The Water-Energy Nexus in the Amu Darya River Basin: The Need for Sustainable Solutions to a Regional Problem

September 2012

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ADRB – Amu Darya River Basin

BVO – River Basin Organization

CAR(s) – Central Asian Republic(s)

CAPS – Central Asian Power Station

GWh – Gigawatt hours

HA – Hectares (1 hectare = 2.471 acres)

KWh – Kilowatt hours

MWh – Megawatt hours

NATO – North Atlantic Treaty Organization

1. Abstract

The Amu Darya River is the only source of water for the four countries and regions through which it passes: Tajikistan, northern Afghanistan, Turkmenistan, and Uzbekistan. In recent decades, the expansion of agriculture has put extreme strain on the surface waters and groundwater reserves. If planned expansion of agriculture continues, the Amu Darya River Basin is at risk of extreme drought, resulting in both economic and human crises. This crisis of resources is closely linked to the energy crisis in which millions of people in the Amu Darya River Basin do not have access to clean and reliable electricity. This is called the water-energy nexus. In order to ensure its survival as a region in the face of climate change and economic growth, cooperation between these four states is urgent. I suggest that Afghanistan and the three Central Asian Republics do as follows:

- Restructure the BVO;
- Create a better financial system for water and energy exchanges;
- Improve the efficiency of irrigation;
- Diversify the agriculture sector;
- Invest in renewable energy; and
- Create local education programs to involve farmers in both the scientific and policymaking processes.

2. Introduction

2.1 The Amu Darya River Basin

The Amu Darya River is one of two major rivers in Central Asia. It begins at the convergence of the Pyanj and Vakhsh Rivers in the Pamir mountains in Tajikistan and flows northwest through Tajikistan, Afghanistan, Turkmenistan, and Uzbekistan.[1] Sixty-one percent (61%) of the Amu Darya River is located in the Central Asian Republics (CARs), while 39% of the river is located in Afghanistan. As shown in Figure 1, at its furthest downstream point, the Amu Darya reaches the Aral Sea,[2] making it an important source of water for the landlocked and crisis-ridden Aral Sea basin.

Figure 1: The Amu Darya River Basin
Source: Jerker Jarsjo, et al., "Health Risks from Large-Scale Water Pollution: Trends in Central Asia", *Environment International*, 39, no. 2 (Feb. 2011): 435-442, 14 August 2012

[1] Kai Wegerich, "Hydro-hegemony in the Amu Darya Basin", *Water Policy*, 10, no. 2 (2008): 71-88, 25 June 2012, doi: 10.2166/wp.2008.208.
[2] Bouchra El Oifi, et al., "Groundwater Resources Use and Management in the Amu Darya River Basin (Central Asia)", *Environmental Earth Sciences*, 59, no. 6 (2010): 1183-93, 25 June 2012

The Amu Darya River Basin (ADRB) is made up of the surrounding regions that rely on the river's water supply to sustain the ecosystem and provide water for human consumption. This area is split into two larger geographical regions: the mountainous southeast, which includes northern Afghanistan and Tajikistan; and the low-lying northwest, including other CARs and contains deserts and steppe lands used for livestock ranching and agriculture.[3]

2.2 The Problem

The Amu Darya River is the largest river in Central Asia and is the only channel through which water is locally available to the lower Central Asian Republics, making it extremely significant to the region, as shown in Figure 2. The depletion of surface flow, combined with an increase in contamination due to runoff, has led to groundwater overexploitation and pollution.

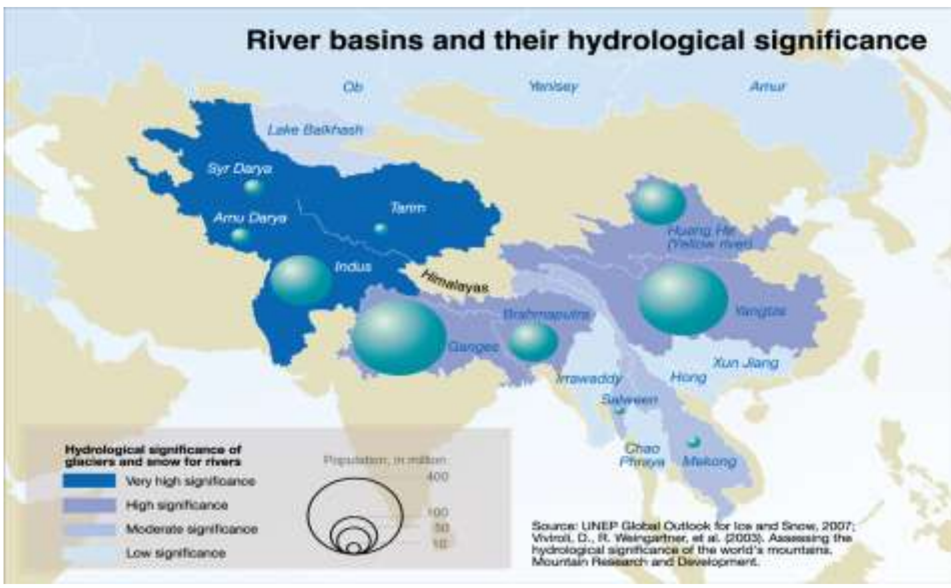

Figure 2: Hydrological Significance of the Amu Darya River
Source: "Too Much—To Little Water: Adaptation to Climate Change in the Hindu Kush Himalayas and Central Asia", *United Nations Environmental Programme GRID-Arendal* (2007)*:* 1-12, 31 August 2012

Lack of clean drinking water is directly related to health problems, including the spread of infectious diseases, as well as to crop failure. Should the Amu Darya River dry up, the entire Basin population could die. In short, access to clean, reliable, and sustainable water sources are necessary for the roughly 50 million people who live in the river basin.[4]

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[3]El Oifi et al 2010.

[4]M. Akmurdov et al, "Environment and Security in the Amu Darya Basin", *UN Environment Programme* (2011): 1-98, 30 June 2012

The situation is further complicated by the water-food-energy nexus. As of 2004, roughly 3 million people lacked access to clean drinking water in the ADRB.[5] Better water sanitation could be provided by access to clean energy (electricity); but, electricity requires water in order to be available on a mass scale. Access to electricity means that large amounts of water are needed for cooling processes. This is called the water-energy nexus, or the mutual interdependence between the provision of water and energy. Furthermore, clean and reliable water is needed for crop irrigation. However, irrigation requires a complex infrastructure of pumps and canals, which in turn require energy. Food security is intimately connected to access to water and clean energy, creating a triangular water-food-energy nexus as shown in Figure 3.

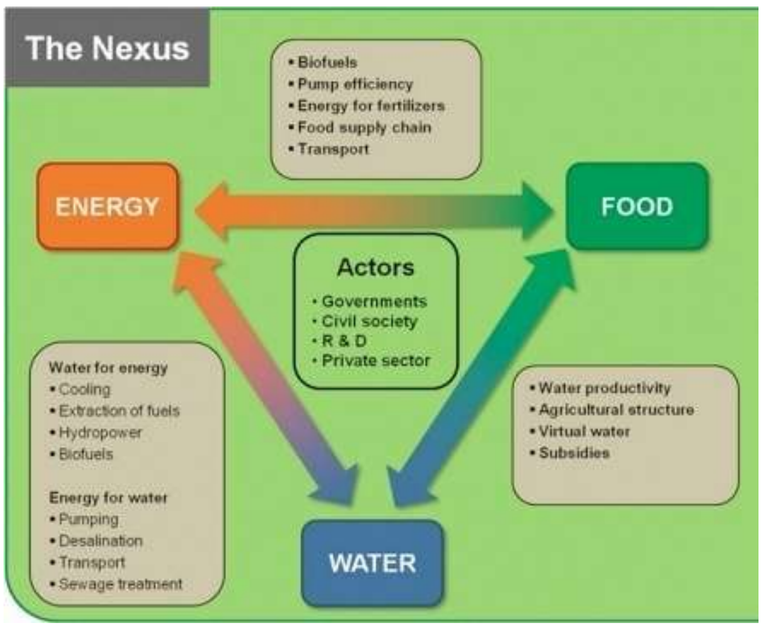

Figure 3: The Water-Food-Energy Nexus
Source: *Water in the Green Economy*, water-energy-food.org, last modified January 1, 2011

Thus, the central question of this paper is: What policies will ensure sustainability and better resource management of the Amu Darya River Basin?

