficiency. The government aimed to save up to 3,200 million kWh of electricity and increase its summer energy exports by 40% by 2017, thereby completely omitting its reliance on energy imports. Although these goals have not yet been reached, there is significant potential for energy savings. According to the Asian Development Bank, the potential electricity consumption to be saved in 2011, summing up the potential of new machinery, efficient water use and

<sup>8</sup> Of this amount 17% was accounted for by irrigation pumps, while the rest is consumed by livestock farming and lighting, equipment, tools etc.

introduction of better crop patterns, was at least 50% of total agricultural electricity consumption [19].

A recent study conducted by the World Bank has concluded that different combinations of institutional interventions could improve 5-15% of the efficiency rate [2]. Additionally, with the added possibility of exporting the energy saved by these measures, a large financial cost reduction could be achieved. If electricity can be exported instead of wasted on inefficient irrigation pumps, the revenues raised from the energy trading could in turn be reinvested in the agricultural sector for the rehabilitation of the most deficient assets. The World Bank deduced that returning revenues could potentially decrease annual irrigation and drainage costs to the national budget by 62%, from USD 31.09 million to USD 11.70 million [2]. One institution through which this can be reached is the Water Users Association (WUA).

The need to effectively manage water systems in Tajikistan led to the introduction of WUAs in the late 1990s and early 2000s [20, 21]. The introduction of these institutions in Tajikistan started after the implementation of the first phase of land reforms in 1998-2000 and was spurred by the government and several international development projects. The “Water Users Association” Law was adopted on November 8, 2006 and laid the foundation for establishment, operation and management of WUAs as “non-commercial organizations providing services for operation and maintenance of irrigation systems for the benefit of water users” [22]. WUAs were to be operated by a group of water users within one or more distributary canals, including individual members of lease-holding farms, cooperatives, owners of private land and owners of home garden plots. One of the main purposes of this system was to effectively operate, maintain and use on-farm irrigation systems to ensure the optimal operation and allocation of water sources within a certain jurisdiction [23]. WUAs aimed to exercise fair, effective, and timely distribution of water between farms, collect payments for the water supply and settle disputes related to the distribution of water.

Within a very short time, hundreds of WUAs were established in Tajikistan. By the end of 2015 around 409 WUAs have been created with a total service area of 380,425 ha (including 48,725 ha of house gardens) and involving nearly 51,000 dehkan farms. However, most WUAs currently exist only on paper. In practice, many of the organizations do not have a real functional or administrative role [24, 25]. Although the government, local communities and international organizations have taken active steps for the initial establishment of WUAs, there has not been enough support to sustain them as fully-fledged and self-sufficient organizations. At present, many WUAs suffering from weak governance, are not able to mobilize both in-kind and cash contributions, and face difficulties on managing water within their boundaries.

In 2015, the government introduced the Water Sector Reforms 2016-2020 which is based on a new river basin management approach. The reforms will include a revision of the operation of WUAs, increasing their roles and responsibilities [5]. WUAs will have a leading role in ensuring effective water management as well as in improving the country’s energy efficiency. Improving their institutional strength is, therefore, of paramount importance.

#### 4.1 Technical obstacles and solutions

WUAs face major technical, legal, management, operational and financial constraints, which threaten their existence. We may synopsize the current hindrances in two major groups: the technical constraints on one hand (Table 3) and the institutional and socio-economic constraints on the other (Table 4).

**Table 3.** Technical and administrative obstacles for agricultural energy efficiency

<b>Problem</b>	<b>Explanatory note</b>	<b>Proposed solution</b>	<b>Estimated cost</b>
Aged and damaged assets	Most of the facilities are out-dated and in poor state, with low maintenance and operational performance	Rehabilitation and construction of irrigation facilities	High
Aged drainage systems	The drainage canals are mostly damaged resulting in water-logging, salinization, etc.	Rehabilitation of drainage systems	High
Frequent power cuts	There are frequent and unscheduled power cuts that severely reduce water supply	Construction of buffer reservoirs	High
Poor flooding protection	There is inefficient flooding protection on most of the agricultural land	Rehabilitation and construction of flooding protection	High
Lack of inventory	There is no inventory on the irrigation and drainage assets and facilities in the country	Creation of national inventory	Medium
Lack of water metering	Many water metering devices are damaged or absent and volumes are estimated inaccurately	Installation of new and rehabilitation of existing meters*	Medium
Water - demanding crops	Farmers grow water demanding crops and/or employ cropping patterns that do not support water savings	Training and education on crop patterns	Low
Weak knowledge capacity	WUA personnel lack knowledge capacity to estimate issues like water distribution plans, crop water requirements etc.	Training and education on water saving methods	Low

