# Water-Energy-Food-Ecosystems Nexus Assessment in the Context of Central Asia

**TRAINING MANUAL**

The training manual was prepared with the support of the United Nations Economic Commission for Europe (UNECE) by a team of experts and staff from the Kazakh-German University (DKU): Zharas Takenov (PhD), Alexey Kobzev, Larissa Kogutenko, Maira Kussainova, Marhabo Yodalieva and Barbara Janusz-Pawletta (PhD).



**Almaty, 2020**

## FOREWORD

When managing water, energy, food and ecosystem resources in Central Asia, it is necessary to identify and assess their interrelations to improve water, energy and food security, protect ecosystems, taking into account natural and man-made threats for the region. The study of interrelations is a new challenging field of knowledge that requires comprehensive and in-depth training of the experts to conduct such multidisciplinary and large-scale assessments.

Resource management at the country level is complicated by division and segmentation of the national governance structures. Management of transboundary resources of the macroregions including two or more countries is even more difficult task due to different economic, political and social interests. This requires an ongoing dialogue between the countries to find mutual benefits and compromise.

Such a dialogue between the countries can be based on various international agreements and treaties, such as the Global Sustainable Development Goals (SDGs) by 2030. 17 SDGs cover a wide range of topics and issues, thus interrelating the various goals. No goal can be achieved separately, but only together with other goals. Key sectors such as energy, water, agriculture and ecosystems are vital components in terms of general strategy and planning in the furtherance of SDGs by 2030.

At the same time, a scientific methodology is required to identify the interrelation between water, energy, food and ecosystem resources at the level of macroregions. The United Nations Economic Commission for Europe (UNECE) develops such methodology under the Water Convention.

This teaching guide is intended as a methodological guide for training the specialists of higher education institutions; it can also be used to extend knowledge to a wider audience, including government officials involved in water resources management, food security, energy, preservation of ecosystems and infrastructure development. Moreover, the guide can be used as an introduction to an integrated approach to solving cross-border challenges of the macroregions that go beyond one issue.

We hope this guide will contribute to the creation and strengthening of "capacity to support mutual learning across watersheds, sectors and states, thus facilitating the experience exchange and strengthening of local cooperation between countries"[1].

Dr. iur. Barbara Janusz-Pawletta (PhD)
Vice-rector for International Cooperation
Head of IWRM in Central Asia Master Program
UNESCO Chair Holder in Water Management in Central Asia at DKU

[1] Approach proposed to assess the interrelation between water, food, energy and ecosystems under the UNECE Water Convention. Discussion document. April 4, 2013. Prepared by the UNECE Secretariat with the participation of Finland, Food and Agriculture Organization of the United Nations (FAO), Stockholm Environment Institute (SEI), and Stockholm International Water Institute (SIWI). http://www.unece.org/fileadmin/DAM/env/documents/2013/wat/Nexus_mtg/RU_nexusAssessmentApproach_forWeb_final.pdf

# TABLE OF CONTENTS

## TERMS, ACRONYMS AND ABBREVIATIONS

**Agent-based modeling** – includes the elements of game theory, complex systems, multiagent systems, etc.

**River watershed** (also water-shed area, catch basin) – a territory of earth surface from which all surface and groundwater flows into the watercourse including its tributaries.

**Iteration process** – allows to easily make changes, receive comments and suggestions and take them into account in the project, reduce risk in advance and dynamically adjust the process.

**Macroregion** "is defined as the area of territories of two or more countries connected by a transboundary freshwater basin affected by interrelated energy and food sectors due to the connecting role of water resources"[2].

**Delphi method** – "includes a quick search for solutions based on their generation during "brainstorm" by a group of specialists, and selection of the best solution based on expert assessments. The Delphi method is used for expert forecast by organizing a system for collection and mathematical processing of expert assessments".[3]

**IUCN** – International Union for Conservation of Nature.

**Nexus** (lat. Nexus – "relation, connection") – has various meanings in different fields, but in general means the central part of a subject matter, the center of any connections[4].

**Backwater** – in hydraulic engineering, raising of water level as compared to "natural" (normal) water level. Backwater occurs when the culverts are constructed in rivers which limit a watercourse (for example, dams), but it can also occur due to natural conditions: wind blowing from downstream, changes in the configuration of groundwater runoff, ice jams and clogs, blockings.

**SPECA** – UN Special Programme for the Economies of Central Asia[5].

**SEA** – Strategic Environmental Assessment.

**TDA** – Transboundary Diagnostic Analysis.

**LEAP** – Long-range Energy Alternatives Planning System.

**NWSAS** – North-Western Sahara Aquifer System.

**WEAP** – Water Evaluation and Planning System.

**TARWR** – Total Actual Renewable Water Resources. Indicator – annual total actual renewable water resources – theoretical maximum annual volume of water resources available in the country.

**TBNA methodology** – Transboundary Basin Nexus Assessment methodology.

---

[2] Approach proposed to assess the interrelation between water, food, energy and ecosystems under the UNECE Water Convention. Discussion document. April 4, 2013. Prepared by the UNECE Secretariat with the participation of Finland, Food and Agriculture Organization of the United Nations (FAO), Stockholm Environment Institute (SEI), and Stockholm International Water Institute (SIWI). http://www.unece.org/fileadmin/DAM/env/documents/2013/wat/Nexus_mtg/RU_nexusAssessmentApproach_forWeb_final.pdf

[3] Expert focus. https://studme.org/12090810/marketing/ekspertnoe_fokusirovanie

[4] Water-food-energy-ecosystem nexus. https://nexusexpedition.com/blog_entry.php?blog_id=24

[5] http://www.unece.org/env/water/nexus

# 1. INTRODUCTION

## 1.1 SPECIFIC FEATURES OF RESOURCE MANAGEMENT IN CENTRAL ASIA

In Soviet times, the water-abundant republics which are geographically located in the upper reaches of rivers, in summer season provided water for irrigation for the republics located downstream of the rivers, and in exchange for this in winter season they received electricity. At the same time, the environmental aspects of natural resource management were not taken into account. The drying up of the Aral Sea which was a unique natural object that provided the ecological and climatic balance of the vast territory of the Eurasian continent – is the best-known example of the consequences of disregard of environmental impact. Following independence of the former Soviet republics of Central Asia in 1991, the existed regional approach to centralized water and energy management was replaced by a national approach which, for example, in the water supply system resulted in fragmentation of water distribution networks and caused conflicts mainly between neighbors located upstream and downstream of transboundary rivers.

Since the Central Asian states still share the rivers the largest of which are the Syrdarya and the Amudarya crossing their borders, any changes in the use of water upstream have an immediate impact on the states located downstream. Water originating in Tajikistan and Kyrgyzstan accounts for more than 80 % of water flowing into the Aral Sea. These two countries are more interested in using available water resources to generate hydropower. Thus, Tajikistan controls about 60 % of total Amudarya basin and about 9 % of total Syrdarya basin by means of dams. Kyrgyzstan controls about 58% of the water volume in the Syrdarya basin due to reservoirs located on its territory. . On the contrary, Turkmenistan, one of the largest consumers receiving about 45 % of the Amudarya water through the 1445 km long Karakum Channel, which was built in the Soviet period, has a few reservoirs and almost entirely depends upon its upstream neighbors. Downstream coastal states – Kazakhstan and Uzbekistan – need these water resources for irrigation in summer period. Upstream coastal states are interested in discharging maximum amounts of water in winter period when electricity needs are at their peak, while downstream coastal states need maximum water in summer period and during irrigation[6].

In Central Asia, water management is a critical issue, as water withdrawals for agriculture account for over 90 % of total water use, mainly for cotton fields in Uzbekistan and Turkmenistan. Soil salination increases due to water losses in irrigation channels and cultivation of unstable monocultures, and huge water losses produce a load on the water supply. Balancing the needs for agricultural production and hydropower generation is challenging as water flow is disrupted and becomes uncontrolled. Climate change and population growth are placing additional stress on the water resources of the region, as the above-mentioned rivers are projected to have 10–30 % less water by 2050[7].

Kazakhstan largely depends on transboundary waters; out of one hundred cubic kilometers of water available in Kazakhstan, forty-six cubic kilometers are received from the rivers flowing from Kyrgyzstan, Uzbekistan, Russia and China. Of the eight existing large Kazakhstan water basins[8],

---

6 Water in Kazakhstan, a key in Central Asian water management. Aibek Zhupankhan, Kamshat Tussupova and Ronny Berndtsson. Published online: 22 Mar 2018. https://www.tandfonline.com/doi/full/10.1080/02626667.2018.1447111#:~:text=Thus%2C%20the%20total%20water%20resources,Kazakhstan%20in%20the%20new%20millennium

7 Water in Kazakhstan, a key in Central Asian water management. Aibek Zhupankhan, Kamshat Tussupova and Ronny Berndtsson. Published online: 22 Mar 2018. https://www.tandfonline.com/doi/full/10.1080/02626667.2018.1447111#:~:text=Thus%2C%20the%20total%20water%20resources,Kazakhstan%20in%20the%20new%20millennium

8 Water basins in Kazakhstan: Aral-Syr Darya, Balkhash-Alakol, Irtysh, Ural-Caspian, Ishim, Shu-Talas, Tobol-Turgay, and Nura-Sarysu.

seven are transboundary. Water demand is increasing in neighboring states and, accordingly, its level is falling in Kazakhstan.[9]

The rivers of Irtysh, Ili, Talas, Horgos are the largest of 20 transboundary rivers that flow from China to Kazakhstan and are the most important sources of fresh water for Kazakhstan. At the same time, the situation with the use of resources of transboundary rivers between Kazakhstan and China remains unsettled. Insufficient discussions between the near-border parties and signing of a limited number of bilateral agreements (see *Box 1*) eventually resulted in a situation where the amount of water reaching Kazakhstan depends on the neighbors, as to this date there is no agreement with China to regulate the ecological and minimum sanitary flows for these transboundary rivers.

The active development of Xinjiang Uygur Autonomous Region (XUAR) leads to an increasing population in the Chinese part of the Ili and Irtysh river basins, which requires a significant increase in the cultivated areas for grain and cotton in XUAR, construction of new channels, dams, reservoirs and energy sources on these transboundary rivers.

The Ili river and its tributaries: Charyn, Chilik, Turgen, Issyk, Talgar and Kaskelen (with tributaries – Little Almatinka and Big Almatinka) is a freshwater artery feeding the Lake Balkhash[10]. However, 80 percent of the flow is still formed in China, and the Kapchagay reservoir[11] and Hydro Power Plant (HPP) located on the territory of Kazakhstan depend on its water content. Balkhash is 40 times larger than the Lake of Geneva and is located 400 kilometers north of Almaty. The public of Kazakhstan is concerned that in recent years the Balkhash-Alakol water basin where 20 % of the country's population live, has faced a drastic shortage of water inflow which led to the drying up of the Lake Balkhash[12] (only 5 of 16 lake systems survived), the reduction in agricultural yield and the increased desertification of the territories adjacent to the lake. Flora and fauna of Balkhash are also endangered. There are about 20 fish species in the lake, more than 120 bird species on the territory of the reservoir 12 of which are listed in the Red Book. There are up to 60 species of unique plants growing on land and in water[13].

The Irtysh river (the main left tributary of the Ob river, the length of Irtysh is 4248 km which exceeds the length of Ob by 598 km) flows from the XUAR through Kazakhstan, feeds the Lake Zaisan, and further flows to Omsk and Tyumen regions of the Russian Federation. In Kazakhstan, the Irtysh river provides the cities of Ust-Kamenogorsk, Semey, Pavlodar, Temirtau, agriculture in some regions of Central Kazakhstan; moreover, the Irtysh-Karaganda canal which draws water upstream of Pavlodar and flows to the west, supplies drinking water to the cities of Nur-Sultan, Karaganda and Ekibastuz, and therefore is very important for the development of the country.

---

[9] Water in Kazakhstan, a Key in Central Asian Water Management. Aibek Zhupankhan, Kamshat Tussupova, Ronny Berndtsson. 1 Mar 2018, Published online: 22 Mar 2018. https://www.tandfonline.com/doi/full/10.1080/02626667.2018.1447111

[10] Kazakh lake 'could dry up'. BBS News, 15 January, 2004. http://news.bbc.co.uk/2/hi/asia-pacific/3397077.stm

[11] Where does the Kapchagay "goes"? A submerged village appeared on the reservoir surface. September 2020. https://spik.kz/kuda-ukhodit-kapshagay-na-poverkhnosti-vodokhranilishcha-pokazalsya-zatoplenniy-poselok-iliysk?fbclid=IwAR0lHy4nkHY7_KQlDDRnjANIvWHuZN8wvdWfUle_kPeoLlGyNDoBNE8hfxQ

[12] Yesekin B.K., Water Partnership for Central Asia, Mongolia and Caucasus. TRANSFER OF BEST PRACTICES AND KNOWLEDGE. Ecology and industry of Kazakhstan. 2 /66/ 2020. https://drive.google.com/file/d/1_cwpph9VA9weNZjCd9lK8Cm7UrHU5ehX/view?fbclid=IwAR1WJKI6wd30HUuIBbl-ICa32XTPOxNWV-2231I3Ubl4FuA-ksnbXCKvqUU

[13] Save Lake Balkhash! Public petition to the President of the Republic of Kazakhstan Kasym-Zhomart Kemelevich. https://secure.avaaz.org/community_petitions/ru/prezident_respubliki_kazahstan_kasymzhomart_kemele_sohranim_ozero_balhash_1/?faiAZkb&fbogname=Zharas&utm_source=sharetools&utm_medium=facebook&utm_campaign=petition-1123584-sohranim_ozero_balhash&utm_term=aiAZkb%2Bru&fbclid=IwAR20HcXPB2BXQ-9wUzFkuwE84ACvZjbp9_lACLHeNlCxUE8wRc-TDwb-F40

**Box 1.** ***"Intergovernmental agreements on transboundary waters concluded by Kazakhstan with neighboring states":***

1. ***"Agreement between the Government of the Russian Federation and the Government of the Republic of Kazakhstan on joint use and protection of transboundary water bodies dated August 27, 1992, Orenburg."***
2. ***"Agreement between the Government of the Republic of Kazakhstan and the Government of the Kyrgyz Republic on the use of interstate water facilities on the Chu and Talas rivers dated January 21, 2000, Astana."***
3. ***"Agreement between the Government of the Republic of Kazakhstan and the Government of the People's Republic of China on cooperation in the use and protection of transboundary rivers dated September 12, 2001, Astana[14]."***
4. ***"Memorandum of urgent notification of the parties about natural phenomena on transboundary rivers between the Government of the Republic of Kazakhstan and the Government of the People's Republic of China dated October 19, 2004, Almaty."***
5. ***"Agreement between the Ministry of Agriculture of the Republic of Kazakhstan and the Ministry of Water Management of the People's Republic of China on urgent notification of the parties about natural disasters on transboundary rivers dated July 4, 2005, Astana."***
6. ***"Agreement between the Ministry of Agriculture of the Republic of Kazakhstan and the Ministry of Water Management of the People's Republic of China on the development of research cooperation on transboundary rivers dated December 20, 2006, Beijing."***

If China annually will take for its own needs at least 30 % of the total Irtysh river flow and 12 % of the Ili river flow, then according to Kazakhstan analysts, this would lead to a large-scale environmental disaster in the downstream areas of Kazakhstan and Russia[15]. In particular, the following negative consequences are predicted for Kazakhstan in the near future:

- in the basin of Lake Balkhash and Lake Zaisan, the ecological balance and natural water balance will be disturbed;
- climate degradation will increase: environmental conditions and epidemiological situation will worsen in the region;
- hazardous substance concentration in water will increase so that the population will not be able to use water;
- electric power production will decrease on the Irtysh river; it is expected to fall by 25 % by 2030 and by 40 % by 2050;
- floodplain meadows will degrade and navigation will stop on the Irtysh river;
- level of the Bukhtarma reservoir will decrease and it will separate from the Lake Zaisan;
- the problems with water supply to coastal settlements will worsen and agricultural yield will decrease.