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[5] Jochen Froebrich and Odil Kayumov, "Water Management Aspects of Amu Darya: Options for Future Strategies", *Dying and Dead Seas*: 49-76, Eds. J.C.J. Nihoul et al. (Netherlands:Kluwer Academic Publishers, 2004), 50.

3. Background

3.1 Geography of the Amu Darya River Basin

Figure 4: The Southeast and Northwest Regions of the Amu Darya River Basin
Source: **Tirdad Gorgani, *Welcome to Xoroq (Khorogh)*, 2005**

The Amu Darya River Basin can be split into two distinct geographical regions, as shown in Figure 4. The southeastern, or upstream, region is largely mountainous. It includes the Pamir and Tian Shan mountain ranges in Tajikistan and Afghanistan, which are 5,000 – 6,000 meters above sea level.[6] Although largely arid, the southeastern mountains provide most of the water for the Amu Darya River. Winter rainfall is stored mountainside in the form of snow and ice, and is discharged in the spring and summer as runoff. However, the southeastern region contains little-to-no natural gas deposits or oil reserves. Water is the biggest resource in Tajikistan, and one of the most important in northern Afghanistan.

The northwestern or downstream region of the ADRB is made up of desert and steppe lands. This region is low-lying, with a maximum elevation of 200 meters above sea level. Downstream, the ADRB receives significantly less rainfall. Like the upstream region, the northwest is largely arid, but contains large oil and natural gas reserves.[7]

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[6] El Oifi et al 2010.
[7] Akmurdov et al 2011.

3.2 Demography of the Amu Darya River Basin

Country	Population	Ethnic Makeup
Tajikistan	7 million	80% Tajik, 15% Uzbek, 5% Other
Turkmenistan	5 million	85% Turkmen, 5% Uzbek, 4% Russian, 6% Other
Uzbekistan	28 million	80% Uzbek, 5.5% Russian, 5% Tajik, 9.5% Other
Northern Afghanistan	Est. 15-30 million	Tajik, Uzbek, Turkmen, Pashtun (exact numbers unknown)

Figure 5: **Population of the Amu Darya River Basin**
Source: Author, with data from Akmurdiv, et al., 2011 and *CIA Fact Book,* 2010

In 2010, the population of the Amu Darya River Basin was recorded as 50 million. Of the basin regions, the most densely populated are southwest Uzbekistan, southern Tajikistan, and Northern Afghanistan.[8] While exact data is unavailable for Northern Afghanistan, Akmurdov et al., estimate that the population could have grown by about 15 million, making the basin region in Afghanistan populated by a total of roughly 30 million people (Figure. 5).[9]

The ethnic makeup of the Amu Darya River Basin is relatively predictable. Tajikistan, Turkmenistan, and Uzbekistan are majority Tajik, Turkmen, and Uzbek.[10] Northern Afghanistan contains significant Tajik, Uzbek, and Turkmen populations, as well as some ethnic Pashtuns.[11]

8 Akmurdov et al 2011.
9 Ibid.
10 CIA World Factbook 2009.
11 Ibid.

3.3 Modern History of the Amu Darya River Basin

Under the Soviet Union's regime, the Central Asian Republics (CARs) were ruled as one entity and resources were centralized. However, extensive resource and economic development did not occur until 1953, when Nikita Krushchev implemented the "virgin land" policy, leading to a huge expansion of agriculture.[12] The Soviet Ministry of Land Reclamation and Water Resources managed the Republics' water systems. Under this centralized administration, the upstream and downstream states were divided in terms of development. The upstream region was awarded control of the water flow and developed for hydropower, while the downstream region was irrigated in order to grow more cotton and mined for gas and oil.[13] The Ministry set up a system of mutual interdependence, whereby the water provided to downstream crops was reciprocated by the provision of oil and gas to upstream villages in the winter, as shown in Figure 6.[14]

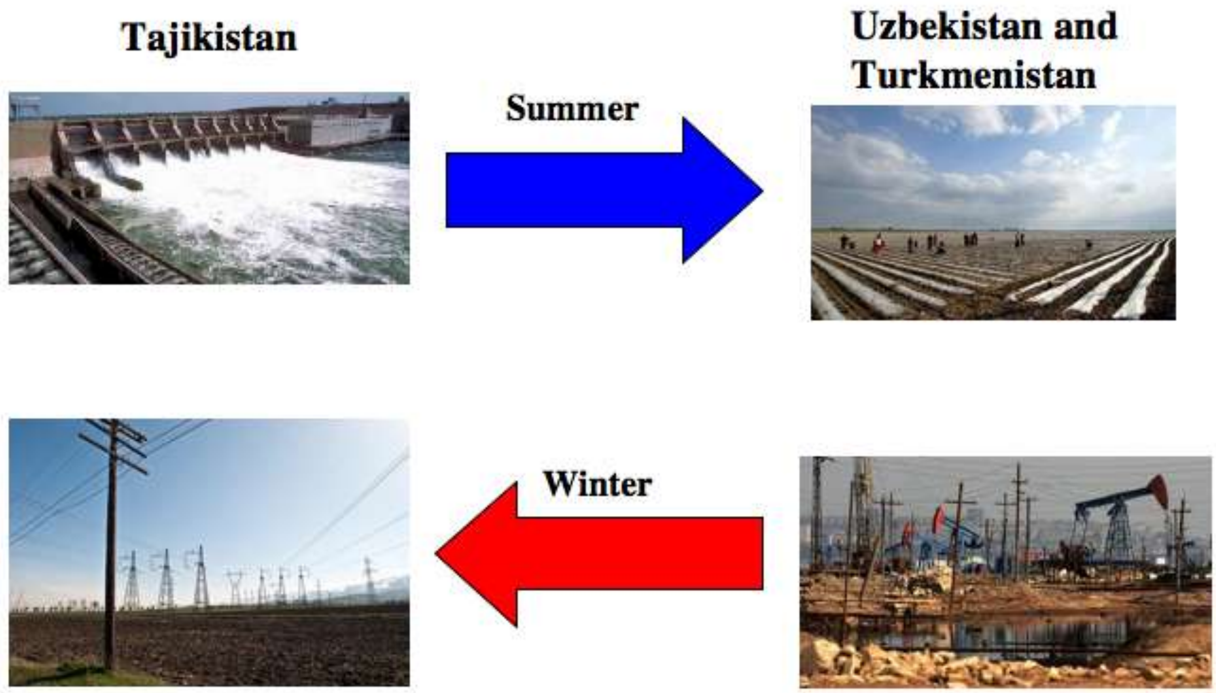
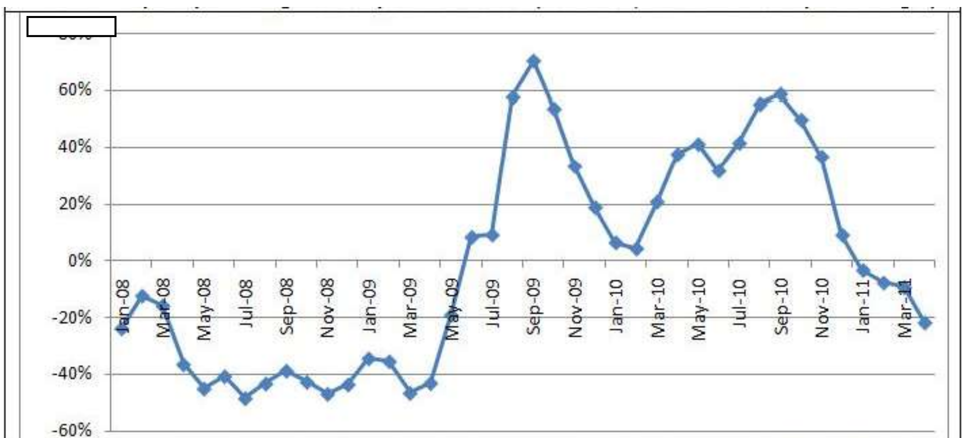


Figure 6: The Water-Energy Trade-off
Source: Author

[12] Wegerich 2008, 73.
[13] Wegerich 2008, 76.
[14] Akmurdov et al 2011, 24.