\*For the proper flow measurement the installation of low-cost reprofile flumes are suggested [35]

Large-scale structural technical constraints, some of which have already been mentioned above, require costly investments. Currently WUAs lack the financial capacity to protect themselves from flooding, maintain and clear drainage canals, adapt to power shortages and maintain technical facilities as canals and pumping stations. Aged and damaged facilities require rehabilitation and further sustainable maintenance. These problems require years of highly costly investments. However, other technical measures would be less capital-intensive, and could offer low- or medium-cost solutions for a maximum amount of energy savings.

Small-scale technical measures such as the development of water measurement systems could significantly improve water and energy savings of pumped water.

Currently there is inadequate insight in water intake on farm and WUA level. Relying solely on rough estimations, many farmers take in too much or too little water for their irrigation systems. They lack proper methods to measure their water intake in a sustainable way. Many water measuring devices are broken, out-dated or abandoned, and need to be replaced. Accurate water measurements offer water users the insights to use the most efficient amounts of water, possibly saving a large part of the energy bills. The replacement or rehabilitation of these water metering devices could improve the insight of water intake, incentivizing farmers to use their resources more efficiently, and provide an overview for WUAs on which to base fee collections. A similar issue is a lacking inventory of quantity, characteristics and quality of technical facilities. An inventory will immensely help WUAs to better comprehend the current conditions and needs of each irrigation component and later on to request more precise support from the state and donors.

Low knowledge capacity of farmers, service providers and WUA personnel are affecting functioning of technical facilities. Knowledge enhancement is, therefore, an important aspect in the opening of energy efficiency in agriculture. Capacity-building programmes should cover both institutional and technical trainings: strengthening organizational aspects of water resources management, leadership development, conflict management, financial management and audit procedures. Technical topics covered should be water distribution concepts, irrigation water record keeping, operation and maintenance of farm-irrigation and drainage systems and methods of cleaning drainage and collector systems. Further trainings are needed to introduce agronomic courses on drought-resistant crops and cropping patterns, hence introducing water saving irrigation methods and encouraging a better usage of water intake for crop-specific needs. Both farmers and service providers should ascertain this knowledge in order to further disseminate their insights to others.

#### ***4.2 Institutional obstacles and solutions***

The development of 'soft components' dealing with managerial and administrative aspects may also offer significant improvements with low or no-cost implications. WUAs can have an important role in influencing the effectiveness of water delivery in the field. To this end, some institutional interventions are proposed that could improve the performance of WUAs and promote energy savings.

**Table 4.** Institutional obstacles for agricultural energy efficiency

<b>Problem</b>	<b>Explanatory Note</b>	<b>Proposed solution</b>	<b>Estimated cost</b>
Outdated legislation	The legislation on WUAs does not fully reflect the current needs and responsibilities in the framework of the Water Sector Reform	Provide a transition period, strengthen WUA legal position and ensure funding channels	Low
Weak coordination	There is lack of coordination between ALRI, the regional authorities and WUA due to communication gaps	Include a comprehensive legal framework on cooperation	Low
Double water service fees	The attribution of double fees to the regional ALRI and WUAs adds to pressures on farmers	Establish a clear tariff system that accounts for costs in practise	Low
No financial incentive to improve water efficiency	High subsidies on water and electricity prices mean that farmers are not incentivized to decrease their water intake	Provide a legal framework for a tiered tariff system in which prices are increased with higher water intake	Low
Fee evasion	There is no strong legal framework to penalize WUA members when evading fees	Strengthen WUA legal knowledge and management capacity	Low
No clear WUA boundaries	There is unclear land demarcation of WUA areas and many illegal activities are overlooked like water abstraction, sand extraction, etc.	Strengthen WUA legal knowledge and management capacity	Low
Few farmers in WUAs	The non-compulsory inclusion of all farmers in WUAs allows free-riders in water supply	Strengthen WUA legal knowledge and management capacity	Low