As a result, the strain in China-Kazakh and China-Russian water relations may increase due to the above-mentioned problems of sustainable use of water resources, and this in the near future may have a negative impact on the socio-economic situation in the regions of Kazakhstan and Russia.

Central Asia is one of the regions with the highest probability of water conflicts. Kazakhstan is a large economic country of Central Asia, and therefore it is important to understand how the country's water management policy affects water availability in other Central Asian states. The economies of the Central Asian countries are already developing in conditions of growing water

[14] Kazakh-Chinese transboundary water cooperation. International Fund for Saving the Aral Sea. Interstate Coordination Water Commission. Science Information Center. http://cawater-info.net/library/rus/legal_36.pdf

[15] Problems of transboundary rivers in the context of Kazakh-Chinese relations, Izimov R.Yu., 21-06-2013 http://cc-sauran.kz/rubriki/politika/39-rivers_rk_knr.html

scarcity which leads to development problems. The main reasons for this are growing political tension and deteriorating socio-economic and environmental conditions.

Although the Central Asian republics have adopted multilateral regional agreements and bilateral agreements on the use of water resources of international watercourses, and they undergo socio-political and economic transformations since the beginning of the 1990-s, including natural resources management systems, nevertheless the regional economic development policy is still based on increasing resource consumption, rather than their reorientation and improvement of efficiency. "Hydrocracies"[16] (water bureaucracies) still hesitate to share decision-making powers with other water management sectors. New water sources are becoming more expensive and scarcer in the region. The efforts to improve water and energy use efficiency at the local and national levels are limited and fragmented. National governments do not properly prioritize biodiversity and ecosystem services – key elements of water resource generation. The risks of delaying the transition to sustainable development are significant. Despite common desire of the countries to benefit for their national interests, it should be borne in mind that only good neighbor relations and amicable cooperation provide a clear way to the improvement of cross-sector coordination and the management not only at the national level, as well as to the resolution of international transboundary issues.

[16] Water Energy Food Environmental Nexus in Central Asia From Transition to Transformation. December 2017
DOI: 10.1007/698_2017_180 In book: The Handbook of Environmental Chemistry (pp.1–18)Chapter: Water Resources in Central Asia: International Context Publisher: Springer International Publishing AG Editors: S.S. Zhiltsov et al
https://www.researchgate.net/publication/321673745_Water-Energy-Food-Environmental_Nexus_in_Central_Asia_From_Transition_to_Transformation

## 1.2 CLIMATE, ENVIRONMENT AND SECURITY IN CENTRAL ASIA

Climate change is projected to accelerate in Central Asia due to continuing global warming. Although the methods used by hydrometeorological services differ between countries, the general idea is that the temperature is expected to rise by about 1–2 degrees Celsius by 2030[17]. One example is the current forecast of water consumption in the Chu and Talas river basins until 2020, which envisages an increase in water withdrawal up to 1195 million cubic meters in the Kazakh part of the Chu river basin, and up to 1048 million cubic meters in the Talas river basin. According to the State Program for Water Resources Management of the Republic of Kazakhstan, even without taking into account the climate change, an annual shortage of water resources is expected in the amount of 1,700 million cubic meters. Climate change impacts could exacerbate the expected water scarcity[18] . It is necessary to find acceptable ways to reduce the volume of water used in agriculture to ensure sufficient environmental flow.

At the same time, the Central Asian countries are to cope with the significant risk of river flooding. River floods mainly occur in spring and summer on the main rivers and their tributaries. Snow and rain rivers tend to flood in spring, while the rivers

**Photo 1. The scale of flooding of the Maktaaral district in the Turkestan oblast of Kazakhstan. (Photo from Kazakh satellites of MDDIAI RoK[19]).**

fed by snow and melting glaciers flood in late spring and summer. Landslides during floods promote backwater through overlapping channels which in case of a breakthrough can suddenly cause large waves. River overflows are most often in the mountainous regions of the Central Asia. River floods in Central Asia have become more common in the last 20–30 years. This is shown by hydrographs of the basins of the largest rivers in the region – Amudarya and Syrdarya.

---

[17] Natural Disaster Risks in Central Asia: A Synthesis. Michael Thurman, UNDP/BCPR, Regional Disaster Risk Reduction Advisor, Europe and CIS. 11 April 2011. http://www.undp.org/content/dam/rbec/docs/Natural-disaster-risks-in-Central-Asia-A-synthesis.pdf

[18] Development of cooperation on adaptation to climate change in transboundary basins of the Chu and Talas rivers, Kazakhstan and Kyrgyzstan. Summary. http://www.unece.org/fileadmin/DAM/env/water/publications/brochure/chu.talas141028-rus-lowres.pdf

[19] MDDIAI RoK – Ministry for Digital Development, Innovation and Aerospace Industry of the Republic of Kazakhstan

Transboundary river systems in Central Asia are strictly regulated by the system of large reservoirs (up to 19 km3 in volume). Thus, flooding of most large rivers is quite as much caused by poor operation and maintenance as by hydrological variability. In May 2020 huge volumes of water flooded the villages in Maktaaral district of the Turkestan oblast of Kazakhstan after the breach of the dam on the Sardoba reservoir in Uzbekistan. The Government declared the man-caused emergency (Photo 1)[20]. 8 Thousand hectares of crop fields were flooded, more than 1030 houses and 15 social facilities (schools, kindergartens, medical and cultural institutions) were damaged. More than 31 thousand people from 14 settlements were evacuated. In Uzbekistan, 90 thousand people had to leave their houses, 4 people died and one was missing during the flood[21]. The upper reaches of the Amudarya river are in particular danger. As the Vakhsh river is the only regulated tributary of the Amudarya, floods often occur between the head of the Amudarya in Tajikistan and the Tuyamuyun reservoir in Uzbekistan.

The lack of consensus among the Central Asian countries regarding the exploitation and maintenance of transboundary waters has led to severe flooding in the lower reaches of the Syrdarya river. The upper reaches of the Syrdarya river basin are known to be the area of preferential hydropower development. The middle and lower parts of the basin where the main irrigation lands are concentrated, constitute the zone of intensive development of irrigated farming. The river delta with adjacent sea waters is an area of fish and animal farming. Due to considerable increase in hydropower generation on the Toktogul reservoir in autumn and winter, water releases during these seasons increased from about 3.2 km3 in the 1980-s to an average of about 7.4 km3 in the 1990-s to km3 in the 2000-s. This exceeded the capacity of river bed and infrastructure in downstream areas, which caused flooding of the Arnasay depression (about 180,000 hectares in the Jizzakh and Navoiy regions, Uzbekistan) and the city of Kzyl-Orda, Kazakhstan. The Koksaray compensating reservoir built in 2008–2011 allows to ensure the population safety in the South Kazakhstan and Kyzylorda regions. The reservoir also controls the water balance of the republic using 3 billion cubic meters of winter runoff accumulated in the compensating reservoir. This water will raise the water level of the Small Aral Sea, eliminate the water losses by discharging into the Arnasay depression. Moreover, this allows to increase the electric power output of Chardara HPP by 20–25 % in winter period, and to improve the environmental situation in floodplain and delta of the Syrdarya river. After the water is released from the basin back into the river in early summer, more than 90 % of the flooded area will be used as estuary fields for forage crops and cattle grazing.[22]

Flooding in Kyzyl-Orda is also the result of precipitation and snowmelt in the steppe. Ice jams along the Syrdarya river make things worse and impede the delivery of water to the Aral Sea. Despite the high degree of uncertainty in the available results of climate models and their associated hydrological models, all analyses show that the runoff and river levels during future floods will be higher and higher.

The Central Asian countries are highly prone to seismic hazards and seismic zones in the region cross the national borders. Seismic services in most countries annually register about 3000 earthquake shocks of various intensity. All Central Asian countries have experienced severe earthquakes over the past 150 years. Most impacts occur at the territory comprising one or more regions and districts within the country.

---

[20] Flood in Maktaaral district. Is Uzbekistan to blame for flooding of Kazakh villages?
May 7, 2020, Zhanna Khabdulkhabar, Anastasia Novikova https://informburo.kz/stati/navodnenie-v-maktaaralskom-rayone-vinovat-li-uzbekistan-v-zatoplenii-kazahstanskih-syol.html

[21] Shavkat Mirziyoyev: the flood is our painful lesson. 05/05/2020. Official website of the President of the Republic of Uzbekistan. https://president.uz/ru/lists/view/3543

[22] Koksaray compensating reservoir – attainment of independence and safety assurance in southern region. December 30, 2011. inform.kz https://www.inform.kz/ru/koksarayskiy-kontrregulyator-dostizhenie-nezavisimosti-i-garantiya-bezopasnosti-yuzhnogo-regiona_a2430103

The secondary effects of earthquakes can be highly destructive, as seismic events can directly trigger or accelerate other hazards, including landslides, mudflows, soil liquefaction, formation of glacial lakes and outburst floods. These secondary effects cause more damages from seismic events.

Landslides are common in the mountainous regions of Central Asia. In this region they are caused by increased steepness of slopes (due to geological processes), seismic events, meteorological and hydrological anomalies, as well as various anthropogenic processes. Most landslides occur in piedmont and mountain areas at an altitude of 1000 to 2400 meters above sea level on the slopes of 19 degrees or more (depending on soil type). They can be hundreds of meters wide and up to 20 meters thick. The number of landslides increased over the past decades due to ongoing geodynamic movements, groundwater rises and increased heavy rainfalls, deforestation, as well as mining and earthworks. Increased groundwater infiltration due to irrigation also contributes to landslides. All these conditions disrupt the stability of slopes in mountain and piedmont areas. Construction of spontaneous and unplanned settlements increased their exposure.

Meteorological hazards in Central Asia include not only floods of various types, but also drought, hail, strong winds and extreme temperatures. They are more frequent than geophysical hazards and occur on a wide scale, from small river basins (floods) to large river basins and considerable parts of regions (severe floods and droughts). Some meteorological hazards have regional implications. Due to ongoing climate change, the glaciers in the region are melting which creates the risk of greater water shortages in future and conflicts across the region. According to CAREC, "a global temperature rise by four degrees will increase the demand for irrigation water by 30 % by 2050. At the same time, temperature rise by two degrees can reduce the area of glaciers by one third, by 4 degrees – by 80 %".[23]

Arid, sharply continental climate of Central Asia often exposes its large areas to meteorological droughty conditions. Drought occurs in one or several regions almost every year (at different times). Severe and widespread meteorological drought (precipitation deficit of 50 % or more) occurs in piedmonts about three times a century, moderate drought (seasonal precipitation deficit of 20–25 %) occurs every three to four years. Droughts are more frequent in desert and semi-desert lowland areas (precipitation deficit of 50 % or more every 10 years; 20 % – every five years). The worst meteorological drought in recent times occurred in Central Asia in 2000–2001, when a precipitation deficit of 30–70 % was observed in most countries, along with above-average temperatures. The areas affected by a widespread meteorological drought expanded beyond the national boundaries, i.e. constituted a regional danger[24].

In connection with the above, the interaction between water, energy and food sectors is fraught with difficulties for development at the national level, and the development of transboundary basins is significantly complicated by a difficult coordination between countries at the regional level.

[23] Environmental specialists assessed the climate change impacts in Central Asia. April 3, 2019. https://uz.sputniknews.ru/society/20190403/11143924/Ekologi-otsenili-posledstviya-izmeneniya-klimata-v-Tsentralnoy-Azii.html

[24] World Bank, 2007. Drought Management and Mitigation Assessment for Central Asia and the Caucasus: Regional and Country Profiles and Strategies. https://reliefweb.int/report/argentina/drought-management-and-mitigation-assessment-central-asia-and-caucasus-regional-and

# 2. GENERAL APPLICATION OF THE NEXUS CONCEPT

Understanding the interrelation of water, energy, food and ecosystem resources is important for decision-making to achieve the overall economic development of countries. “Interrelation-based approach” to managing interdependent resources appeared to meet the contemporary challenges as a way to improve water, energy and food security through raising of efficiency, reduction of compromises, creation of synergies and improvement of management along with protection of ecosystems and taking into account natural and man-made threats to the region.

## 2.1 Scientific Framework of Studying Nexus

In different economic sectors, water is used for different purposes. For example, for energy production at HPPs, or for cooling other types of power plants. At the same time, energy is needed at different stages of water extraction, transportation over considerable distances or elevations, for distribution between consumers and water treatment in order to improve its quality. A real breakthrough is currently being achieved in the use of renewable energy sources, including not only the use of wind and solar energy, but also the expansion of hydropower and biofuels. The agriculture consumes a huge amount of the world's water resources, and in future the water consumption by agriculture is predicted to increase even more. The prospects for agricultural development and food production are significantly limited by available water and land resources which, in turn, depend on the ecosystem stability. It is important to understand that natural ecosystems are quite fragile. At the same time, ecosystems are of great value for development, as they provide ecosystem services not only for water, agricultural and energy sectors, but also conserve the biodiversity of flora, fauna and landscapes, support tourism, promote economic development, facilitate adaptation to climate change and climate change mitigation, but nonetheless they are also endangered.

Increasing energy and food requirements due to population growth, urbanization, industrialization and economic development, as well as climate change are making difficulties in assurance of sufficient water availability and water security. In addition, the load on natural ecosystems increases. “Humanity faces a global challenge to meet common development needs on a long-term sustainable basis, without compromising the functioning of ecosystems.”[25]. This is very difficult to accomplish, as any activities are usually carried out independently in various economy sectors, such as energy, land management and water planning. Analysts should strive to obtain appropriate answers to the following questions: “What will be required from all involved sectors for the planned development?” and “What are the expected consequences of the planned development?”. All of the countries - developing, developed and countries with economies in transition– face insufficient cross-sectoral coordination at both national and transboundary levels.

“Environmental practitioners and policymakers seek ways to promote sustainable growth and at the same time ensure ecosystem health and adaptation to climate change. This implies the balance between the needs of many stakeholders. In a transboundary context, tensions and potential conflicts can lead to strains between sectoral and national issues, unintended consequences due to mismanagement of resources, and negative cross-sectoral interrelations”[26].