As growing populations in all regions demanded more drinking water and the growing agriculture sector required more water for irrigation, the USSR created the River Basin Organization (BVO) in 1987. The purpose of the Organization was to set and oversee water limits in each of the Soviet Socialist Republics, so that annual water use could be regulated.[15]

Since the collapse of the Soviet Union, the CARs have maintained the water quotas set in 1987. The BVO continues to function as a joint management organization.[16] However, the CARs have since created independent programs for national development that conflict with the water quotas set by the BVO. Turkmenistan and Uzbekistan have increased agriculture production, especially of cotton; Tajikistan has expanded its hydroelectric output. Northern Afghanistan has also begun to tap into its water resources and to expand its cropland. Because of the corresponding increase in surface water and groundwater use, the Amu Darya River flow has decreased over the last decade (Figure 7).



UNDP calculations, based on data from CAwater-Info (http://www.cawater-info.net/analysis/index_e.htm). Each data point shows the average water volume for that month relative to the average volume for that month for every year going back to 1991-1992. Data points along the horizontal axis (zero deviation from monthly averages) correspond to monthly norms.

Figure 7: Average Monthly Water Volume at Tyuyamuyun Reservoir
Source: "The Return of Drought Conditions to Central Asia: Update and Possible Impact on Food Security," *UNDP*, 2011

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[15] Wegerich, 2008.
[16] Ibid.

4. Water Resources and Management in the Amu Darya River Basin

4.1 Surface Water: Current Conditions of the Amu Darya River Basin

Due to privatization and the unregulated expansion of agriculture, surface waters in the downstream river facing states have an increasing amount of dissolved minerals and salts, as shown in Figure 8. The direction of river flow has a positive relationship with mineralization. Furthermore, annual river flow has decreased over time; scholar Kai Wegerich estimates that no water reached the Aral Sea from 1993 to 1999, and concludes that this trend is likely to have continued throughout the first decade of the twenty-first century.[17]

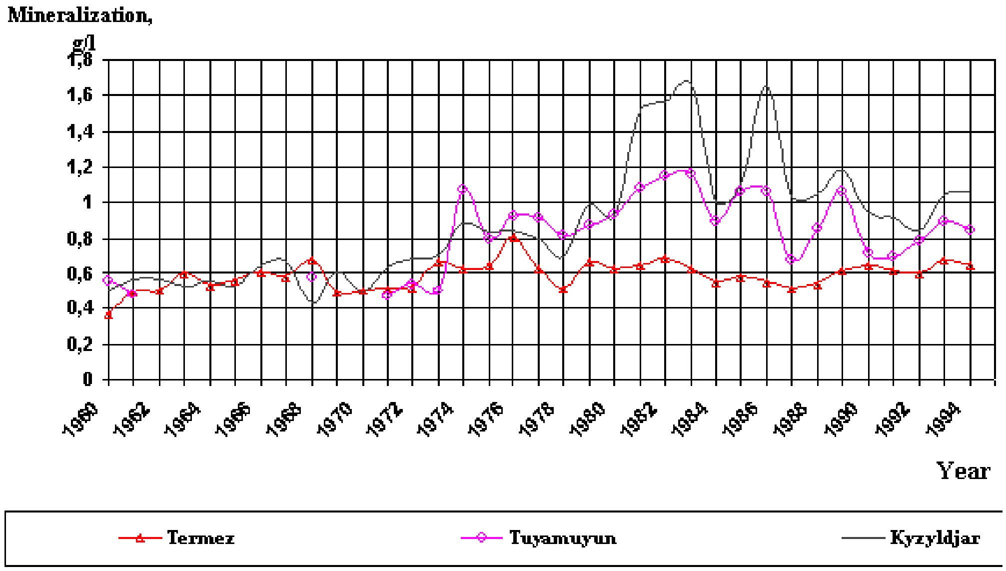

Figure 8: Surface Water Mineralization in Uzbekistan and Turkmenistan[18]
Source: CA Water *Aral Sea*, 2012

Higher mineral concentrations in surface water mean a decrease in water quality. Amu Darya River water is too contaminated to be used for drinking water in the downstream states, yet is the only source of water available to the large downstream population. As of today, very little has been done to improve water withdrawal management, which suggests that the problem of surface water mineralization will only become worse in the near future.

4.2 Groundwater: Current Conditions in the Amu Darya River Basin

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[17] Wegerich 2008.

[18] "Aral Sea", cawater-info.net, 25 August 2012, http://www.cawater-info.net/aral/water_e.htm.

In the post-Soviet era, groundwater has become an increasingly popular source of water for irrigation and human consumption. There are two types of groundwater reserves – those replenished by rainfall and snow, and those refilled by agriculture run-off and river flow from mountainous areas.[19] These two types of groundwater correspond with the upstream and downstream regions, respectively.

In the downstream states of Uzbekistan and Turkmenistan, groundwater pollution is on the rise. This is due to the many points at which pollution can occur in groundwater that is fed by runoff and river discharge, as shown in Figure 9. This is especially important, as nearly half of all groundwater extraction is used for drinking water in the downstream states.[20]

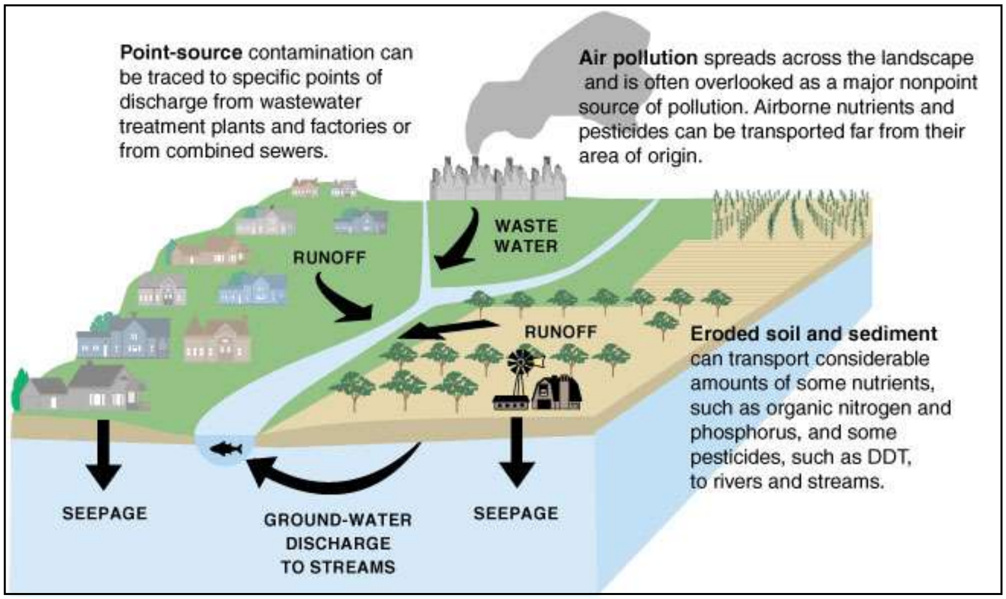

Figure 9: Groundwater Recharge and Pollution in Downstream States
Source: Geology Café *Introduction to Geology* 2012

Because of the increase in agricultural run-off since 1992, groundwater in the ADRB is relatively saline. As farmers recycle wastewater, more minerals and salts are dissolved into the groundwater reserves, leading to a decline in water quality.[21]. Less than 10% of groundwater in the ADRB has a salinity level of 1 gram/liter; the rest is moderately or highly saline. Surface and groundwater supplies are now so contaminated that purification by natural mixing is no longer guaranteed.[22]

[19] El Oifi et al. 2010.
[20] Ibid.
[21] Op cit.
[22] Ibid.