With the upcoming Water Sector Reforms the government is expected to progressively hand over the operation and maintenance of assets like major pumping stations, canals and drainage systems to WUAs. However, the transition phase of major legal and administrative transformation could have great consequences for the institutionally weak WUAs. This transition from a centralized to decentralized management status should be cautiously arranged. As mentioned above, most irrigation assets are in bad shape, while the accumulated debts of irrigation pumping are already a major hindrance. Care should be given to ensure that the funding from the state and donors are directly forwarded to WUAs for the sustenance of facilities. At the same time, the changes should ensure that WUAs acquire strong legal status and acknowledgement.

With larger responsibilities and power, WUAs will need to address the issues of free-riders and unclear boundaries. WUAs will have to clearly authorize control and intervene in any situation that might disturb their proper functioning. Not all the command areas are currently irrigated under the WUAs' supervision. Some farmers practice water pumping directly from surface waters (rivers, lakes) without prior permission. In other cases, some temporal river diversions are developed by farmers to their plots without supervision. New legislation and enforcement should be introduced to ensure that water intake is directed only by the WUA and all land-owners under its jurisdiction are paying members.

A related issue is water fee collection. Farmers are obliged to pay two fees, leading to many farmers to complain of overpricing [26]. Firstly, an Irrigation Service Fee (ISF) is to be paid per hectare to WUAs for the water supplied to the plots. The ISF encompasses the costs associated with the water provision from the pumping stations to farms. WUAs often have difficulty in collecting all the membership fees that are needed in order to maintain and operate the irrigation systems. Water users do not always have insight into the required maintenance costs and, therefore, are often reluctant to pay, making fee collection difficult. On the top of this, the farmers are asked to pay water fees. These fees are to be collected by a WUA and paid to the Agency of Land Reclamation and Irrigation (ALRI) for the preservation of the main pumping stations outside of WUA control.

Due to the use of pumps, individual electricity prices are an additional expenditure. Because of low effectiveness of pumping systems, the costs of pump extraction are raised even further. As pumping efficiency goes down, farmers spend an increasing amount of money on every cubic meter that is pumped up. Currently, electricity prices are heavily subsidized to cover these costs. Due to heavy subsidies, electricity prices in Tajikistan are among the lowest in the world. Subsidies are especially high for pumping irrigation: in 2015 subsidies covered up to 70% of the total energy costs in this sector [2]. Subsidies support agriculture and rural households by alleviating them from financial pressures and stimulating agricultural production, which is crucial for the livelihoods of rural subsistence farmers, as well as the country's food security.

However, the current subsidy system aggravates the energy situation negatively, in two ways. Firstly, there is no incentive for the farmers to decrease their electricity consumption, even if they are able to do so. The low prices mean that wastage of water does not financially impact farmers to an extent that they might reconsider their water intake, even if they are capable to do so.<sup>9</sup> Secondly, high costs of maintenance and rehabilitation juxtaposed to artificially low fees strain the national budget, creating an unsustainable system for the longer term. The subsidy system adds to the already huge financial strains of the electricity prices to the state [27].

Direct and indirect subsidies have put Barqi Tojik, the national integrated power company, close to bankruptcy. Financial pressures are aggravated by a large part of electricity bills that

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<sup>9</sup> Current law permits the water fees can be doubled in the case of excess water intake by farmers, and tripled for unauthorized water intake [17]. However, this is not enforced in practise.

remains unpaid by water users. An insufficient fee collection rate by WUAs means that only a small part of the energy costs are recovered. Between 2005 and 2013, only 21% of energy costs were ultimately repaid by water users to the WUAs (World Bank 2017). In turn, WUAs could not repay Barqi Tojik. To save it from bankruptcy, the state has decided to cover the electricity bills by engaging in debt cancellations to Barqi Tojik. In total, debt cancellations for unpaid power fees, combined with forgone profits due to the subsidized electricity tariffs in pumping irrigation, have cost USD 281.98 million to the state budget in the period between 2005 and 2013 (World Bank 2017).<sup>10</sup> Pumped irrigation therefore comes at a high cost to the state.