---

[25] Alazani /Qanix river basin. Assessment of interrelation between water, food, energy and ecosystems. Prepared by the Royal Institute of Technology (RIT, Stockholm) under the guidance of the Secretariat of UNECE Water Convention. June 19, 2014. http://www.unece.org/fileadmin/DAM/env/documents/2014/WAT/09Sept_8-9_Geneva/Alazani_Ganikh_River_Basin_Water-Food-Energy_-Ecosystems_Nexus_assessment_RUS.pdf

[26] Alazani/Qanix river basin. Assessment of interrelation between water, food, energy and ecosystems. Prepared by the Royal Institute of Technology (RIT, Stockholm) under the guidance of the Secretariat of UNECE Water Convention. June 19, 2014. http://www.unece.org/fileadmin/DAM/env/documents/2014/WAT/09Sept_8-9_Geneva/Alazani_Ganikh_River_Basin_Water-Food-Energy_-Ecosystems_Nexus_assessment_RUS.pdf

Reduction of negative interrelations, creation of synergies, raising of efficiency and improvement of management system in various sectors will help countries to strengthen water, energy and food security and preserve ecosystems. This is the main **"goal of nexus approach to resource management".**

The term **"nexus"** (lat. Nexus - "relation, connection") – has various meanings in different fields, but in general means the central part, the center of any connections considered as a whole.

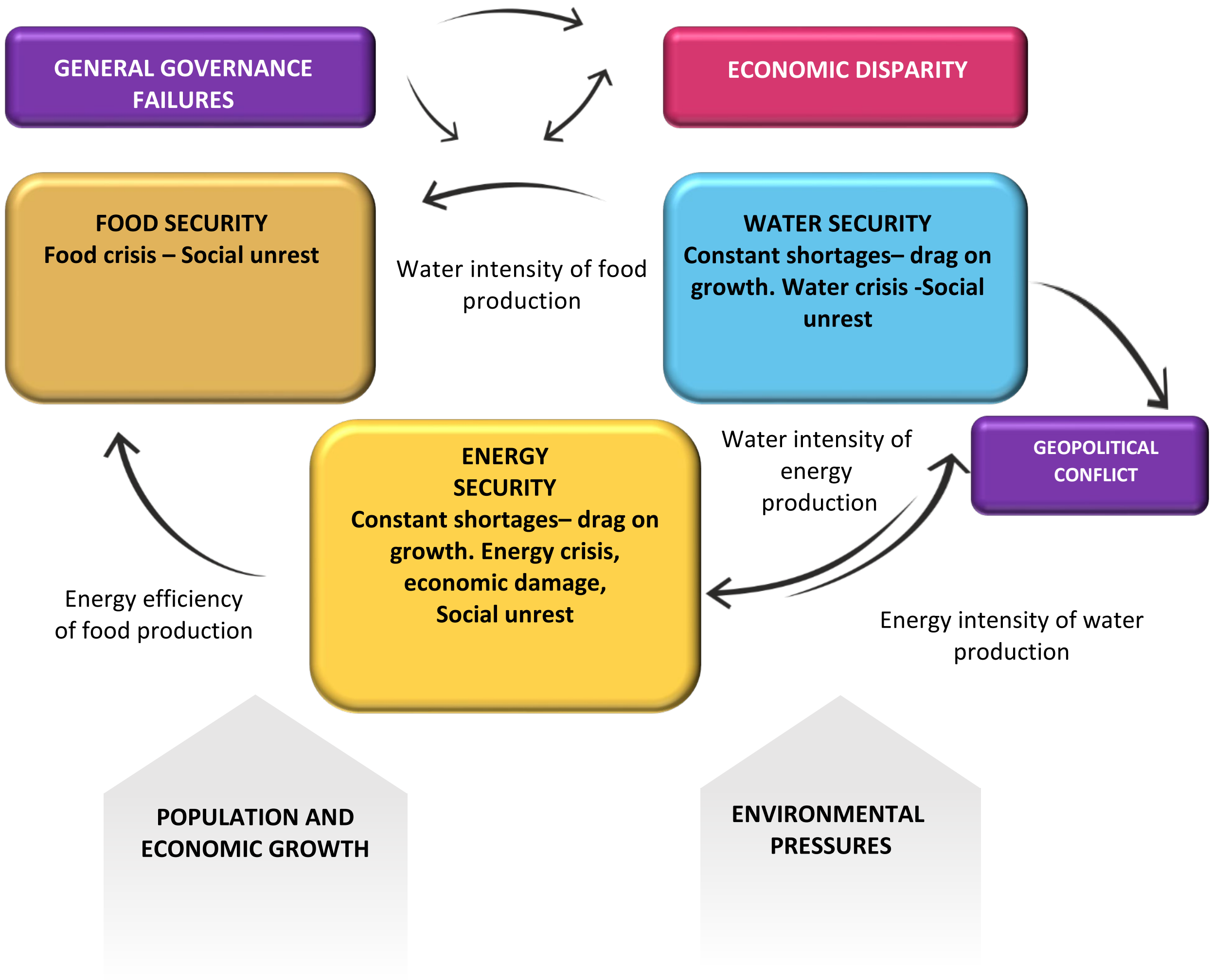



**Figure 1. Interrelation between nexus management and development[27].**

Hereinafter the term **"nexus"** will be viewed in the context of interconnection of resources: water, food and energy within ecosystems and "implies that these sectors are inextricably interconnected in such a way that any actions in one field usually affect the others, and also have an impact on ecosystems"[28].

---

[27] The Water-Energy-Food Nexus: A systematic review of methods for nexus assessment. Tamee R Albrecht, Arica Crootof, and Christopher A Scott. Environmental Research Letters, 13 (2018) 043002. https://doi.org/10.1088/1748-9326/aaa9c6

[28] Alazani/Qanix river basin. Assessment of interrelation between water, food, energy and ecosystems. Prepared by the Royal Institute of Technology (RIT, Stockholm) under the guidance of the Secretariat of UNECE Water Convention. June 19, 2014. http://www.unece.org/fileadmin/DAM/env/documents/2014/WAT/09Sept_8-9_Geneva/Alazani_Ganikh_River_Basin_Water-Food-Energy_-Ecosystems_Nexus_assessment_RUS.pdf

The study of nexus is rapidly spreading in the scientific literature and policies as a new way of solving the complex relationships of resources and development issues.

The existing portal of the "Global Nexus Secretariat"[29] proclaims its mission to promote the nexus approach for fundamental transition from a purely sectoral approach to solutions covering cross-sectoral, coordinated and integrated approaches. The portal highlights the following key benefits of the nexus approach:

1. Increasing the resource productivity by promoting synergies across the three sectors.
2. Protecting and strengthening natural ecosystems with the nexus-based solutions.
3. Promoting multipurpose investments to achieve stable solutions.

The approach based on nexus analysis is aimed at identifying compromises and synergies between water, energy and food systems, taking into account social and environmental impacts, guided by the development of cross-sector policy. Although understanding of interconnection between water, energy and food systems suggests a promising conceptual approach, the use of nexus methods for system assessment of synergies between water, energy and food resources and for development and support of socially and politically significant resource policies, is very challenging. This approach requires consideration of various methods for studying the nexus of water, energy and food systems in order to provide a basic knowledge of existing approaches and to facilitate further development of analytical methods.

In 2018 a systemic review[30] of 245 magazine articles and book chapters was conducted. The review showed that the challenging problems of the resource and development nexus requires the mixed methods and transdisciplinary approaches which include social and policy aspects of water, energy, land resources and food, and needs the involvement of all stakeholders and decision makers of the analyzed region.

While the analytical approaches to assessment of water-energy-food nexus are based on different disciplines and show the need to use numerous and various analytical tools. Many approaches combine multiple methods. The most commonly used methods were from environmental management and economy. Environmental management methods were used in 60 % of the studies; economic instruments were used in 45 % of the studies. Researchers also found a wide range of social science methods (e.g. institutional analysis, Delphi method[31], agent-based modeling[32], joint workshops) at least one of which was used in 26 % of the studies.

It is necessary to develop a basic knowledge of the methods of interrelation between water, energy and food systems which demonstrate a conceptual approach to the solution of inherent complexity of the nexus. Integrated models, economic instruments and environmental management approaches have been found to be predominant methods of studying the nexus, and while these established methods offer many useful approaches, new perspectives are needed that expand our understanding of the interactions and independence of water, energy and food systems. Specifically designed for nexus analysis, such methods should also take into account the social and policy context of water, energy and food systems to achieve optimal solutions.

---

[29] https://www.water-energy-food.org/

[30] The Water-Energy-Food Nexus: A systematic review of methods for nexus assessment. Tamee R Albrecht , Arica Crootof and Christopher A Scott. Environmental Research Letters, 13 (2018) 043002. https://doi.org/10.1088/1748-9326/aaa9c6

[31] Delphi method – a quick search for solutions based on their generation during "brainstorm" by a group of specialists, and selection of the best solution based on expert assessments. The Delphi method is used for expert forecast by organizing a system for collection and mathematical processing of expert assessments.

[32] Agent-based modeling includes the elements of game theory, complex systems, multiagent systems, etc.

The nexus concept can be used more effectively as an analytical tool by using the approaches described in "Water-Energy-Food Nexus: System review of nexus assessment methods"[33] which take into account four key features: i) innovation, ii) socio-political context, iii) cooperation; and iv) feasibility of policy implementation and practical application.

To understand physical and social aspects of water, energy and food systems, interdisciplinary and mixed approaches are required that combine quantitative and qualitative methods from various disciplines. The contribution of social sciences to this issue is significant, especially for understanding the social and political context of water-energy-food nexus and obtaining feedback to ensure resources use efficiency, policy integration and sustainable development.

Nexus methods and tools should be available to both researchers and practitioners. They have to take into account many drivers and aspects of water-energy-food nexus and support various approaches in order to help find innovative ways to study the interrelation between water, energy and food systems, take into account the local context, facilitate cooperation and addressing of political agenda and support of practical implementation. It is crucially important to develop approaches that provide useful and relevant information for management and coordination of cross-sectoral policies.

Nexus assessments are best linked to the policy outcomes, based on various basic knowledge and active involvement of both stakeholders and decision-makers.

In general, although the water-energy-food nexus offers a promising approach to solve of challenging problems related to resources and development, it requires more detailed further methodological development that will be more effective as a politically significant approach.

[33] The Water-Energy-Food Nexus: A systematic review of methods for nexus assessment. Tamee R Albrecht, Arica Crootof and Christopher A Scott. Environmental Research Letters, 13 (2018) 043002. https://doi.org/10.1088/1748-9326/aaa9c6

## 2.2 Global Policy Framework for Promotion Nexus for Sustainable Development

"2030 Agenda for Sustainable Development" (2030 Agenda) adopted by the UN General Assembly in 2015, includes 17 Sustainable Development Goals (SDGs) and 169 targets each aiming at encouraging particular actions over a 15-year period (Box 2). The overarching goal of the 2030 Agenda is to create a more fair, peaceful and prosperous global society by balancing the three inherent aspects of sustainable development, namely economy, society and environment.

SDGs cover a wide range of topics and issues, thus interrelating the various goals. No goal can be achieved separately, but only together with other goals. The interconnected nature of SDGs requires a holistic, multi-sectoral and multidimensional approach to their implementation. Since nowadays administrative structures are largely based on separate industry-specific policies, this approach challenges traditional processes and requires various sectors to drive for synergy between their individual industry-specific development plans and at the same time search for compromises that will inevitably occur.


***Box 2*** **Global Sustainable Development Goals[34].**

Thus, the nexus concept is well suited for informing of the actions and policies in support of SDGs. Key resource management sectors, such as energy and agriculture are vital components in terms of overall strategy and planning in view of the 2030 Agenda and can greatly benefit from using the nexus approach.

[34] https://sdgs.un.org/ru/goals

| Number and description of interacting SDGs | Description of interrelation |
|---|---|
| 2.4 Improving the sustainability of food production<br>7.2 Significantly increase the share of renewable energy | Agricultural products and waste can serve as sustainable energy sources. |
| 7.2 Significantly increase the share of renewable energy<br>2.3 Twofold increase of agricultural production | Increased agricultural activity (irrigation, fertilizers, machinery) requires significant energy consumption. |
| 2.3 Twofold increase of agricultural production<br>6.4 Solving the problem of water use efficiency and water scarcity | Increased agricultural production (irrigation) requires improved water use efficiency. |
| 2.3 Twofold increase of agricultural production<br>6.3 Improving water quality by abatement of pollution | Increased agricultural activity (fertilizers, pesticides) affects water quality. |
| 7.2 Significantly increase the share of renewable energy<br>6.1, 6.2 Increase in water supply and development of sanitary infrastructure | Development of water and sanitation infrastructure requires energy (pumping and purification). |
| 7.2 Significantly increase the share of renewable energy<br>6.6. Protecting and restoring water-related ecosystems | Energy production (hydropower, cooling) affects water-related ecosystems. |
| 15.3 Desertification control and land restoration<br>6.5 Implementation of IWRM at all levels, including transboundary cooperation | Water resources management can exacerbate desertification. |
| 6.5 Implementation of IWRM at all levels, including transboundary cooperation<br>15.1 Preserve, restore and promote the sustainable use of land and freshwater ecosystems | Water management directly impacts freshwater ecosystems. |
| 15.1 Preserve, restore and promote the sustainable use of land and freshwater ecosystems<br>6.6. Protecting and restoring water-related ecosystems | Both goals aim to protect water-related ecosystems. |
| 15.1 Preserve, restore and promote the sustainable use of land and freshwater ecosystems<br>6.3 Improving water quality by abatement of pollution | Although growing agricultural production (land use) affects ecosystems, it also depends on functioning ecosystem services. |
| 15.1 Preserve, restore and promote the sustainable use of land and freshwater ecosystems<br>7.2 Significantly increase the share of renewable energy | Energy production (all resources and technologies) has a major impact on ecosystems. |
| 15.3 Desertification control and land restoration<br>*2.4 Improving the sustainability of food production* | Sustainable agriculture preserves ecosystems and restores land. |
| *2.4 Improving the sustainability of food production*<br>6.5 Implementation of IWRM at all levels, including transboundary cooperation | Sustainable agriculture influences the water management methods. |

**Box 3 Description of interrelation between various Sustainable Development Goals.**

"The same applies to specific goals for climate change mitigation and adaptation in accordance with the Paris Agreement adopted under the United Nations Framework Convention on Climate Change (UN FCCC), to benefit greatly from the nexus approach.)"[35]

Four SDGs are of particular relevance to the nexus under the Water Convention: SDG 6 "Clean Water and Sanitation" which includes integrated water resources management and improved transboundary cooperation beyond rivers; SDG 2 "Zero Hunger" which includes achieving food security and promoting sustainable agriculture; SDG 7 "Affordable and Clean Energy" which includes ensuring access to sustainable energy for all; and SDG 15 "Life on land" which includes protection, restoration and sustainable management of ecosystems.

While each of the 17 SDGs is linked to many other goals and targets, the four goals outlined above are particularly strongly interrelated. Actions taken for one of these four goals are likely to have direct impacts on one or all of the other goals. There are numerous links between these goals which

[35] Central Asia Nexus Dialogue Project: Fostering Water, Energy and Food Security Nexus Dialogue and Multi-Sector Investment. Ideas of WEF Nexus projects. Investment Portfolio https://carececo.org/publications/nexus/RUS_Investment_Portfolio_Nexus.pdf

as such is an indirect appeal for a nexus approach to promoting the sustainable development (Box 3 describes these links in more detail).