4.3 Water Resource Development: Planned Uses

Currently, 95% of water in the Amu Darya River Basin is used for agriculture.[23] Figure 10 shows the current use of land, most of which consists of irrigated cropland. Despite this, Tajikistan and Turkmenistan plan to add 50,000 and 450,000 HA of irrigated land, respectively. Nearly all of this land will be to grow rice, cotton, and wheat.[24]. As of 2008, northern Afghanistan contained 385,000 HA of irrigated land, with a potential to expand this area by at least 100,000 HA in the next two decades[25].

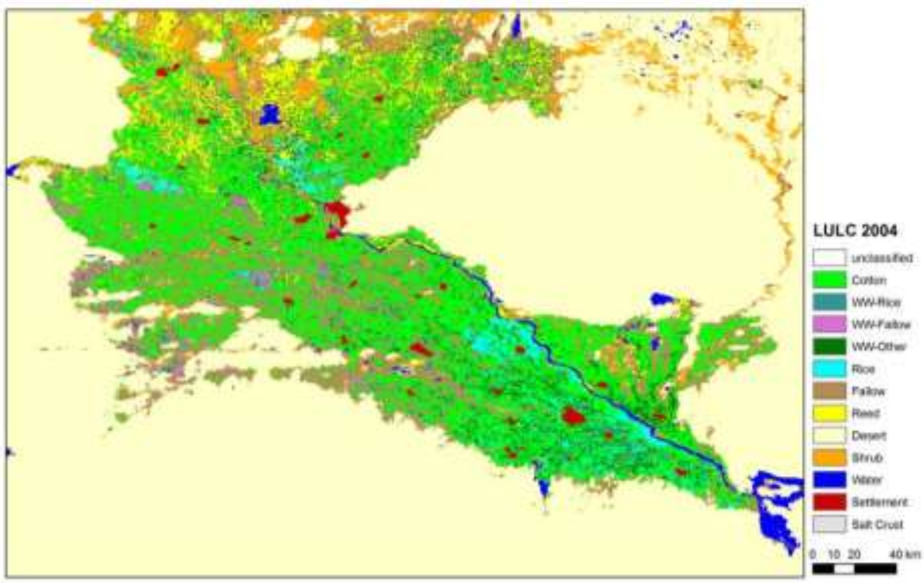

Figure 10: Current Land Use in the ADRB
Source: **"**Remote Sensing Products and Data Integration," *Central Asia Water*, 2010

The planned expansion of agriculture will require that more water be diverted from both surface and groundwater sources. Any increase in water use will put enormous strain on the water system in the ADRB and could cause droughts.

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[23] R. J. Thomas, "Opportunities to Reduce the Vulnerability of Dryland Farmers in Central and West Asia and North Africa to Climate Change", *Agriculture, Ecosystems, and Environment*, 126 (2008): 36-45, August 2012, doi: 10.1016/j.agee.2008.01.011.
[24] Wegerich 2008.
[25] Ibid.

4.4 Water Sharing Agreements in the Amy Darya River Basin

The most important water sharing agreement between these states was the Almaty Agreement of 1992. Signed a few months after independence, the Agreement upheld the 1987 water quotas created under the USSR under the management of the BVO (Fig. 11). Afghanistan was given an assumed water limit as well, and was not party to the Agreement.[26] Since 1992, the water allocations have remained the same, despite growing populations, expanding agricultural sectors, and a decreasing supply of water.

Country	Water Withdrawal Limit Under Almaty Agreement
Kyrgyzstan	0.45 km^3
Tajikistan	9.5 km^3
Turkmenistan	22 km^3
Uzbekistan	22 km^3

Figure 11: Water Quotas Under the Almaty Agreement of 1992
Source: Author, with data from Akmurdov, et al., 2011**:**

The Almaty Agreement has not inspired cooperation between the states in terms of water management. Unofficial data suggests that both Uzbekistan and Afghanistan are withdrawing more water than allowed by the Agreement, yet action has not been taken to either amend the Agreement or to encourage better water management in these countries.

[26] Wegerich 2008.

5. The Role of Climate Change: Ongoing and Future Changes

Central Asia is warming faster than the global average. The glaciers in Tajikistan and Afghanistan are melting, which is projected to create a sharp increase in the amount of surface water available, followed by a sharp decline as the sources of river water begin to disappear (Figure 12).

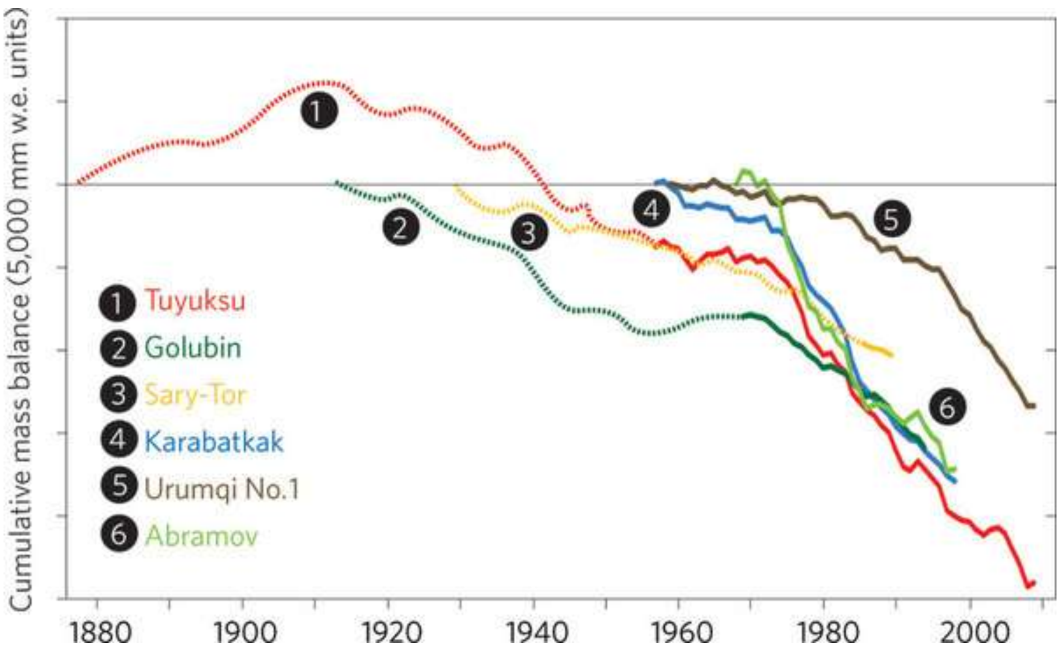

Figure 12: Glacier Melt in the Upper Reaches of the Amu Darya River
Source: Martin Beniston, et al., "Climate Change Impacts on Glaciers and Runoff in Tien Shan (Central Asia)", *Nature Climate Change, 2012*

In un-irrigated steppe lands, aridity increased 200% over the course of the 20th century, and will most likely continue to rise. However, irrigated areas experienced an increase in precipitation over the same period as a result of the increase in plant life due to the expansion of croplands.[27] Overall precipitation trends are negative; however, the significance of the effect of man-made microclimates should not be overlooked. These effects stem from the massive expansion of irrigated agriculture. The drying of the Aral Sea has released highly saline dust into the atmosphere. Already, there has been a negative recorded effect on surrounding plant life in the Aral Sea basin; this could easily spread to include the upper reaches of the Amu Darya River basin as well.[28]

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[27] J.M. Adams, R. Cole, G. Kapustin, and E. Loubimtseva.,"Impacts of Climate and Land Cover Changes in Arid Lands of Central Asia", *Journal of Arid Environments*, 62, no. 2 (Jul. 2005): 285-308, 30 July 2012, doi:10.1016/j.jaridenv.2004.11.005.
[28] Ibid.