The government of Tajikistan has agreed to increase electricity prices, starting with an increase of 16.2% in 2017, gradually turning up prices by 300% in all sectors until 2020 [32]. However, increasing electricity prices in the agricultural sector comes with many challenges. Food production is heavily dependent on pumped irrigation, so this could impact the food security gravely. A sudden rise in costs will add to financial pressures of farmers. As a result, decreased competitiveness will limit the possibilities of farmers to compete with international food prices which could affect their livelihoods. A two or multi-tiered tariff system should therefore be introduced to lessen this impact. In this system, which is already established in many WUAs worldwide,<sup>11</sup> farmers are asked to pay a higher price per cubic meter if they consume above a certain amount of water volume. The pricing may be divided in two or multiple levels depending on the structural schedule of the tariff system. Water prices can also be increased if farmers end up using more irrigation water than the amount they requested before the start of the vegetation period, encouraging them to measure and calculate efficient water intake. However, earlier attempts to implement such tariff systems could not be applied because of lacking water measuring systems.<sup>12</sup> A combination of several proposed solutions is therefore necessary.

## 5. Conclusion

Tajikistan faces severe pressures on sustaining its water, food and energy security. In the current situation energy shortages cause big losses to economic growth, while food insecurity affects large parts of the population, especially those in vulnerable rural areas. All resources come together in the agricultural sector, which is a large consumer of water and energy, and on which, many Tajiks rely for their livelihoods and food production. Inefficient pumping irrigation is an important factor to blame for the current unsustainable situation. As a consumer of 21% of total energy, irrigation pumping increases the stress on an already heavily burdened electricity network. Limited water and energy resources subsequently affect food

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<sup>10</sup> The government has cancelled a debt of USD 5.1million in 2009, which accounted for the unpaid Service Irrigation Fees (ISF) from WUAs to ALRI and the second debt of USD 48.2 million was cancelled in 2014 for unpaid energy expenditures of ALRI to Barqi Tojik.

<sup>11</sup> In Israel, for example, the service fee per cubic meter of irrigated water rises as consumption increases. If farmers use more than the crop water requirement norm, a higher tariff will be used for extra water intake [33].

<sup>12</sup> A multiple tier tariff system was issued in 1996 [34].

security and jeopardize the livelihoods of subsistence farmers. Stable agricultural energy supply and efficient water usage is therefore necessary in order to prevent any further food and energy crises.

Water User Associations can play a crucial role in mitigating these problems by balancing and integrating cross-sectoral solutions in the fields of water, energy and food. Legislative reforms will increase the responsibilities of WUAs in the near future, which will heighten their role in sustaining the country's food and energy security. There are major challenges for the effective functioning of WUAs and their proper operation over the country's irrigation and drainage systems. Some technical and institutional solutions with low installation costs have been suggested in this paper, which could offer significant water energy savings and lessen the strains on both farmers and the national budget.

These measures should pay special attention to vulnerable groups such as subsistence farmers and isolated rural communities. Numerous marginal landholders produce mostly staple crops for self-consumption. A potential increase of water and energy prices, WUA membership fees, or compulsory registration in WUAs may threaten their economic survivability. Care should be given to account for these groups and introduce a tiered tariff system. Decentralization should have a transition period and vulnerable groups should be offered sufficient time to incorporate the suggested interventions in a sustainable manner.

Although it is difficult to estimate the exact impacts emanating from simultaneous intervention packages, it is estimated these improvements will significantly enhance energy and economic savings in the irrigation sector. Energy savings emanating from these measures could improve the country's food production as well as energy situation. Energy and water currently wasted can be allocated for the export of hydropower electricity to Tajikistan's neighbours. Lucrative revenues could be re-invested in agriculture, notably in capital-demanding rehabilitation of irrigation systems and power grids. These results may also provide some insight to neighbouring countries such as Uzbekistan and Kyrgyzstan, who are facing similar issues. Further studies are needed to gain more in-depth understanding of the relation between water, energy and food in the region. And although obstacles are still high, it has become clear that the connection between these sectors is of paramount importance in sustaining energy supply, food security and economic growth.

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