## 2.3 Nexus in the Central Asian Management Context

The United Nations Special Program for the Economies of Central Asia (SPECA) is one of the priority programs of the United Nations in the region. As stated in the SPECA Concept, its main goal is "to mobilize additional internal and external resources to address priority issues for all participating countries, which can be resolved more effectively by joint efforts of the region countries rather than on a national basis."

With regard to the Water, Energy and Environment Strategy, SPECA[36] at its 22-nd session (in 2018) proposed to explore the possibilities for development of a new SPECA strategy on water, energy and environment, taking into account the SDGs and reflecting the new development tasks in the SPECA region, having considered the following possible specific goals of this strategy:
(i) improve availability of information and exchange of national practices and experience in implementation of SDG 6 and SDG 7;
(ii) raise awareness of the nexus between water, energy and environment issues relevant to SDG 6 and 7;
(iii) joint development of policies, strategies, and support of specific mutually beneficial activities related to SDG 6 and 7.

Thus, SPECA creates framework prerequisites for further promotion of the nexus approach in the Central Asian region, which can draw on some positive experience, such as a transboundary diagnostic analysis (TDA) in the Chu and Talas river basins. Thorough diagnostics helps to better solve complex problems, as well as better understand the root causes of socio-economic trends or industry-specific policies.

Climate change further enhances the value of the nexus approach as it provides for the opportunities for adaptation and mitigation of climate change. TDA can be further supported and supplemented by integration with the nexus approach[37]. These rivers are the main sources of water in the Chu and Talas regions of the Kyrgyz Republic and the Zhambyl region of Kazakhstan.

The emerging problem of water scarcity can lead to irrigation water deficit, reduction in yields, reduced income of the people engaged in crop and livestock farming, reduction in fishing, deterioration of meliorative condition of irrigated lands, as well as lack of environmental flows, which ultimately can result in the loss of riparian woodland in the lower reaches of river basins and increased desertification processes.

Deteriorating water quality in the Chu and Talas river basins is becoming an increasingly significant problem for both countries due to economic development, population growth requiring more and more water consumption. The main causes of water pollution in the Chu and Talas river basins are discharges of untreated or poorly treated municipal wastewater. By joint efforts of two main water departments of Kazakhstan and Kyrgyzstan, thanks to a considerable support by international organizations and financial institutions, a stable coordination structure was created in July 2006 which included the Chu-Talas Water Commission (CTWC, Commission), its permanent secretariat and expert working groups. The Commission was created to implement the "Agreement between the Government of the Republic of Kazakhstan and the Government of the

[36] Report. United Nations Special Programme for the Economies of Central Asia (SPECA) 23rd Session of the Working Group on Water, Energy and Environment. 2 October 2019, Tashkent, Uzbekistan.
https://www.unece.org/fileadmin/DAM/env/Projects_in_Central_Asia/Report_23rd_Session_SPECA_WG_WEE_2019_Tashkent_final_ENG.pdf
[37] See an example in subsection 4.5. Summary of the nexus assessment of the Drin River Basin

Kyrgyz Republic on the use of interstate water facilities on the Chu and Talas rivers" signed on January 21, 2000[38]. In May 2018, a delegation from Kyrgyzstan visited Croatia to learn more about the activities of the International Sava River Basin Commission using the nexus approach[39].

Since 2019, the Regional Environmental Centre for Central Asia (CAREC) publishes a bulletin[40] for capacity building in Central Asia. The bulletin was prepared under the "Central Asia Nexus Dialogue Project: Fostering Water, Energy and Food Security Nexus Dialogue and Multi-Sector Investment"[41]. This bulletin is a collection of short articles to introduce to the concept of "water-energy-food security" nexus, from its theoretical and conceptual perspective to practical application at various levels and scales, aimed at achieving multi-sector mutually beneficial solutions.

## 2.4 Nexus Solutions

The "Concept of Nexus approach"[42] is rooted in the idea of a strong need **to make sectoral and national policies more consistent** in order to reduce conflicts in resource management and approve its multiple uses. Policy coherence may be enhanced **through intersectoral communication, active coordination and comprehensive planning, due consideration of various interests, approval of compromises, up to maximum synergies and cooperation in achieving common goals.** It should be noted that policy coherence is a prerequisite for effective measures to combat climate change, which requires multi-sectoral activities (energy, food, environmental protection, etc.) at multiple levels (from global to local and transboundary).

**Policy coherence may bring economic benefits by promoting synergies and partnerships** which, in turn, **stimulates co-investments**: using public and private funds, with participation of multiple sectors and multiple countries. In transboundary context, increasing trust between riparian countries is essential in terms of **reducing political risks for investors**. Cross-border cooperation in the field of investments also envisages consideration of various interests and issues, more **efficient placement of investments**, and harmonization of environmental requirements.

Increasing benefits from a single project (e.g. multipurpose infrastructure; improving efficiency of water, land and energy use thanks to the innovative solutions) is the most practical way to promote the simultaneous achievement of multiple goals. However, without a consistent strategic basis for consultation processes and planning systems that support integration, it will be difficult to scale up or replicate this type of investments.

The governments of various countries and the various institutions participated in dialogues and assessments of the nexus undertaken under the Water Convention and by partner organizations around the world. But despite this experience, there is still a lack of convincing examples (including due to poor awareness and dissemination of information) demonstrating tangible advantages of the approaches (to policy development and investment planning) based on the nexus system as compared to the traditional sectoral approaches.

---

[38] Transboundary cooperation in the Chu and Talas river basin. https://www.unece.org/ru/env/water/centralasia/chutalas/ru.html
[39] See below section 4.3 Summary of the nexus assessment of the Sava and Drina river basins.
[40] BULLETIN NEXUS No. 1. CAREC. 04/12/2019. https://carececo.org/main/ckh/publications/byulleten-neksus-1/
[41] Funded by the European Union and the German Federal Ministry for Economic Cooperation and Development (BMZ) and implemented by CAREC in partnership with the International Union for Conservation of Nature (IUCN) and with the support of the Executive Committee of the International Fund for Saving the Aral Sea.
[42] Concept note. The Task Force on interrelation between water, food, energy and ecosystems. Sixth Session. The Palace of Nations, Geneva, Switzerland / virtual participation via Interpfy platform. October 22–23, 2020. http://www.unece.org/fileadmin/DAM/env/documents/2020/WATER/09Sep30-2Oct_15th_IWRM/INF.12_6th_Nexus_TF_ConceptNote_final_RUS.pdf

The nexus approach should result in the development of “interconnected solutions”[43] that will improve the efficiency of resource use and reconcile different interests, and at the same time ensure the protection of water resources and environment and the achievement of maximum social value from investments. However, in many cases, the practical application of these solutions in cross-sectoral and transboundary contexts may be fraught with difficulties. In this regard, many questions remain open: “Who should develop these solutions and how?”, “What are the costs and benefits?”, “What institutional frameworks (especially in transboundary basins) are needed to support their implementation?”, “What are the funding sources and investment mechanisms?”. And last but not least: “What can we learn from the experiences of national governments and other key stakeholders who participated in dialogues on and assessments of the nexus approach?”.

[43] As regards the assessments of the nexus system under the Water Convention, a “5 I-s” framework has been developed that combines decisions as follows: (i) Institutions, (ii) Information, (iii) Instruments, (iv) Infrastructure, and (v) International coordination and cooperation.

# 3. BACKGROUND FOR DEVELOPMENT OF AN ASSESSMENT METHODOLOGY FOR WATER, ENERGY, FOOD AND ECOSYSTEM NEXUS

## 3.1. ASSESSING NEXUS BASED ON INDICATORS[44]

The use of qualitative methods, publicly available data and quantitative simulation allows to assess the nexus. "This approach consists in identification of key indicators of nexus unreliability which can be reduced and/or turned into joint opportunities".

An overview of the situation existing in the country, based on the questionnaires, allows to perform a preliminary analysis of interrelations. Carefully developed questionnaires are based on the data provided by national respondents as well as any quality descriptive information available. Quality is guaranteed by the specialists involved in the analysis, who provide preliminary review of the issues to be considered in the countries of the transboundary basin. In future, with the involvement of a wider range of stakeholders and decision-makers in the countries of the transboundary basin, the preliminary analysis of interrelations is further detailed and considered.

Later, at advanced stages of the nexus assessment, various models may be used. For example, "WEAP[45] and LEAP[46] integrated in SEI[47]; water management model implemented by SIWI[48], as well as Strategic Environmental Assessment (SEA), approaches initiated by the European Union and the World Bank, supplemented by detailed consultations of stakeholders at various stages. The international legal framework for SEA provided by the SEA Protocol of the UNECE Convention on Environmental Impact Assessment in a Transboundary Context (Espoo Convention), encourages individual states parties to include environmental assessment in their plans and programs, and provides for broad public participation in government decision-making".[49]

Basing on available financial resources and intentions, it is possible to apply the nexus assessment to various basins of transboundary watercourses by using the advisory methodology of nexus assessment[50] described below. This approach allows the countries of a specific macroregion to establish good partnerships with each other and is based on a diagnostic analysis using various available indicators. In addition, this system is supplemented with the information obtained from questionnaires, as well as from publicly available databases.

Moreover, the focus is on the dialogue of macroregion stakeholders, which allows to:

(i) conduct a joint analysis of these indicators and information,
(ii) develop an agreed assessment and
(iii) explore alternative approaches to searching for compromises.

This approach can facilitate better cooperation, confidence-building, further collaboration in fact-finding and in-depth assessment at advanced stages of the process.

---

[44] Approach proposed to assess the interrelation between water, food, energy and ecosystems under the UNECE Water Convention. Discussion document. April 4, 2013. Prepared by the UNECE Secretariat with the participation of Finland, Food and Agriculture Organization of the United Nations (FAO), Stockholm Environment Institute (SEI), and Stockholm International Water Institute (SIWI). http://www.unece.org/fileadmin/DAM/env/documents/2013/wat/Nexus_mtg/RU_nexusAssessmentApproach_forWeb_final.pdf

[45] WEAP – Water Evaluation and Planning System.

[46] LEAP – The Long-range Energy Alternatives Planning System.

[47] SEI – Stockholm Environment Institute.

[48] SIWI – Stockholm International Water Institute.

[49] Purkey, D. (2012): Integrated water-energy-emissions analysis: Applying LEAP and WEAP together in California. Stockholm Environment Institute – Policy Brief; Granit, J. & Joyce, J. (2012). Options for cooperative action in the Euphrates and Tigris Region. Paper 20, Stockholm: SIWI.; Granit, J., King, R. M. & Noël, R. (2011). Strategic Environmental Assessment as a Tool to Develop Power in Transboundary Water Basin Settings. International Journal of Social Ecology and Sustainable Development. 2(4), 1–11, October–December 2011. IGI Publishing.

[50] see 3.2. CONSULTATIVE METHODOLOGY OF NEXUS ASSESSMENT.

## 3.2. CONSULTATIVE METHODOLOGY OF NEXUS ASSESSMENT[51]

"Review of transboundary water condition in the region by the United Nations Economic Commission for Europe (UNECE)" prepared under the "Convention on the Protection and Use of Transboundary Watercourses and International Lakes" ("Water Convention") in 2011 is the so-called "Second assessment of transboundary rivers, lakes and groundwaters."

The review "evaluates load factors of transboundary waters, implemented measures and current trends". We can see a weak integration and a lack of policy coherence in the UNECE region. It was revealed that many transboundary basins are characterized by conflicts between consumers, and this situation forces the conflicting countries to seek compromises in challenging political and socio-economic conditions.

The "Second assessment" showed that ever-increasing water demand without due regard to the principles of sustainable development in various economy sectors is a challenging problem, in view of growing population and climate change impact. Therefore, it is extremely important to gain a better understanding of the interrelation between water, food, energy resources and related ecosystems of river basins to enhance cooperation and policy coherence between water, agriculture, energy and land management.

In transboundary basins, the nexus assessment between various sectors is highly relevant. If the issue of cross-sectoral interrelation is actively addressed, they can achieve interaction and find solutions, which will reduce the number of challenging situations and potential conflicts, enhance sustainable development. Based on the recommendations of the Water Convention, a proposal was prepared for **"specific" nexus assessment of water, food, energy and ecosystems**. The original concept was developed at the "Strategic Workshop on Future Work under the UNECE Water Convention: Building on the findings of the Second Assessment and other results achieved" (Geneva, February 14–15, 2012). Subsequently, in order to analyze the comments made during the joint meeting of the Working Group on Monitoring and Assessment and the Working Group on Integrated Water Resources Management (Geneva, July 3–4, 2012), the participating countries supported the proposal to develop a "specific" nexus assessment of water, food, energy and ecosystems. Initial data was obtained from consultations with potential partners, and comments were obtained at the sixth session of the Meeting of Parties to the Water Convention (Rome, November 28–30, 2012). Recognizing the importance of such interrelations, the sixth session of the Meeting of Parties approved development of the concept of nexus assessment of water, food, energy and ecosystems in certain transboundary basins[52] and included this in its work plan for 2013–2015. By the end of January 2013, the Parties to the Water Convention invited the states and authorities of the shared transboundary basins in order to obtain the parties' consent to participate in the nexus assessment process. Proposals for nexus assessment of various basins were received and summarized in an annex to the agreed document. The Meeting of Parties has established the "Task Force on the Nexus of Water, Food, Energy and Ecosystems" to prepare

[51] Approach proposed to assess the nexus of water, food, energy and ecosystems under the UNECE Water Convention. Discussion document. April 4, 2013. Prepared by the UNECE Secretariat with the participation of Finland, Food and Agriculture Organization of the United Nations (FAO), Stockholm Environment Institute (SEI), and Stockholm International Water Institute (SIWI). http://www.unece.org/fileadmin/DAM/env/documents/2013/wat/Nexus_mtg/RU_nexusAssessmentApproach_forWeb_final.pdf

[52] Economic Commission for Europe Meeting of the Parties to the Convention on the Protection and Use of Transboundary Watercourses and International Lakes. Sixth session, Rome, 28–30 November 2012. http://www.unece.org/fileadmin/DAM/env/water/mop_6_Rome/Official_documents/ECE_MP.WAT_2012_L.1_e.pdf

guidelines for such assessment. The adopted concept of nexus assessment also included an estimate of resource requirements for its implementation"[53].

[53] Approach proposed to assess the interrelation between water, food, energy and ecosystems under the UNECE Water Convention. Discussion document. April 4, 2013. Prepared by the UNECE Secretariat with the participation of Finland, Food and Agriculture Organization of the United Nations (FAO), Stockholm Environment Institute (SEI), and Stockholm International Water Institute (SIWI). http://www.unece.org/fileadmin/DAM/env/documents/2013/wat/Nexus_mtg/RU_nexusAssessmentApproach_forWeb_final.pdf

## 3.3 GOALS, KEY PRINCIPLES AND LIMITATIONS OF THE NEXUS ASSESSMENT METHODOLOGY FOR WATER, FOOD, ENERGY AND ECOSYSTEMS

The development of specific methodology for nexus assessment of water, food, energy and ecosystems was based on active interaction with all participants, included direct practical learning and led to the creation of a very **flexible structure** which is easily adapted to any environmental changes.