6. The Energy Sector in the Amu Darya River Basin

6.1 Overview of the Electrical System in the Amu Darya River Basin

These states have an interconnected power system called the Central Asian Power System (CAPS). Centered at Tashkent, Uzbekistan, CAPS was constructed by the Soviet government and was connected to the Soviet power grid. From 1992 to 2000, the CARs cut their connection to Russia; however, they collectively re-connected to the Russian power grid in 2000.[29] In 2003, Turkmenistan withdrew from CAPS and from the Central Asian Power Council (CAPC), choosing instead to connect to Iran.[30]

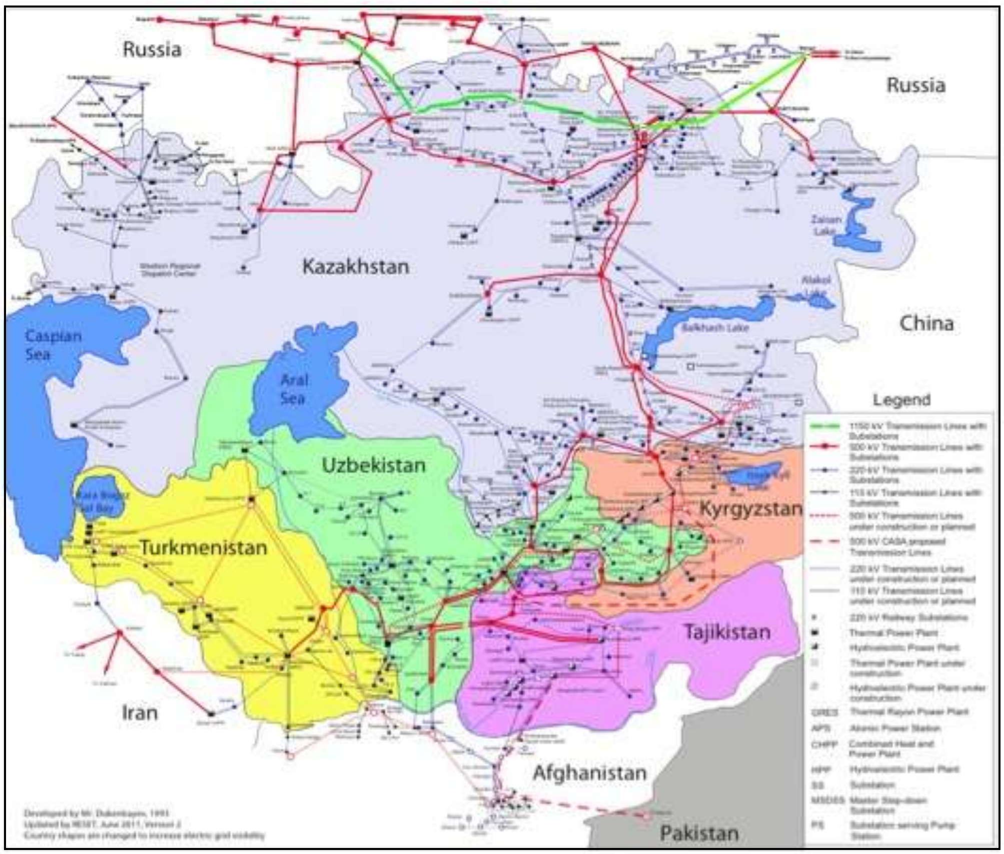


Figure 13: The Central Asian Power System
Source: Central Asia Power System, *One Steppe At a Time*, 8 June 2012, 24 August 2012

[29] Sebastien Peyrouse, "The Hydroelectric Sector in Central Asia and the Growing Role of China", *China and Eurasia Forum Quarterly*, 5, no. 2 (2007): 131-148, 1 August 2012
[30] Ibid.

The CAPS connects the major power-generating stations to regional distribution plants in each country, but does not connect to small villages and remote areas, as shown in Figure 13. Also, it is not organized in such a way that each country can take independent control of its electricity distribution. There are split grids in each country that do not connect to each other or that rely on power from a trans-boundary distribution center. Overall, the system is outdated and prone to shortages.[31]

6.2 Tajikistan: Current Electricity Sources and Renewable Potential

Tajikistan produces electricity through hydroelectric stations in the Pamir Mountains and through relatively insignificant natural gas plants. The hydroelectric sector is currently operating at just 5% of its potential; however, the consequences of relying exclusively on hydropower for electricity production could be catastrophic to the downstream states and could become a source of economic vulnerability in the face of climate change.[32] Tajikistan could diversify its electricity production by investing in wind and solar power, both of which have high potentials.

Source	Amount Generated (GWh)
Hydroelectric Stations	15,800
Natural Gas Stations	327
Total Generation	16,184
Total Energy Consumption	**13,540**

Renewal Resource	Energy Generation Potential
Hydropower	300,000 GWh
Wind	16,655 GWh
Biomass	Estimated: 2,000 GWh
Solar	25,000 GWh
Geothermal	Unknown
Total	**343,655 GWh**

Figure 14: Electricity Generation and Renewable Potential in Takikistan
Source: Author, with data from the European Bank for Reconstruction and Development

[31] World Energy Council, "Electricity in Central Asia: Market and Investment Opportunity Report", *World Energy Council* (Jul. 2007): 1-71,31 August 2012
[32] "Tajikistan: Country Profile", *European Bank of Reconstruction and Development: Renewable Development Initiative,* last modified 2010, 28 August 2012

Tajikistan produces the majority of its energy from a renewable source. Whether this renewable source will be a reliable source of energy in the future is uncertain. Development of solar, wind, and biomass resources could help alleviate the strain on the Amu Darya River, while also making the country energy independent. Investment in renewable energy sources could act as insurance against future climate, water, and energy shocks.

6.3 Turkmenistan: Current Electricity Sources and Renewable Potential

Turkmenistan generates the vast majority of its electricity by burning its large reserves of natural gas. There is also a small amount of hydropower output; but, it is insignificant in comparison to Turkmenistan's use of natural gas. This is unsustainable, as natural gas reserves are expected to decline in the next three or four decades.

Source	Amount Generated (GWh)
Natural Gas	15,997
Hydroeletric Stations	3
Total Generation	15,980
Total Energy Consumption	**12,180 GWh**

Renewal Resource	Energy Generation Potential
Hydropower	Economically feasible: 1,700 GWh
Wind	Estimated: 87,650 GWh
Biomass	1,989 kWh/m^2
Solar	Unknown
Geothermal	Unknown
Total	**Minimum: 1,700 GWh**

Figure 15: Electricity Generation and Renewable Potential in Turkmenistan
Source: Author, with data from the European Bank for Reconstruction and Development

The current hydropower output of 3 GWh represents only 35% of Turkmenistan's potential hydroelectric output. However, because of the strain already put on the Amu Darya River, it is important to consider other renewable alternatives. Turkmenistan is in danger of experiencing an economic and energy crisis in the next three or four decades if it continues to rely exclusively on fossil fuel energy. Development of hydropower, solar, and wind resources could help to prevent future energy crises while insuring the country against price shocks and environmental change.

6.4 Uzbekistan: Current Electricity Sources and Renewable Potential

Uzbekistan's energy is largely derived from its abundant natural gas deposits, although a significant portion of generated electricity comes from hydroelectric stations (Figure 16). Overall, about 81% of Uzbekistan's energy comes from fossil fuels.

Source	**Amount Generated (GWh)**
Coal and Peat	2,308
Oil	1,037
Natural Gas	37,495
Hydroelectric Stations	9,330
Total	50,170
Total Energy Consumption	**45,430 GWh**

Renewal Resource	**Energy Generation Potential**
Hydropower	29,700 GWh
Wind	Estimated: 37,690 GWh
Biomass	Minimum: 3.5 GWh
Solar	Estimated: 108,720 GWh
Geothermal	Minimum: 135 – 1150 MWt
Total	**Minimum: 212,700** GWh

Figure 16: Electricity Generation and Renewable Potential in Uzbekistan
Source: Author, with data from the European Bank for Reconstruction and Development

The energy demand in Uzbekistan is higher than its neighbors' due to its dramatically larger population and its expanding agriculture sector. While Uzbekistan's hydropower potential is large, it is most likely not a sustainable source of energy in the face of climate change. However, Uzbekistan's significant solar and wind resources could provide a lucrative source of renewable energy, as shown in Figure 16. Continued reliance on fossil fuels and perhaps on hydropower could lead to energy crises by 2050.

By developing renewable energy resources besides hydropower, the Uzbek government could help prevent an energy and economic crisis as its supplies of oil and gas are depleted. Furthermore, by securing renewable sources of energy, the government could ensure some measure of political stability in the future, as it makes the shift away from fossil fuels entirely while striving to be energy independent.

6.5 Afghanistan: The Forgotten Market

Due to the current conflict and a history of political instability, Afghanistan is lacking in both infrastructure and data. Currently, only about 6% of the country has access to reliable electricity, and the average per capita consumption is a mere 45 KWh per year. Most electricity is produced by small diesel generators and hydropower stations, and Kabul is the only region with a centralized power grid.[33]

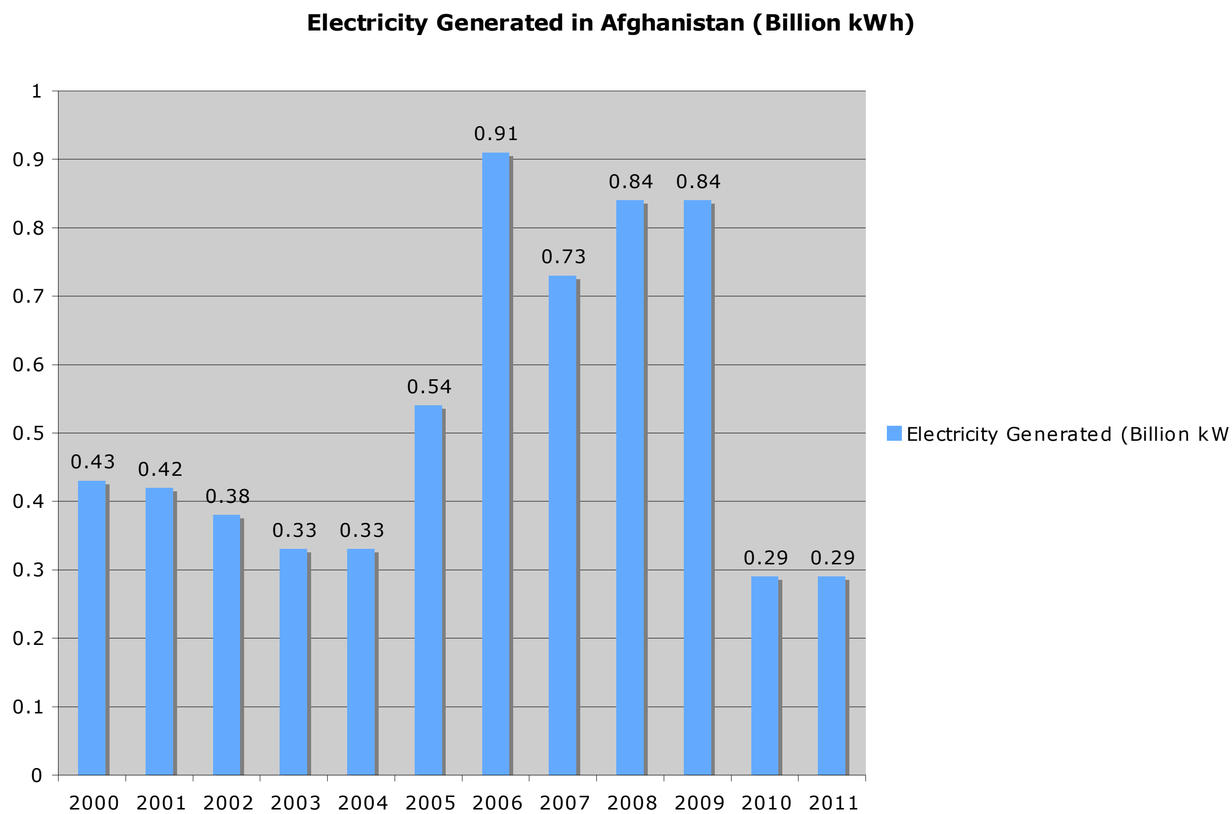


Figure 17: Electricity Generation in Afghanisan (2000 – 2011)
Source: Author, with data from IndexMundi, 2001 and 2012

[33] Malik Mortaza, "Afghanistan's Power Production System", *The Society of Afghan Engineers*, 2010, 28 August 2012

Since 2000, Afghanistan's electricity production has been erratic, due mainly to the military involvement of the United States and NATO and the ongoing conflict within its borders. Electricity production largely stabilized from 2006 to 2009; but, like consumption, dropped off sharply after 2009, reaching a stable low of 285 GWh in 2010 and 2011.[34] Increasingly, Afghanistan has relied on energy imports from the Central Asian republics to offset its decline in energy production.

Afghanistan's renewable energy potential is as yet unknown. However, it is not difficult to estimate that the hydropower potential in the Tien Shan and Pamir Mountain ranges along the borders of Tajikistan and China might be significant, and that there may be a high solar power potential in the southern desert regions. Afghanistan may be best suited to the creation of mini-grids due to the high geographic isolation of its many regions.

[34] "Electricity Production (billion kWh)", *Index Mundi*, Central Intelligence Agency, 1 Jan. 2011, 28 August 2012

7. Why Regional Cooperation is Necessary

The Amu Darya River provides Tajikistan and Turkmenistan with their only source of fresh water. In Uzbekistan, the Amu Darya is the largest and most important source of water in the country. For northern Afghanistan, the Amu Darya provides water to a population plagued by lack of infrastructure and political instability. When one country withdraws and uses water, it affects the flow and quality of the river in the other countries. If the current numbers are correct, the growing Central Asian population is withdrawing more water than the river can replenish, and climate change analysts are predicting river shrinkage due to glacial melt in the next 40 years.

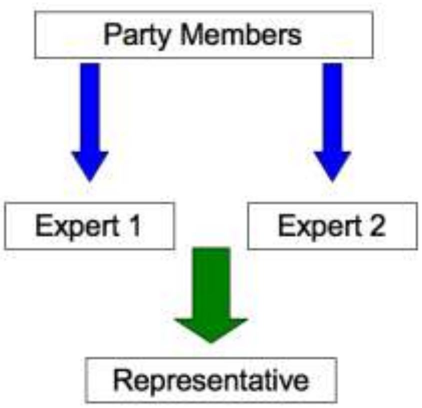
Figure 18: Cooperation
Source: www.Clker.com

If the four countries do not coordinate their water policies and attempt to diversify their energy sectors to include renewable sources of energy, the entire region may lose its only water source and, for Tajikistan and Afghanistan, the most important source of electricity, by 2050, causing humanitarian, economic, and energy crises, if not political instability. Regional cooperation is necessary to manage water intake, help conserve the ecosystem, and increase electric efficiency and sustainability.

The current BVO is inadequate and wields little power among the CARs. Afghanistan has been left out altogether in the dialogue about water, and has only recently been included in discussions and deals made about electricity. If inclusive, genuine, and enforced regional cooperation does not occur, the entire ADRB is in danger of drought, famine, and economic depression.