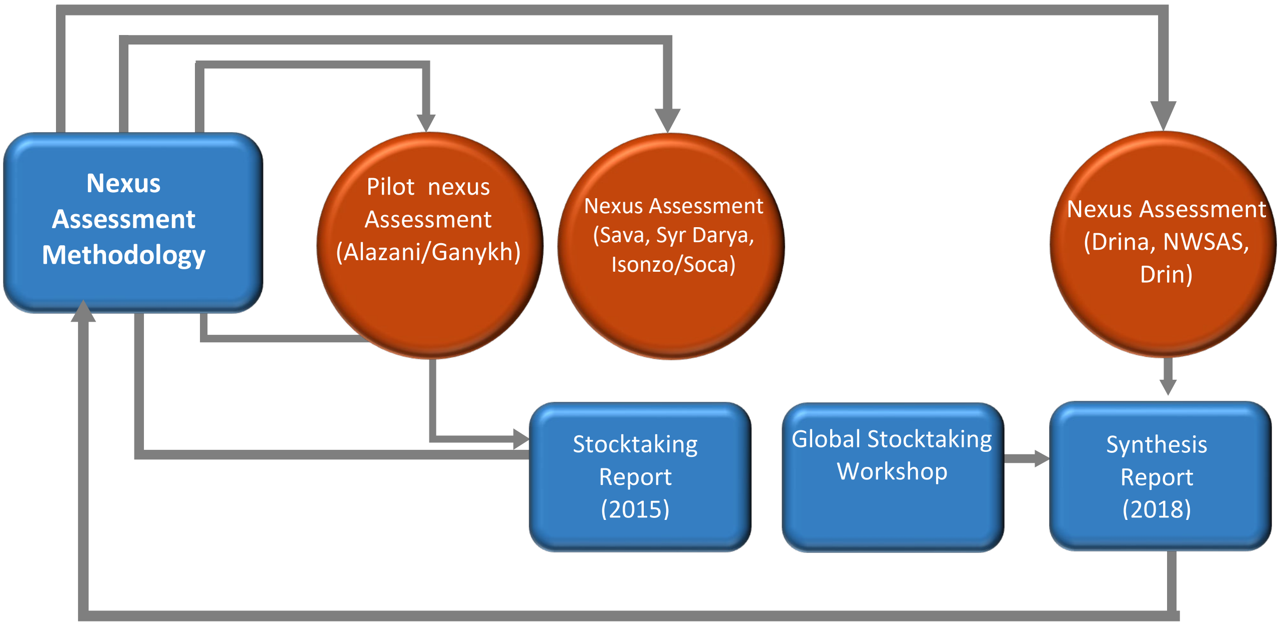



**Figure 2. Iterative process[54] of development of the nexus assessment methodology[55].**

The first version of the nexus assessment methodology was developed in 2013–2015[56] with the participation of key experts from the Royal Institute of Technology (RIT, Stockholm) and based on the comments on its first use in a number of representative transboundary basins in Southern Europe, Caucasus and Central Asia. From 2016 to 2018, the nexus assessment methodology was improved with additional assessments (including the first aquifer in North Africa[57]) and ever-increasing multidisciplinary approach (see Figure 2).

In the course of all basin assessment processes, about 300 officials, experts and other key stakeholders contributed directly or indirectly to the formation of the nexus assessment methodology. The nexus assessment in transboundary river basin is a participatory process based

[54] Iterative process allows to easily make changes, receive comments and suggestions and take them into account in the project, reduce risk in advance and dynamically adjust the process.

[55] A nexus approach to transboundary cooperation. The experience of the Water Convention. UNECE. https://www.unece.org/fileadmin/DAM/env/water/publications/WAT_NONE_12_Nexus/SummaryBrochure_Nexus_Final-rev2_forWEB.pdf

[56] A proposed approach to assessing the Water-Food-Energy-Ecosystems Nexus under the UNECE Water Convention Discussion paper. 4 April, 2013. https://www.unece.org/fileadmin/DAM/env/documents/2013/wat/Nexus_mtg/NexusAssessment_DiscussionPaperOnApproach_final_forWeb.pdf

[57] First Regional Consultation Workshop: Assessing the Water-Food-Energy-Ecosystems Nexus in the North-Western Sahara Aquifer/ 18 - 19 July 2017. https://www.unece.org/environmental-policy/conventions/water/meetings-and-events/water/workshops-water-convention-and-protocol-on-water-and-health/2017/first-regional-consultation-workshop-assessing-the-water-food-energy-ecosystems-nexus-in-the-north-western-sahara-aquifer/doc.html

on an ongoing exchange of information between the analysts performing the assessment and all stakeholders involved in the process. In addition, during assessment it was necessary to collect, process, analyze and discuss a large amount of various materials (including opinions of various sectors and countries).

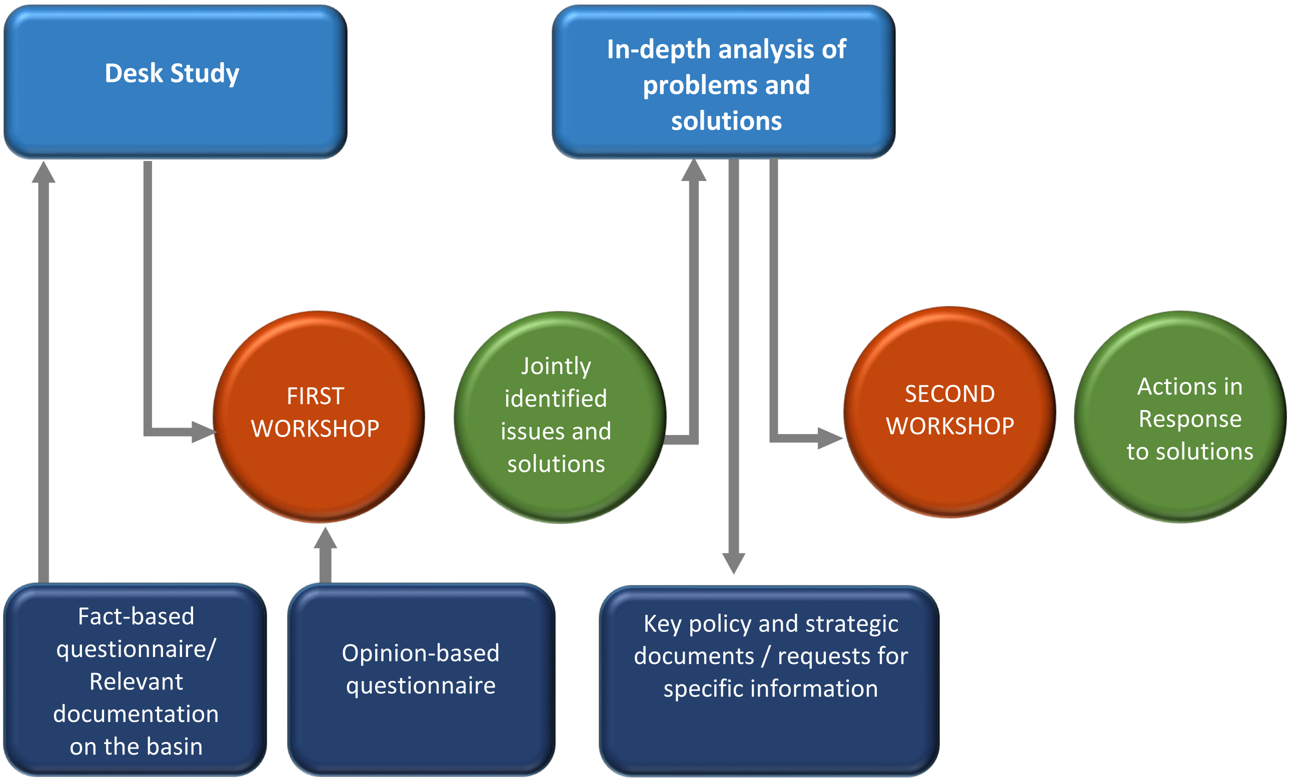



**Figure 3. Process of development and participation in the nexus assessment methodology**[58]

The **ultimate goal** of the joint nexus assessment process is to collect a wide range of responses to pressing common problems that are jointly defined by a representative group of stakeholders from key sectors from all riparian countries in the transboundary basin (see Figure 3).

To involve all participants in the joint process, workshops were used that represent a platform for direct consultations and, most important, intersectoral transboundary dialogue.

**The workshops** were specially designed to hear all interested sectors, facilitate dialogue with stakeholders and discuss possible solutions and associated benefits based on analysis.

Based on the experience with previous assessments, and in view of the nature and purpose of work under the Water Convention, the following key principles underpin the approach to development of the nexus assessment[59]:

I. **Participation in process** – i.e. participation of a representative number of Parties to the Water Convention and non-Parties, as well as representatives of relevant sectors and stakeholders in the process that encourages connectedness and meaningful participation of

[58] A nexus approach to transboundary cooperation. The experience of the Water Convention. UNECE. https://www.unece.org/fileadmin/DAM/env/water/publications/WAT_NONE_12_Nexus/SummaryBrochure_Nexus_Final-rev2_forWEB.pdf
[59] Approach proposed to assess the interrelation between water, food, energy and ecosystems under the UNECE Water Convention. Discussion document. April 4, 2013. Prepared by the UNECE Secretariat with the participation of Finland, Food and Agriculture Organization of the United Nations (FAO), Stockholm Environment Institute (SEI), and Stockholm International Water Institute (SIWI). http://www.unece.org/fileadmin/DAM/env/documents/2013/wat/Nexus_mtg/RU_nexusAssessmentApproach_forWeb_final.pdf

all participating countries and organizations. The opinions of stakeholders are taken into account through joint identification of intersectoral relations, through dialogues at the workshop and through follow-up consultations and discussions. National administrations of riparian countries work together on assessments, which not only complies with the spirit of cooperation of the Water Convention, but also guarantees an ownership.

II. **Mobilization of knowledge** from participating countries in various economy sectors and experience of resource use; as well as management supplemented by international expertise if necessary. The nexus assessment methodology is developed so as to make the most of local knowledge, data and previous experience, and combine these elements for use in nexus assessment.

III. **Reliable scientific analysis** – the nexus assessment is based on technically sound analysis, available knowledge and understanding of the scope of available resources. Analytical work improves the quality of assessment, the results, and provides critical information for policy development, decision making and cooperation.

IV. **Capacity building** to support mutual learning across river basins, sectors and states, thus facilitating the experience exchange and strengthening of local cooperation at the basin level. Application of the methodology in the nexus assessment should help the authorities of riparian countries and other key stakeholders, firstly, to gain a better understanding of interrelations within their river basin (or aquifer) and, secondly, to gain experience and awareness of more sustainable management of natural resources.

V. **Collective effort**, thanks to encouraging the participation of all parties, the methodology allows to create the nexus assessment that reflects a wider range of views and experiences.

VI. **Benefits and Solutions** – the methodology is focused on the benefits of cooperation and therefore allows to reach constructive solutions through discussions aimed at mobilizing broad support.

For analysts, the entire **process of nexus assessment** of transboundary basins consists of **six successive stages**[60]:

**Stage 1**: identify the population's needs for the basin, as well as national needs that depend on the basin. This develops understanding of socio-economic condition of the basin, its resource base and management structure.

**Stage 2**: identify the needs of existing sectors and institutions. In this way, key sectors and stakeholders are identified that can contribute with their knowledge and influence on subsequent actions.

**Stage 3**: analyze the key sectors by using the cause-effect relationship "aspiration-pressure-state-impact-response". Further refinement of analysis is carried out jointly at the workshop.

**Stage 4**: detail the issues across sectors when considering the industry-specific plans and links with other sectors during direct discussions at the workshop.

**Stage 5**: jointly generate the interrelation diagrams that include the components of nexus assessment of water, food, energy, ecosystems, and other identified interrelations. This work is carried out during "brainstorming" in groups and summarized in a workshop.

[60] The Nexus Methodology. UNECE. https://www.unece.org/environmental-policy/conventions/water/areas-of-work-of-the-convention/envwaternexus/the-nexus-methodology.html

**Stage 6**: discuss and identify possible solutions to the most pressing cross-sectoral issues. Stakeholders offer various solutions, such as land use management, cooperation agreements, political decisions, infrastructure projects or economic instruments.

The first three assessment stages (1–3) are basically diagnostic and largely based on desk work (with a limited contribution and participation of local authorities and coordinators, as needed);

The next three stages (4–6) relate to priority issues and require a higher level of direct interaction between stakeholders (see Figure 4).

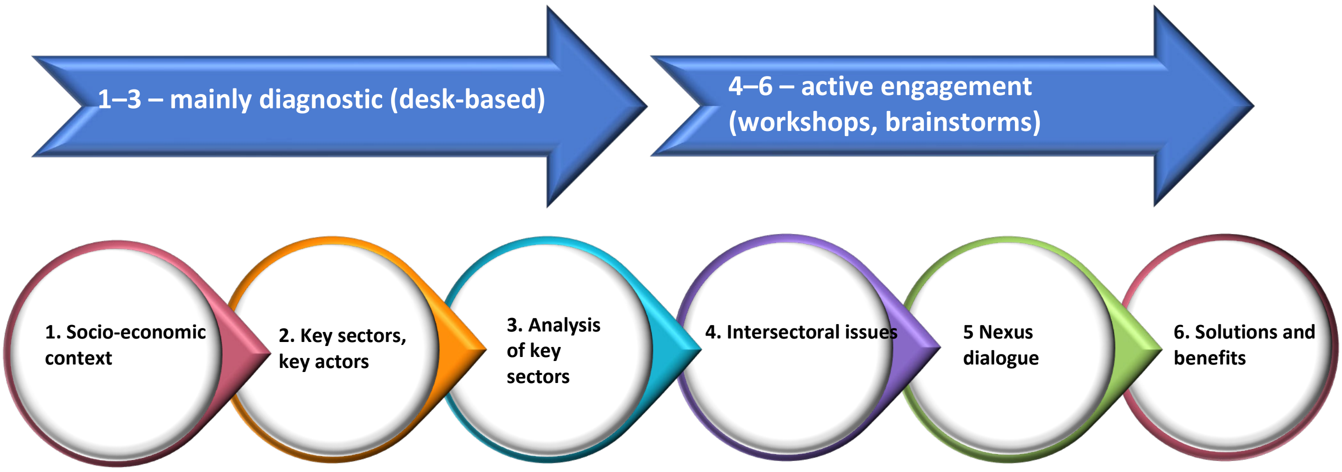



**Figure 4. Six stages of the nexus assessment methodology for transboundary basin[61].**

**Joint method** of nexus assessment involves consultations with authorities and key stakeholders at various stages of assessment process. In fact, **effective participation** can be a decisive factor in ensuring the relevance of findings and acceptance of the results by the parties involved.

The **key participation techniques** used in the methodology are:

- mapping stakeholders, key sectors and participating parties;
- questionnaires for preliminary factual information;
- opinion-based questionnaires to identify different views;
- "brainstorming" to identify interrelations; and
- dialogue to develop a common understanding of the interrelations by all parties.

Analytical work is built on two inter-complementary areas: **technical analysis and management analysis**.

The first area is **technical analysis** of natural resources in order to determine their availability and quality, as well as consideration of the evolution of multiple use of natural resources in terms of necessity and impact.

The second area is **management analysis** in order to gain understanding of how the rules and entities determine the management of these resources. In-depth analysis of management includes consideration of the entities and other participants, the legal and regulatory framework and the

[61] A nexus approach to transboundary cooperation. The experience of the Water Convention. UNECE. https://www.unece.org/fileadmin/DAM/env/water/publications/WAT_NONE_12_Nexus/SummaryBrochure_Nexus_Final-rev2_forWEB.pdf

policies relating to key sectors. The purview includes consideration of various scales and cycles of decision-making, institutional arrangements and culture of management.

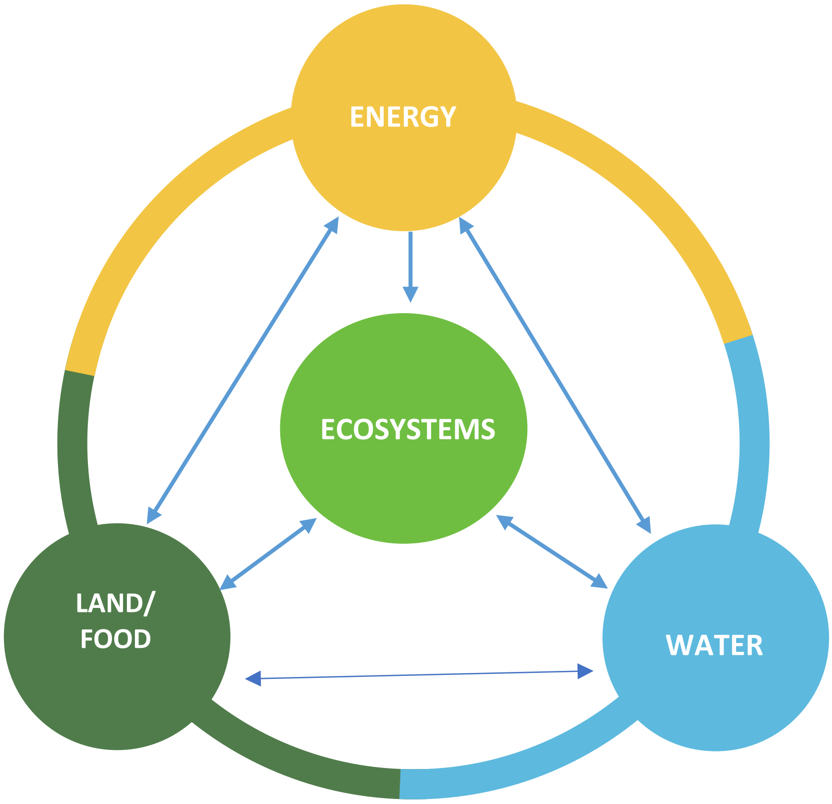



**Figure 5. Basic frameworks of Nexus Dialogue Workshop[62].**

The nexus assessment methodology allows the stakeholders to jointly reflect both positive relations (synergies) and negative relations (compromises, impacts) between sectors, with account taken of future changes. Working with officials and experts from the sectors and countries concerned, the relations are identified and mapped in a quality manner based on broad participation of various sectors (see Figure 5).

It is essential to provide perspectives for all key sectors: to this end, **"brainstorming"** sessions are conducted in sectoral groups prior to the **actual dialogue on the interrelations** during which the use of nexus assessment gains overall support and priority.

A limited quantitative nexus assessment is performed to encourage more targeted follow-up analysis. Priority interrelations (identified by the nexus assessment participants) can be quantified as compromises, solutions or benefits, provided the data and applicable analytical tools are available.

While some quantitative evaluation is included in the nexus assessment, it is primarily intended to illustrate the potential of quantitative evaluation of the interrelation and provide a basis for more targeted and expanded follow-up analysis (for example, to compare various degrees of cooperation between hydropower operators all along the river in terms of energy production, greenhouse gas emissions and flood response).

The cooperation is shown to be beneficial for all sectors. Consideration of the range of benefits from the nexus assessment approach helps explain the value of cross-sectoral cooperation at the transboundary level. The very important aspect is a constant and open informing of the civilian

[62] A nexus approach to transboundary cooperation. The experience of the Water Convention. UNECE. https://www.unece.org/fileadmin/DAM/env/water/publications/WAT_NONE_12_Nexus/SummaryBrochure_Nexus_Final-rev2_forWEB.pdf

population of the transboundary watercourse basin through both official media and social networks. Moreover, it should be borne in mind that the use of social networking platforms has increased significantly at present. Highlighting the benefits of the nexus assessment solutions provides additional incentives to support and implement the assessment recommendations. At the same time, nexus assessment makes it possible to identify previously lost benefits from possible coordinated actions in the basin (both from national and basin points of view). This may lead to the **creation of a common ground for broader cooperation: although every riparian state may not benefit in all respects, the sum of all benefits (including non-economic benefits and across multiple sectors) will be greater than from mere distribution of water and other resources.**

The Meeting of the Parties to the Water Convention, having assessed the progress of the three-year program for 2013–2015, recognized the following as the **main results**[63]:

- an idea was formed about the needs, the possible conflicts, the required compromises and the expected socio-economic benefits from the assessment of interrelations of multiple sectors, taking into account the climate change and the conservation of biological diversity.
- various packages of industry policies were formed. A prospective integration between water, energy and food sectors was analyzed in order to ensure their security and preserve ecosystems in terms of water and land resources management.
- to further deepening the nexus approach in the interests of the participating countries, the following **tasks** were formed for the second period from 2015 to 2018:

  i. To assess in more detail the interdependence of various sectors both within the country and across the countries sharing any transboundary water system.

  ii. To show how the optimization of mutually beneficial cooperation in the use and production of energy, food and ecosystem services and goods can help achieve a common benefit for water, energy and food security in all the countries sharing the transboundary water basin.

  iii. In a joint dialogue of countries and sectors, to identify barriers and opportunities of their overcoming through closer integration in creating of the necessary policies and organizing of joint planning in various sectors with a purpose of equitable distribution of resources.

  iv. To provide reliable and up-to-date information to all stakeholders at all levels (districts, regions, country, basin) to support adoption of agreed and mutually beneficial political decisions, improve transboundary cooperation and achieve broad public participation[64] in taken decisions and gained benefits.

The nexus assessment process and its scope are constrained by limited funding at a global level, therefore various possibilities for raising additional funds through the assessment of resource requirements need to be considered, as presented in the lessons learned analysis[65]. Therefore, to this end, analysts should plan possible cooperation with other programs, projects or additional resources and partners that could contribute to synergies.

---

[63] Draft programme of work for 2013–2015.UNECE. Sixth session. Rome, 28–30 November 2012. http://www.unece.org/fileadmin/DAM/env/water/mop_6_Rome/Official_documents/ECE_MP.WAT_2012_L.1_e.pdf

[64] PANEL: "GREEN RECOVERY IN CENTRAL ASIA". Presentation. Anna Kirilenko. Ecological Movement BIOM. https://docs.google.com/presentation/d/1hm76RVpUcrKDK0cVRqYipH9gehHiL7yxswk83romg38/edit#slide=id.p1

[65] Lessons learned from the preparation of the Second Assessment and plans for future assessments under the Convention. http://www.unece.org/fileadmin/DAM/env/water/mop_6_Rome/Official_documents/ECE_MP.WAT_2012_2_e.pdf

## 3.4 METHODOLOGICAL APPROACHES TO NEXUS ASSESSMENT

Unfortunately, the water, energy and food sectors are routinely managed and operated in significant isolation from each other and do not take into account the impacts on ecosystems that provide conditions for the renewal of water and land resources. Very often, the desire of one of these sectors to create more favorable conditions and benefits leads to threats to security and significant problems for the development of other sectors.

This situation is somewhat complicated when the provision of water, energy, food and ecosystem services is carried out within a **macroregion**, which is defined by the Water Convention as "the area of the territories of two or more countries connected by a transboundary freshwater basin exposed to the impact of interconnected energy and food spheres due to the connecting role of water resources". At the same time, the logic and approaches of nexus assessment are also quite applicable to the use of nexus assessment within one country.

To ensure the security of a macroregion, a high interest of countries is needed, which can be achieved by creating specific market mechanisms[66], which, in turn, could contribute to increasing benefits for each country in this macroregion. At the same time, the countries of the macroregion can interact both on a bilateral level (for example, create dams to protect against floods and produce energy), and on the basin level when trading in electricity or agricultural products), as well as on the global level (to mitigate the effects of climate change or create adaptation programs and projects). In this interaction, the nexus plays a mediating role in which water plays a connecting role in the value chain.

When carrying out a nexus assessment, a huge variety of water basins (rivers, lakes, aquifers) must be taken into account and, therefore, **the approach to carrying out a nexus assessment should be very flexible and adapt** to different water basins, taking into account the fact that they:

- serve as examples of a wide variety of climatic conditions, social and economic characteristics.
- may represent only a "partial" nexus between sectors, for example between production and use of hydropower and agricultural food production, or between hydropower and ecosystems.

Below is a detailed analysis of nexus by its four main parts (see below A, B, C and D), which allows to answer the general question when conducting a nexus assessment: "What are the main questions this nexus assessment should answer?".

Each of these four parts contains both general and more specific indicators. But in the future, analysts, depending on the characteristics of the basin, can add the necessary information, or, conversely, remove irrelevant information:

[66] A proposed approach to assessing the Water-Food-Energy-Ecosystems Nexus under the UNECE Water Convention Discussion paper. 4 April, 2013. https://www.unece.org/fileadmin/DAM/env/documents/2013/wat/Nexus_mtg/NexusAssessment_DiscussionPaperOnApproach_final_forWeb.pdf

## A. BASIN DESCRIPTION: OVERALL SETTINGS

### a. Policy in the economy of the macroregion

- Sectiral policies and aspects, both at the national level and at the macro level, include descriptions of:
  - characteristics of the main sectors,
  - relative importance of different sectors of the economy,
  - macroeconomic trends,
  - demographic trends: population and population growth, aging, urbanization,
  - existing development strategies and policies in different sectors (for example, agriculture, renewable energy sources (RES), etc.) and how coherent they are with each other)[67].

Additionally, a checklist can be developed to assess current policies. This will help to answer the questions: "Which policies affect certain sectors?" and "How significant is the influence of these policies?". These questions may include, but are not limited to, the following:

- Do you know about subsidizing certain sectors? If yes, how? What possible subsidies can be considered in relation to the sectors (quality criteria, production volumes, etc.)
- What is the current pricing policy for the use, transportation, distribution of various resources (water and energy)? Do the prices for consumed resources differ for different user groups? How does pricing stimulate efficient and economical consumption of resources by different users? How is the demand for resources regulated?
- How is the profitability and, therefore, the attractiveness of various energy sources formed through the existing indicators of emissions and quotas?
- Are there strategies for adaptation to climate change on the country or basin level? What actions and activities are planned for the different sectors? What are their target indicators?
- What is being done on the country and basin level to control and maintain the required quality and sufficient quantity of water resources? Do the current policy measures encourage action to use resources efficiently, reduce waste and release of pollutants, etc.?
- What are the prospects for the development of infrastructure for flow regulation and storage of water resources? Are there plans for use of such infrastructure for any purpose other than intended? If yes, do such plans take into account ecological needs for ecosystems, such as creating conditions for fish migration? What alternative options are proposed?

### b. Analysis of institutional and management aspects of the nexus.

  - What is the institutional and governance structure on the national level? Are there any mechanisms for intersectoral coordination?
  - Are there institutional and management structures and mechanisms for intersectoral coordination on the transboundary basin level? What are the prospects and the need for creating such structures on the transboundary basin level?

### c. Biophysical features of the transboundary basin.

  - What is the state of water resources in the basin? Their quality and quantity?

[67] Policy coherence means that incentives and signals from different policies provide non-conflicting signals to target groups. Policy coordination and policy integration help increase coherence by introducing processes and tools that reduce problems of coherence across sectors. Relevant literature is available for an overview of the conditions and some details, for example you can refer to the following publication: Per Mickwitz et al 2009, Climate Policy Integration, Coherence and Governance. Partnership for European Environmental Research.

- What is the availability and diversity of water resources?
- What are the climatic conditions of the transboundary basin?
- What is the storage potential, natural and anthropogenic infrastructure?
- What is the degree of development and exploitation of water resources?

**d. The state of the climate, its change and variability.**
- Observation and monitoring system.
- Existing forecasts.
- Vulnerability assessment of various sectors.

Questions for clarification to all participants:
- To what extent do the above components help to provide the most complete description of the transboundary basin and overall setting?
- Is anything relevant missing?

## B. DESCRIPTION OF THE NEXUS THROUGH ITS COMPONENTS[68].

It shows how descriptive indicators describe the characteristics and peculiarities of an individual sector and its relationship to other sectors. In addition, these indicators help to describe the barriers and prospects for the development of nexus between sectors in the transboundary basin. Below is a preliminary, but not definitive, list of indicators that can be used but will need to be further refined based on feedback from partners and stakeholders. The descriptive nexus assessment and other information will need to be further illustrated and supplemented with indicators. It is necessary to select a common set of key indicators that would be presented for all basins selected for assessment.

A preliminary list of possible indicators may include, but is not limited to, the following indicators:

- Indicators for water security.
  - Total Actual Renewable Water Resources (TARWR[69]) per capita.
  - Potential water storage capacity per capita.
  - Access to water supply and sanitation services.
  - Intensity of use of actual water resources (percentage of withdrawals from TARWR).
  - Use of water resources in different sectors.
  - Indicators of runoff variability, occurrence of extreme hydrological events.
  - Energy intensity of water provision (withdrawal, treatment, conveyance; special attention to the use of methods with high-energy requirements like desalination).

- Food security indicators.[70]
  - Supply, access, quality, stability, health, absorbing nutrients.
  - Water use productivity in agriculture.
  - Share of irrigated and non-irrigated agriculture.
  - Degree of cultivation of arable land.

---

[68] Approach proposed to assess the interrelation between water, food, energy and ecosystems under the UNECE Water Convention. Discussion document. April 4, 2013. Prepared by the UNECE Secretariat with the participation of Finland, Food and Agriculture Organization of the United Nations (FAO), Stockholm Environment Institute (SEI), and Stockholm International Water Institute (SIWI).
http://www.unece.org/fileadmin/DAM/env/documents/2013/wat/Nexus_mtg/RU_nexusAssessmentApproach_forWeb_final.pdf
[69] TARWR - Total Actual Renewable Water Resources.
http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/temp/wwap_pdf/Total_Actual_Renewable_Water_Resources.pdf
[70]The choice should be made using, for example, FAO's list of food security indicators (http://www.fao.org/publications/sofi/food-security-indicators/en/)

  - Energy intensity of agriculture (level of mechanization, etc.).
  - Plant growing and animal husbandry.
  - Exceeding the permissible levels of pesticides and fertilizers/nutrients (in relation to the limit values) in agriculture.
  - Prevalence of organic agriculture.

- Energy security indicators.
  - Primary composition of energy resources.
  - Energy dependence on the basin neighbors.
  - Energy sharing activities.
  - Energy intensity of production, industry, etc.
  - Access to modern electricity.
  - Hydropower potential and level of development.
  - Percentage of use of RES.

- Ecosystem safety indicators.
  - Water quality.
  - Eutrophication.
  - Monitoring the condition and protection of ecosystems in the basin.
  - Main ecosystem services provided.