8. Policy Recommendations for Future Sustainable Water and Energy Development in the Amu Darya River Basin

Regional cooperation in water management and energy resources is necessary to the survival of these four countries. In all possible future scenarios, Afghanistan must be included in the dialogue and implementation of new and existing programs. In order to achieve cooperation and sustainability, the following are recommended as starting points for the creation of comprehensive top-down and bottom-up solutions to present and future challenges in the Amu Darya River Basin:



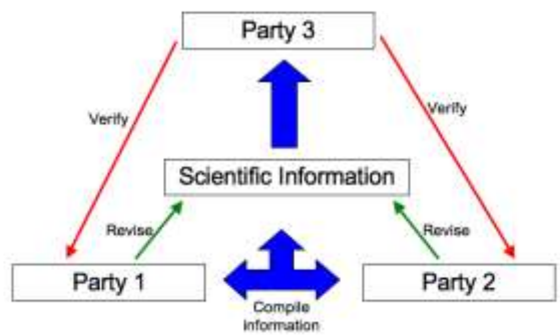


Figure 19: Two-tier Committee Selection **Third Party Monitoring**
Source: Author

Re-structure the BVO (River Basin Organization) in such a way that it becomes a subjective and authoritative regional institution. There are several ways to do this.

- A two-tier committee selection process would help to ensure better cooperation between the delegates, as shown in Figure 19. This process makes it more likely that the delegate(s) will be moderate and willing to compromise.
- The BVO needs to have a stronger monitoring system. The use of third party oversight is suggested. In this case, a delegate from the Syr Darya River Basin located in in Kyrgyzstan and eastern Uzbekistan. Kazakhstan has already started to take a role in mediating disputes between the ADRB states, and might be a good choice to monitor information and transparency within the BVO.

- The BVO needs to become more transparent. One way to do this is to make its processes public, including allowing citizens to attend meetings and creating a free, scientific online database to which scientists can contribute and validate.

Create appropriate financial mechanisms to ensure fair use of water and exchange of fuel resources.

- Raghuveer Sharma et al describe a system for the Syr Darya River countries that may also be applied to the 4ADRB.
- A long-term agreement should be created in a regional political institution that sets a base price for water services to be paid by downstream states. The agreement must be ratified by all participating governments, and should be good for a period of ten years, to be modified as the regional water resources and availability changes.[35]
- After the water service prices are set, electricity and fossil fuel trade should be conducted at market price, and not at an artificial price as compensation for water services.[36].
- Establishing a letter of credit for water services provided by upstream states could minimize risk and debt to upstream states.[37] The Guarantee Fund would provide payments should downstream states be unable to pay, and the defaulting state(s) would assume the debt and be vulnerable to sanctions (Figure 21).[38]
- A reverse system for energy supplies to upstream states could help to establish a healthier financial relationship between the ADRB countries.

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[35] Raghuveer Sharma, et al. Anil, "Water and Energy Nexus in Central Asia: Improving Cooperation in the Syr Darya Basin", The World Bank, Jan 2004, 2 July 2012,

[36] Ibid.

[37] Sharma et al 2004.

[38] Ibid.

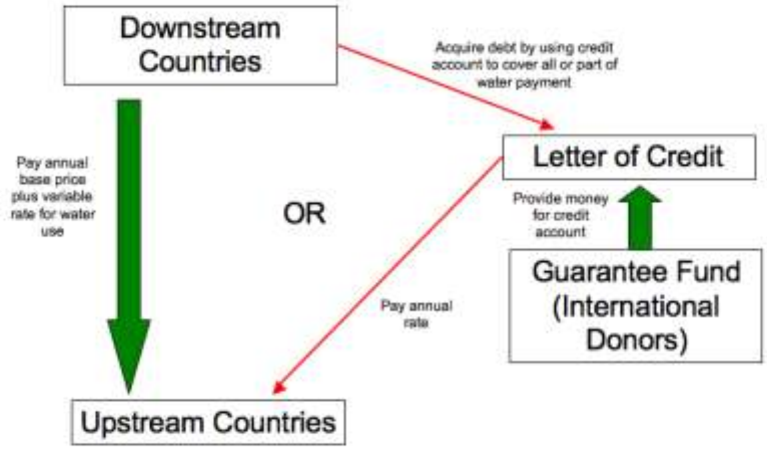

Figure 20: The Letter of Credit System
Source: Author, with concept from Sharma, et al., 2004

Improve the efficiency of irrigated agriculture through the use of available and economically feasible technology, and diversify the agriculture sector. Alternate Dry Furrow (ADF) irrigation, in which every other row is irrigated, has lower startup costs and greater benefits than other types of alternative irrigation (see Figure 22).[39] According to Bekshanov et al, the ADF technique would increase water productivity by up to 57% while increasing annual income by up to 134 USD per hectare.[40]

Figure 21Alternate Dry Furrow Irrigation
Source: Shane Speck, "How Irrigation Works", *How Stuff Works,* 9 Sept. 2012

Drip irrigation, while extremely water efficient and having high economic benefit, also has high initial costs and may prove too expensive for farmers to implement. However, drip

[39] Maksud Bekchanov,et al., "”Pros and Cons of Adopting Water-Wise Approaches in the Lower Reaches of the Amu Darya: A Socio-Economic View", *Water* 2 (20 May 2010): 200-216, 30 July 2012.
[40] Bekchanov et al 2010.

irrigation has the potential to massively impact the water efficiency in the region, and should be considered as a potential future investment by local communities and national governments.[41] Furthermore, by shifting from single cash crops to multiple cash crops, Central Asian farmers reduce the risk of price shocks and can increase soil productivity. Potential alternatives include fava beans, sunflowers, safflowers, and field peas, all of which are being experimented with in the CARs.[42]

[41] Ibid.
[42] Thomas 2008.

Figure 22: Renewable Energy Sources
Source: “Tends in Renewable Energy Production and Consumption in the USA,” *Geology.com*

Invest in the renewable energy sector. The downstream, fossil-fuel producing states would benefit immensely from developing their solar, wind, and geothermal potentials (Figure 23). Upstream, investment in renewable energy resources would help to offset dependence on the uncertain headwater resources and could diminish the strain on the Amu Darya River. Russia, China, and Iran could provide the financial investment needed to implement comprehensive renewable energy programs in Tajikistan, Turkmenistan, and Uzbekistan. As an alternative, the CARs might look to the European Union to provide funding, as it has a good track record with renewable energy investment and may be more amenable to the development of alternative energy resources in Central Asia.

Afghanistan will most likely be left out of this process at first; but, should concentrate on expanding its electrical capacity before shifting to renewable energy sources. Investment in local projects, such as solar panels and wind turbines, would allow rural communities to have access to electricity without the major spending needed to connect them to the main grid. In Afghanistan especially, the creation of mini-grids may be a viable alternative, as the government lacks the funds and stability to carry out massive modernization projects.

Create local education programs to include farmers in the scientific process and harness local knowledge. Private landowners should be encouraged to participate in the scientific process by monitoring their own water use, contributing information about crop yields, farming techniques, and soil quality, and observing the water levels of the Amu Darya River and its canals. By educating and involving farmers in the scientific process, more data can be accumulated and farmers can begin to understand the importance of water management on a personal level. Best practices in the use of crops and irrigation should be shared across local communities, and traditional knowledge of water management and crop patterns can be used to develop new and innovative solutions to water inefficiency.

By empowering small communities to become aware of the larger water crisis, scientists and governments can gain access to information and can better implement new technologies and programs. Local feedback and local outreach to the government can better connect the people to the problem and create a national agenda that is based on the principles of adaptability, sustainability, and innovation. This bottom-up approach is key to the continued use of Amu Darya River water and should be implemented immediately, with the help of non-governmental organizations such as the International Water Management Institute.

These five recommendations should not be considered fully formed solutions to the water and energy problems in the ADRB. Rather, they should be a starting point for further research about and cooperation between the riparian states. By acknowledging the regional interdependence of the CARs and Afghanistan on water and energy, engineers, political scientists, investors, and farmers can begin to make informed and sustainable decisions about resource development that will positively impact the region and allow the river to survive.