Possible additional questions for clarification to all participants in the assessment:

- How accurately and correctly do the above questions help to describe the nexus?
- Do they allow for the identification of barriers that impede nexus in different basins? To what extent do these questions reflect the role of various factors in the nexus?
- How complete and relevant are the indicators listed?
- Which of the key indicators can be common for different basins?
- What other information is needed to complement the indicators and further describe the nexus?

## C. ANALYSIS OF THE NEXUS ASSESSMENT: OPPORTUNITIES AND BARRIERS[71].

This section is planned to mainly work with all stakeholders, and this joint work will focus on the following issues:

- Identification of the links and processes in the nexus.
- Rating assessment of the relative importance of the identified links and processes in the nexus.
- Identifying trade-offs and quantifying them.
- Discuss the potential for efficiency improvements in all sectors.
- Identifying gaps in the institutional and legal basis in existing organizations and governance (agreements, joint bodies, customs unions, etc.).
- Discussion of the impact of projected climate change on various sectors.
- Discussion of various ways to overcome barriers and consultation on possible opportunities.

[71] Approach proposed to assess the interrelation between water, food, energy and ecosystems under the UNECE Water Convention. Discussion document. April 4, 2013. Prepared by the UNECE Secretariat with the participation of Finland, Food and Agriculture Organization of the United Nations (FAO), Stockholm Environment Institute (SEI), and Stockholm International Water Institute (SIWI). http://www.unece.org/fileadmin/DAM/env/documents/2013/wat/Nexus_mtg/RU_nexusAssessmentApproach_forWeb_final.pdf

The analysis and its joint development are proposed to be carried out taking into account the so-called "nexus profiles", which consist of indicators. The discussion for identification and description of the interdependencies could be facilitated by using flow charts or causal chains.

The objective of this section will be to explore how the countries in a macroregion sharing a transboundary basin could benefit from a nexus approach and how to root the possible opportunities on the current policies. This part of the assessment would be based on the conclusions of the basin-level process, building on the ideas for improvements triggered by the joint identification of interlinkages and trade-offs described above.

Questions for clarification to all participants:

- How can the various interlinkages be assessed and ranked by order of importance?
- How will the trade-offs identified be assessed or measured?

## D. COMBINED ANALYSIS, SOLUTIONS AND NEXT STEPS.

The nexus assessment involves considering potential future development trends or scenarios, including identifying possible future measures to strengthen the sustainability of the nexus through a combined nexus analysis.

"It is recognized that development options or scenarios could offer additional insights to the implications of different policies and plans. Furthermore, allowing comparisons through assessing several basins with the same tool would in a certain way add value to earlier exercises. Based on a brief review of some available tools[72], it seems that extensive and systematic application of modelling is not feasible from the point of view of resources expected to be available for the assessment"[73].

The challenge is to find a "one size fits all" approach that can be applied across all basins and, at the same time, would be simple enough to be implemented within a single nexus assessment.

In any case, if the countries participating in the nexus assessment (or river commissions or other partners) are willing to invest additional funds in data collection and analysis, they could work on the nexus assessment further.

It is necessary to justify and assess the consequences of certain development scenarios based on the initial structure of indicators and the consultations carried out as part of this assessment. For example, the following types of changes could be quantified if necessary, for example:

- How will a change in water flow regulation affect many other uses of water resources?
- How can improving water use efficiency by a certain percentage help to respond to projected water needs for different sectors?
- How can an increase in the share of renewable energy sources in relation to different types of energy affect the use of water for energy purposes?
- How can reducing the pressure on ecosystems by increasing environment flow using new water-saving technologies allow various sectors to use water resources most efficiently?

---

[72]Water Evaluation and Planning Model (WEAP), Long-Term Energy Alternatives Planning (LEAP) model, "Foreseer" model, and Aral Sea Basin Economic Allocation Model (BEAM) and ASBmm (an integrated model for assessing alternative scenarios of the Aral Sea Basin development).

[73] Approach proposed to assess the interrelation between water, food, energy and ecosystems under the UNECE Water Convention. Discussion document. April 4, 2013. Prepared by the UNECE Secretariat with the participation of Finland, Food and Agriculture Organization of the United Nations (FAO), Stockholm Environment Institute (SEI), and Stockholm International Water Institute (SIWI). http://www.unece.org/fileadmin/DAM/env/documents/2013/wat/Nexus_mtg/RU_nexusAssessmentApproach_forWeb_final.pdf

- What measures in different sectors will allow to adapt the current water use to the projected decrease in water flow by a certain percentage due to climate variability and change?

Additional questions for clarification to all participants:

- Do you have the potential to experiment with scenarios, quantify multiple development options, or possible strategies? Do you have financial, institutional and human resources for this? Should the assessment include modeling information from other assessments? If yes, could differences in approaches be accepted?
- Is it necessary to evaluate an individual development scenario in "your" basin, i.e. look at planned measures (in river basin management plans or sectoral development plans) and predictions for this particular basin? Is there an existing modelling tool which is applicable to quantifying some aspects of the nexus, is available and has been used on "your" basin?
- Is it possible to agree with a limited number of general development trends, assessing what they will mean in the case of each basin? Could such development options be briefly described, e.g. "more storage capacity/flow regulation", "greener economy", "more renewable energy sources", "intensified agricultural production" etc.?

## E. PILOTING OF THE AGREED METHODOLOGY OF THE NEXUS ASSESSMENT AND NEXT STEPS[74]

The agreed nexus assessment method was first tested in 2013 in the Alazani/Ganikh pilot basin (Figure 2)[75] to test its applicability and make adjustments. During 2013, the scope of work, the level of funding and the availability of other resources were clarified by answering the following questions:

- Which of the proposed basins can be made informative pilot basins?
- Which organizations and people making decisions responsible for the basin-related proposals should be invited to voluntarily participate in the assessment.
- What other basins should be part of this assessment, given the need for strong stakeholder ownership and sufficient representation?

After refining the methodology, the nexus assessment was carried out from 2013 to 2015 in three other basins (the Sava River Basin, the Syrdarya River Basin, the Isonzo/Soka River Basin)[76] together with various interested country authorities and in close collaboration with relevant national and international partners.

The Task Force on the Water-Food-Energy-Ecosystems Nexus was tasked with reviewing and guiding the nexus assessment in all of the above four transboundary basins and discussing the results of these four assessments in the Inventory Report [77](Figure 2) in 2015, together with representatives of countries that are concerned about current and possible future basin assessments, as well as representatives of organizations implementing parallel initiatives, partners, experts and stakeholders. The nexus assessment inventory report had the following objectives:

- To provide an overview of the status of preparations of assessments.
- To discuss the findings and the experience from the basin assessments.

[74] Approach proposed to assess the interrelation between water, food, energy and ecosystems under the UNECE Water Convention. Discussion document. April 4, 2013. Prepared by the UNECE Secretariat with the participation of Finland, Food and Agriculture Organization of the United Nations (FAO), Stockholm Environment Institute (SEI), and Stockholm International Water Institute (SIWI).
http://www.unece.org/fileadmin/DAM/env/documents/2013/wat/Nexus_mtg/RU_nexusAssessmentApproach_forWeb_final.pdf
[75] See 4.1 Summary of the nexus assessment of the Alazani/Ganykh River Basin
[76] See 4. NEXUS ASSESSMENT WITH THE FOCUS ON ITS VARIOUS COMPONENTS.
[77] Third meeting of the Task Force on the Water-Food-Energy-Ecosystem Nexus 28 - 29 April 2015. http://www.unece.org/index.php?id=38157

- To review the draft contents of the overall stocktaking report of the nexus assessment.
- To agree on the steps to complete the presentation of findings for publication.
- To discuss possible follow-up activities for the Convention's program of work 2016–2018.

Further development and refinement of the methodology was carried out within the framework of the Program of work for 2016–2018. The assessment of the Drina River Basin was carried out as a detailed extension of the assessment of the Sava River Basin and the methodology was subsequently applied to the total groundwater resource assessment during the transboundary nexus assessment of the North-West Sahara Aquifer System (NWSAS) and the Drin River Basin.

The Global Inventory Workshop (Figure 2), held in Geneva in December 2016, summarized the results of the nexus activities carried out, analyzed the approaches and tools used to assess the nexus problems, and also summarized all the work done on the nexus assessment for that time period.

On May 30, 2018, the Task Force on the Water-Food-Energy-Ecosystems Nexus released a consolidated publication in Geneva discussing the nexus assessments conducted and the lessons learned in developing the assessment methodology for the entire period from 2013 to 2018.

The Task Force recognized that the practical application of the nexus assessment and the implementation of the solutions recommended in the assessments still require additional feedback and additional documentation. Consequently, this part of the joint work on the methodology is far from complete and the nexus assessment still requires more detailed generalization in the future[78].

Thus, education in universities and training of specialists in the field of studying and assessing the interlinkages between different sectors in order to improve water, energy and food security, and protect ecosystems, taking into account natural and man-made threats, becomes an important component in the long term. The study of interlinkages is a new challenging field of knowledge that requires comprehensive and in-depth training of such experts to conduct multidisciplinary and large-scale nexus assessments.

---

[78] Methodology for assessing the water-food-energy-ecosystem nexus in transboundary basins and experiences from its application: synthesis. UNECE. 2018. http://www.unece.org/fileadmin/DAM/env/water/publications/WAT_55_NexusSynthesis/ECE-MP-WAT-55_NexusSynthesis_Final-for-Web.pdf

# 4. PERFORMED NEXUS ASSESSMENT WITH THE FOCUS ON ITS VARIOUS COMPONENTS

## 4.1 Summary of the Nexus Assessment of the Alazani/Ganikh River Basin[79]

The first pilot project was the Alazani/Ganikh River Basin, which flows through the eastern part of Georgia (as Alazani) and the western part of Azerbaijan (as Ganikh) and partly forms the border between these countries.

During the nexus assessment, it was realized that this approach helps to increase opportunities for the development of electricity trade and facilitates access to modern energy sources, as well as minimizing the impact of new hydropower plants and combating infrastructure erosion through the application of modern aquifer management methods.

The choice was based on the following objective features of this basin:

- There is a long experience of cross-border cooperation between the countries on a number of joint projects.
- Azerbaijan and Georgia have experience in conducting joint transboundary diagnostic analysis in the Kura River Basin and in preparing a Strategic Action Program to address identified problems and develop national IWRM plans. This work was carried out by experts from these countries within the framework of the regional project "Reducing Transboundary Degradation in the Kura-Aras River Basin", which was funded by the GEF and implemented by UNDP to strengthen the capacities of Azerbaijan and Georgia in water resources management and create the necessary intersectoral coordination.
- Azerbaijan and Georgia understand the need to decrease economic costs and reduce environmental impact for the further sustainable development of the basin countries.
- Azerbaijan and Georgia are actively pursuing efforts to reduce environmental degradation in the Alazani/Ganikh basin.
- Azerbaijan and Georgia seek to maximize benefits through agricultural and hydropower modernization.

Given the uncertainties and various constraints associated with climate change, Azerbaijan and Georgia are striving to align their national short-term socioeconomic development goals and long-term goals related to improving the safety of the Alazani/Ganikh basin and to achieve sustainable access for their citizens to the amount of water, food, energy and ecosystem services needed.

The nexus assessment of the Alazani/Ganikh River Basin started with a transboundary workshop organized by the UNECE secretariat in collaboration with the UNDP/GEF Kura River Basin Project staff and the Georgian Ministry of Environment. On November 25–27, 2013, representatives of structures responsible for water resources, agriculture, energy, environmental protection, as well as representatives of various enterprises and civil society gathered in the city of Kachreti. The workshop was active with interactive work in groups and broad discussion in plenary sessions. The panelists discussed and identified priority problems arising between different sectors, as well as priority actions that need to be implemented to correct and improve the situation in the basin. The nexus assessment was based on the following sources of information:

[79] Reconciling resource uses in transboundary basins: assessment of the water-food-energy-ecosystems nexus (chapter 5) ─ Summary nexus assessment of the Alazani/Ganikh River Basin. Published: June 2016 http://www.unece.org/index.php?id=42935

- Minutes of discussions by the workshop participants.

- Results of answers to the questions of the factual and evaluation questionnaires.

- Reports, reviews, briefs, documents and other information presented by various participating stakeholders during the workshop.

- Reports, reviews, references, documents and other information collected additionally after the workshop.

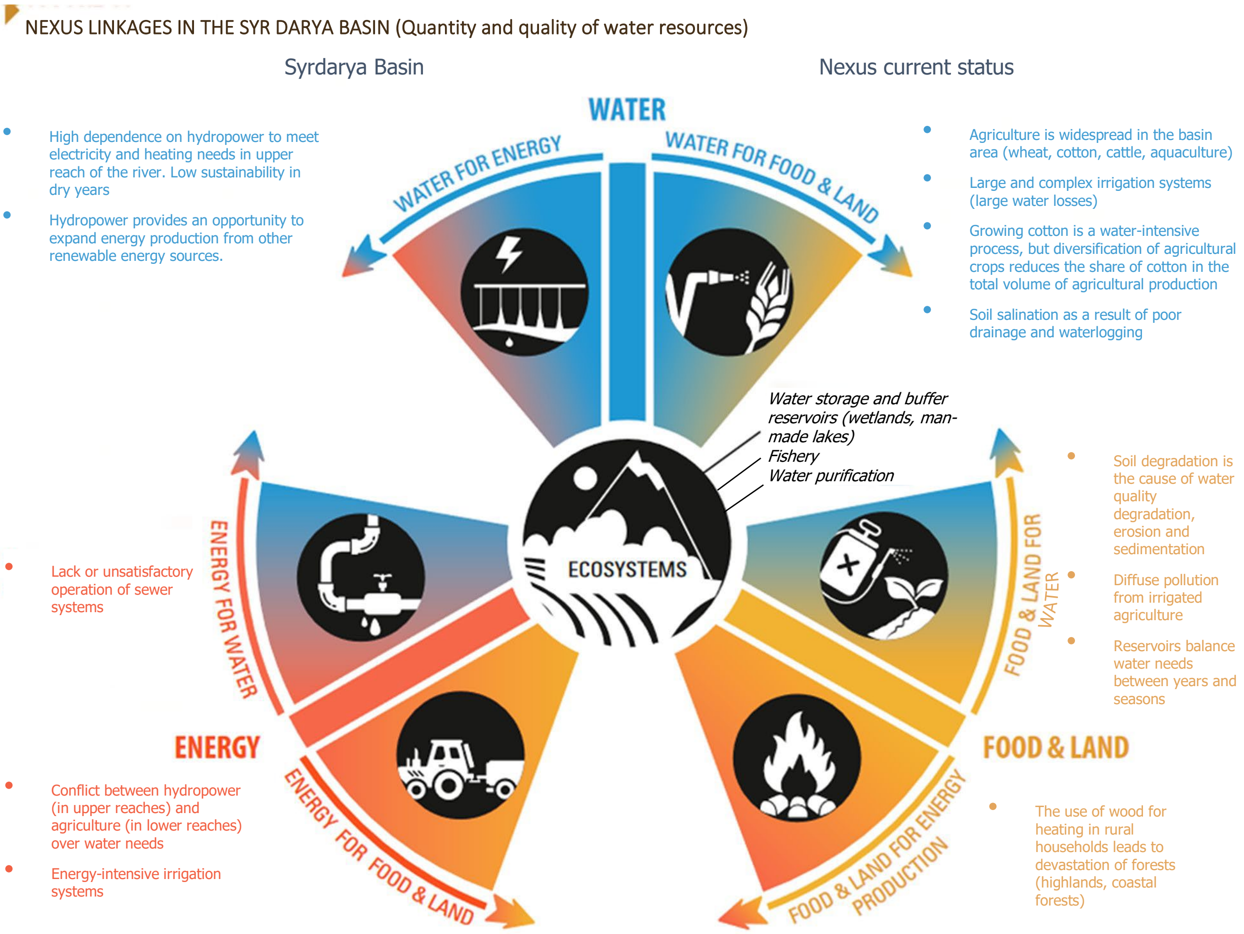
The nexus assessment is an overview of various issues reflecting intersectoral contradictions in the Alazani/Ganikh River Basin, but at the same time it offers promising opportunities for cooperation between the basin countries. The process of this nexus assessment has well demonstrated the importance of taking into account and addressing secondary impacts, assessing multiple sectors at the same time by all representatives of these sectors, and the need for a consistent structural assessment to understand the intersectoral implications of measures and policies.