Bibliography

1. Adams, J. M., R. Cole, G. Kapustin, and E. Loubimtseva.,"Impacts of Climate and Land Cover Changes in Arid Lands of Central Asia", *Journal of Arid Environments,* 62, no. 2 (Jul. 2005): 285-308, 30 July 2012, doi:10.1016/j.jaridenv.2004.11.005.
2. Akmurdov, M. et al, "Environment and Security in the Amu Darya Basin", *UN Environment Programme* (2011): 1-98, 30 June 2012, **http://www.envsec.org/publications/AmuDarya-EN-Web.pdf**.
3. Bekchanov, Maksud, John P. A. Lamers, and Christopher Martius, ""'Pros and Cons of Adopting Water-Wise Approaches in the Lower Reaches of the Amu Darya: A Socio-Economic View", *Water* 2 (20 May 2010): 200-216, 30 July 2012, doi:10.3390/w2020200.
4. "Electricity Production (billion kWh)", *Index Mundi,* Central Intelligence Agency, 1 Jan. 2011, 28 August 2012, http://www.indexmundi.com/g/g.aspx?c=af&v=79.
5. El Oifi, Bouchra, Shavkat Rakhmatullaev, Frédéric Huneau, Jusipbek Kazbekov, Philippe Le Coustumer, Jamoljon Jumanov, Mikael Motelica-Heino, and Zbynek Hrkal, "Groundwater Resources Use and Management in the Amu Darya River Basin (Central Asia)", *Environmental Earth Sciences,* 59, no. 6 (2010): 1183-93, 25 June 2012, doi: 10.1007/s12665-009-0107-4.
6. Froebrich, Jochen and Odil Kayumov, "Water Management Aspects of Amu Darya: Options for Future Strategies", *Dying and Dead Seas*: 49-76, Eds. J.C.J. Nihoul et al. (Netherlands:Kluwer Academic Publishers, 2004), 50.
7. Mortaza, Malik, "Afghanistan's Power Production System", *The Society of Afghan Engineers,* 2010, 28 August 2012, http://www.afghan-engineers.org/afghanistans_power.html.
8. Peyrouse, Sebastien, "The Hydroelectric Sector in Central Asia and the Growing Role of China", *China and Eurasia Forum Quarterly,* 5, no. 2 (2007): 131-148, 1 August 2012, http://www.silkroadstudies.org/new/docs/CEF/Quarterly/May_2007/Peyrouse.pdf.
9. Sharma, Raghuveer, Anil Markandya, Masood Ahmad, Marat Iskakov, and Venkataraman Krishnaswamy, "Water and Energy Nexus in Central Asia: Improving Cooperation in the Syr Darya Basin", The World Bank, Jan 2004, 2 July 2012, http://siteresources.worldbank.org/INTUZBEKISTAN/Resources/Water_Energy_Nexus_final.pdf.
10. "Tajikistan: Country Profile", *European Bank of Reconstruction and Development: Renewable Development Initiative,* last modified 2010, 28 August 2012, http://ws2-23.myloadspring.com/sites/renew/countries/tajikistan/profile.aspx.
11. Thomas, R. J., "Opportunities to Reduce the Vulnerability of Dryland Farmers in Central and West Asia and North Africa to Climate Change", *Agriculture, Ecosystems, and Environment,* 126 (2008): 36-45, August 2012, doi: 10.1016/j.agee.2008.01.011.
12. Wegerich, Kai, "Hydro-hegemony in the Amu Darya Basin", *Water Policy,* 10, no. 2 (2008): 71-88, 25 June 2012, doi: 10.2166/wp.2008.208.

13. World Energy Council, "Electricity in Central Asia: Market and Investment Opportunity Report", *World Energy Council* (Jul. 2007): 1-71,31 August 2012,<http://www.worldenergy.org/documents/central_asia_raoca_study.pdf> .

Figures Cited

1. The Amu Darya River

Source: Jerker Jarsjo, Bakhtiyor Karimov, and Rebecka Tornqvist, "Health Risks from Large-Scale Water Pollution: Trends in Central Asia", *Environment International,* 39, no. 2 (Feb. 2011): 435-442, 14 August 2012, http://www.sciencedirect.com/science/article/pii/S0160412010002369.

2. Significance of the Amu Darya River Basin

Source: "Too Much—To Little Water: Adaptation to Climate Change in the Hindu Kush Himalayas and Central Asia", *United Nations Environmental Programme GRID-Arendal* (2007)*:* 1-12, 31 August 2012, http://www.grida.no/publications/too-much-too-little-water/.

3. The Water-Food-Energy Nexus

Source: "Water in the Green Economy", water-energy-food.org, last modified January 1, 2011, http://www.water-energy-food.org/en/news/view__218/water_in_the_green_economy.html.

4. The Southeast and Northwest Regions of the ADRB

Source: Tirdad Gorgani, "Welcome to Xoroq (Khorogh)", oocities.org, last modified May 2005, http://www.oocities.org/xoroq/.

5. Population of the Amu Darya River Basin

Source: Author, with data from Akmurdov et al 2011 and CIA World Factbook.

6. The Water-Energy Tradeoff

Source: Author.

7. Average Monthly Water Volume at Tyuyamuyun Reservoir

Source: "The Return of Drought Conditons to Central Asia: Update and Possible Impact on Food Security", *UNDP*, last modified 2011, 25 August 2012, http://europeandcis.undp.org/news/show/2D476888-F203-1EE9-BBD365AF8DD66410.

8. Surface Water Mineralization in Uzbekistan and Turkmenistan

Source: "Aral Sea", cawater-info.net, 25 August 2012, http://www.cawater-info.net/aral/water_e.htm.

9. Groundwater Recharge and Pollution in Downstream States

Source: "Introduction to Geology", *Geology Café*, last modified 18 August 2012, 25 August 2012, http://www.geologycafe.com/class/chapter9.html.

10. Current Land Use in the ADRB

Source: "Remote Sensing Products and Data Integration", *Central Asian Water*, last modified 2010, 24 August 2012, http://www.cawa-project.net/page/157.

11. Water Quotas Under the Almaty Agreement of 1992

    Source: Author with data from Akmurdov et al 2011.

12. Glacier Melt in the Upper Reaches of the Amu Darya River

    Source: Martin Beniston, Tobias Bulch, Olga Solomina, Annina Sorg, and Markus Stoffel, "Climate Change Impacts on Glaciers and Runoff in Tien Shan (Central Asia)", *Nature Climate Change* (2012), 25 August 2012, doi:10.1038/nclimate1592.

13. The Central Asian Power System

    Source: "Central Asia Power System", *One Steppe At a Time*, 8 June 2012, 24 August 2012, http://onesteppeatatime.wordpress.com/2012/06/08/central-asia-power-system/.

14. Electricity Generation and Renewable Potential in Tajikistan

    Source: Author, with data from the European Bank for Reconstruction and Development.

15. Electricity Generation and Renewable Potential in Turkmenistan

    Source: Author, with data from the European Bank for Reconstruction and Development.

16. Electricity Generation and Renewable Potential in Uzbekistan

    Source: Author, with data from the European Bank for Reconstruction and Development and the International Exhibition Group of Uzbekistan.

17. Electricity Generation in Afghanistan (2000-2011)

    Source: Author with data from IndexMundi, last modified 1 Jan. 2011, 28 August 2012, http://www.indexmundi.com/g/g.aspx?c=af&v=79.

18. Cooperation

    Source: http://www.Clker.com.

19. Two-tier Committee Selection

    Source: Author.

20. Third-Party Monitoring

    Source: Author.

21. The Letter of Credit System

    Source: Author, from original concept by Sharma et al 2004.

22. Alternate Dry Furrow Irrigation

    Source: Shane Speck, "How Irrigation Works", *How Stuff Works,* 9 Sept. 2012, http://home.howstuffworks.com/irrigation4.htm.

23. Renewable Energy Sources

    Source: "Tends in Renewable Energy Production and Consumption in the USA", *Geology,* 9 September 2012, Geology.com/articles/renewable-energy-trends.