In addition, the nexus assessment showed that joint planning, with an understanding of the need for integration and mutual coordination, is the basis for helping to increase the benefits of different sectors through mutually beneficial agreed solutions. Conducting additional analysis that will help deepen some aspects of this nexus assessment with new qualitative and quantitative information will help improve the benefits for all countries.

The countries have come to realize that continued sharing of information between sectors and increased intersectoral coordination will benefit future planning efforts. It is emphasized that the preliminary analysis requires feedback from all involved sectoral agencies of both transboundary countries and other stakeholders. Feedback will help to not only validate the findings, but also improve the accuracy of the nexus assessment and identify the issues that are most needed, especially regarding current policy developments.

## 4.2 Summary of the Nexus Assessment of the Syrdarya River Basin[80]

The assessment of the nexus system in the Syrdarya River Basin conducted under the UNECE Water Convention 2013–2015 work programme. **The methodology employed was developed specifically for assessing the nexus in transboundary basins with multi-disciplinary expertise. In the course of the analysis of ways of solving current intersectoral challenges, the following directions were identified – such as encouraging the restoration of the regional network and revitalizing the energy market; increasing the efficiency of generation, transmission and consumption of energy; increasing the efficiency of water use (primarily in agriculture).**




The assessment aimed to foster transboundary cooperation by identifying intersectoral synergies and determining measures that could alleviate tensions related to the multiple needs of the riparian countries for common resources. The process looked to generate relevant information to support decision-making, and it engaged diverse expertise and key actors in the basins. The participatory assessment process for the Syrdarya involved an intersectoral workshop for identification of the main intersectoral issues and possible solutions, detailed by a subsequent analysis, and followed by consultations of the various sectoral authorities concerned.

This nexus assessment summary describes the characteristics of the water, food and land, energy and ecosystem services, and their governance. The assessment shows multiple linkages in the

[80] Reconciling Resource Uses in Transboundary Basins: Assessment of the Water-Food-Energy-Ecosystems Nexus in the Syrdarya River Basin. Published: January 2017. https://www.unece.org/environmental-policy/conventions/water/envwaterpublicationspub/water/envwaterpublicationspub74/2017/reconciling-resource-uses-in-transboundary-basins-assessment-of-the-water-food-energy-ecosystems-nexus-in-the-syr-darya-river-basin/doc.html

Syrdarya Basin between the different basin resources, and concludes that strengthening transboundary cooperation on the integrated management of these resources will bring real benefits. The graphics obtained during the assessment illustrate the interlinkages identified. Climate change and socioeconomic drivers, and their effects on intersectoral dynamics, are also considered. A broad range of beneficial response actions are outlined. Solutions proposed span institutions, information, instruments, infrastructure as well as international coordination and cooperation.

The analysis revealed two main problems associated with: 1) the amount of water – its availability, especially in different seasons for different sectors and environmental needs; and with 2) the quality of water – its pollution by many industries that use water and land resources, but at the same time need clean water. It was concluded that the use of a "nexus approach" has the potential to improve resource efficiency and security in riparian countries. In contrast to the national approaches currently used, cooperation involving all countries and sectors has great potential to optimize the use of resources in the basin.

However, the application of certain solutions at the country level, including, inter alia, water and energy efficiency improvements, as well as targeted economic and policy instruments, can gradually create more favorable conditions for transboundary cooperation. Functioning transboundary and intersectoral cooperation is a prerequisite for efficient management of existing infrastructure and optimization of new investment and trade.

## 4.3 Summary of the Nexus Assessment in the Sava[81] and Drina River Basins[82]

**In the Sava and Drina River Basins, the assessment and intersectoral transboundary dialogue revealed the following key opportunities for improving sustainable development: developing hydropower on a sustainable basis with the integration of other renewable energy sources; coordinating the operation of hydropower plants (to deal with floods, generating benefits for the energy system, and ensuring ecological flow) and developing new capacities, ideally on the basis of a common strategy for the entire basin, taking into account conflicting interests with other water uses and ecosystems.**

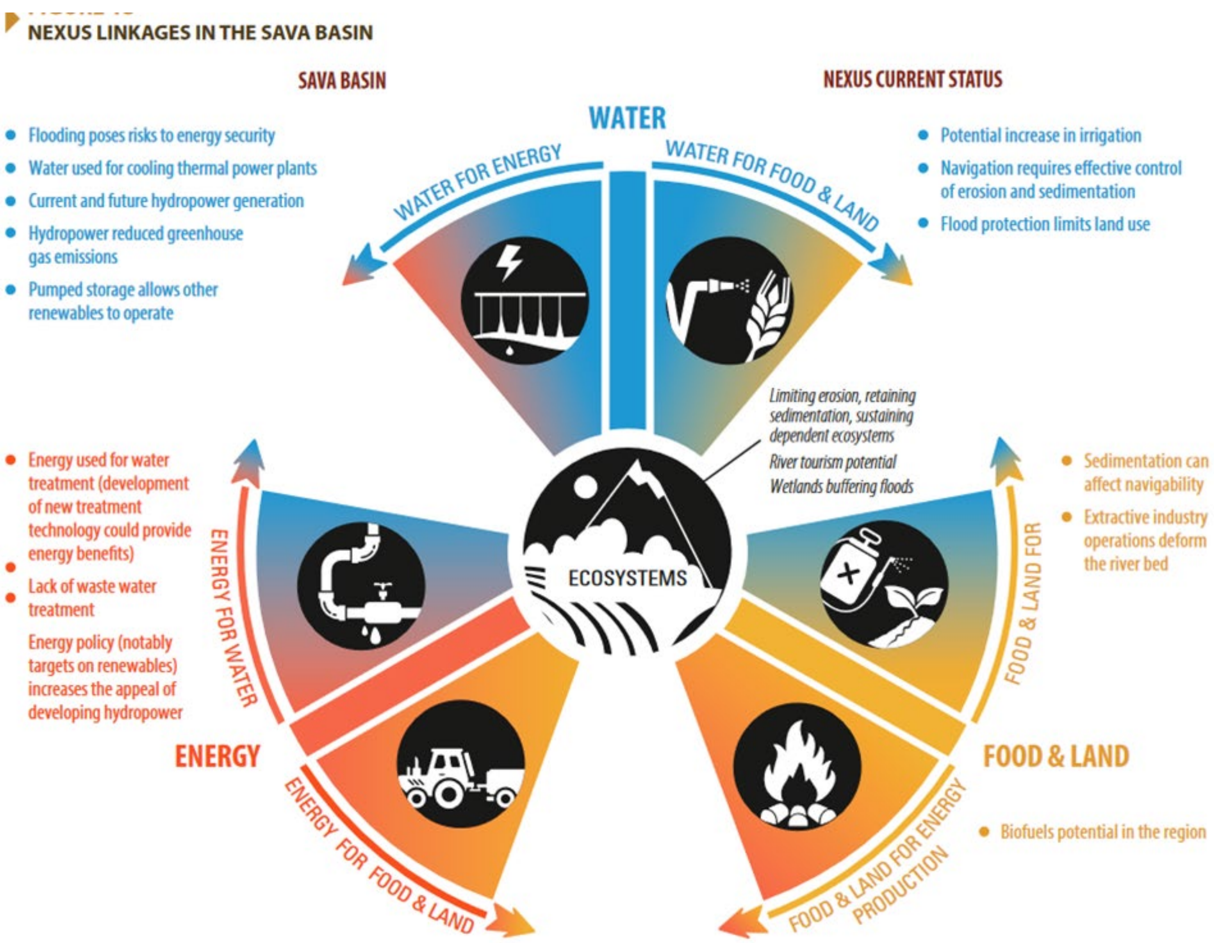
As part of the Danube River Basin, the Sava River Basin covers large areas of Slovenia, Croatia, Bosnia and Herzegovina, Serbia, Montenegro and a small part of Albania, and is an important source of water for settlements, industry, energy, ecosystems and agriculture for all of these riparian countries. The Sava River Basin is also a prime example of a transboundary basin in which advanced transboundary cooperation oriented towards intersectoral dialogue is already taking place. The driving force behind this cooperation and coordination is the International Sava River Basin Commission (ISRBC)[83], set up to implement the Framework Agreement on the Sava River Basin (FASRB)[84]. It was at the request of these countries that an analysis was carried out on the water-food-energy-ecosystems nexus in the Sava River Basin.

The assessment highlighted the importance and need for deep integration in sector management. Such management goes beyond standard integrated water resources management (IWRM) and should also apply to integrated management of other sectors. The assessment was based not only on a detailed quantitative assessment, but also on the results of a multisectoral transboundary dialogue organized by ISRBC and UNECE. As a result of the dialogue, the parties came to an understanding of the importance of interconnection or a "deeper" integration policy.

As a key step in the nexus assessment, a joint intersectoral workshop was organized with the UNECE and ISRBC secretariats, attended by representatives of key ministries as well as other relevant organizations from different sectors from each riparian country (Bosnia and Herzegovina, Croatia, Montenegro, Serbia and Slovenia). The workshop also included a wide range of other stakeholders such as international and local NGOs and research institutions. Representatives from each sector of the economy provided important development prospects for their sectors. While analysts spoke about possible impacts on ecosystems, climate change, in-depth analysis was also presented on other aspects affecting the development of the region.

During the workshop, stakeholders participated in two working sessions. The first session consisted of sector mapping exercises, during which it was analyzed how the expansion of one sector affects other sectors and, conversely, how other sectors affect it. For the sake of simplicity, the groups were divided into four main areas of the nexus: energy, water, food, and ecosystems. This expansion can be seen in the energy sector. As they grow, by investing in new facilities, thermal power plants can affect ecosystems by emitting pollution, and energy crops (grown specifically for fuel use) can change habitats due to changes in land use patterns, but both require water (for cooling and irrigation), thus the production of energy crops can finally reduce the potential for food production and so on.

[81] Reconciling resource uses in transboundary basins: assessment of the water-food-energy-ecosystems nexus in the Sava River Basin. 2016. https://www.unece.org/fileadmin/DAM/env/water/publications/GUIDELINES/2017/nexus_in_Sava_River_Basin/Nexus-SavaRiverBasin_ECE-MP.WAT-NONE-3_WEB_final_corrected_for_gDoc.pdf
[82] Assessment of the water-food-energy-ecosystems nexus and benefits of transboundary cooperation in the Drina River Basin. January 2017. file:///C:/Users/Admin/Downloads/UNECE2017-Drina_final_report.pdf
[83] ISRBC - The International Sava River Basin Commission.
[84] FASRB - the Framework Agreement on the Sava River Basin




In the second working session, scenarios were developed to understand the simultaneous impact of each sector. Attempts have been made to understand what needs to be looked at for further agreement on development plans and their implementation. For example, long-term hydropower production requires sufficient water availability, which could be hampered by climate change or agricultural expansion.

The assessment opened up new opportunities for transboundary and intersectoral cooperation. Now there is hope that eventually intersectoral communication and coordination in governance and deeper policy integration will improve. The nexus approach has shown that peer-to-peer dialogue is at the core of intersectoral synergy and enables everyone to simultaneously consider shared perspectives and priorities, and will lay a promising foundation for improved dialogue between policymakers and all stakeholders.

The Drina River Basin[85], shared by Bosnia and Herzegovina, Montenegro and Serbia, is a water-rich river basin characterized by pristine landscapes and high levels of biodiversity. This assessment, conducted jointly by representatives of Montenegro, Serbia and Bosnia and Herzegovina, is based on the results of a similar assessment on the level of the Sava River Basin (which includes the Drina River Basin) and the use of local expertise obtained, inter alia, after three workshops to identify key links between energy, water, land and ecosystem resources in the basins, as well as the relevant management issues, followed by the identification of potential solutions that will help ensure that basin resources are developed and managed in a sustainable manner.

[85] Assessment of the water-food-energy-ecosystems nexus and benefits of transboundary cooperation in the Drina River Basin. January 2017. file:///C:/Users/Admin/Downloads/UNECE2017-Drina_final_report.pdf

The nexus approach goes beyond traditional, integrated approaches to resource management and therefore can facilitate the search for trade-offs in the development process as well as the identification of opportunities. Such ideas can help in dialogue between countries, as well as help in setting related priorities. Intersectoral coordination, policy coherence and integrated planning are essential both for the transfer of instruments and for the fulfillment of the respective commitments for these countries to join the European Union, as well as the implementation of the 2030 Global Agenda for Sustainable Development. The Sustainable Development Goals (SDGs) on water and sanitation, food security and sustainable agriculture, access to energy, climate action, protection and sustainable use of ecosystems are all closely interlinked. It is clear that the authorities need to have a vision that goes beyond their sectoral mandates and work in better coordination between different sectors.

This nexus assessment identified three key clusters of resource problems that have a major impact on the sustainable development of the basin: flow regulation, rural development, and water quality and solid waste. Links found in these three key clusters include the following:

(i) the importance of using water resources to support the production of hydropower and thermal energy,
(ii) the negative impact of hydroelectric dams on the river ecosystems and on maintaining high water quality,
(iii) the impact of water flow regulation for hydropower generation on the availability of water for other current or potential uses, including irrigation,
(iv) the potential to use hydroelectric reservoirs to mitigate the impact of floods on surface facilities,
(v) the negative impacts of pollution from land-based activities on water quality and aquatic ecosystems,
(vi) the central role of the environment and ecosystems in the development of the rural economy through sustainable agriculture and ecotourism. The distribution of economic activity with nexus effects and associated potential is uneven across the basin, from upstream to downstream.

The nexus assessment identified a set of options for addressing resource management challenges in the Drina Basin. These options include a combination of 5 components: institutions, information, instruments, infrastructure and solutions for international cooperation. Improvements in governance at multiple levels will be critical: improved coordination between sectors within each country, more formal mechanisms for cooperation between countries, greater stakeholder participation and greater emphasis on compliance. In parallel, technical solutions are needed and, in particular, larger and better investments. The best investment involves, among other things, coordination, assessment of alternatives to suit different needs, and consultation. Both governance and technical improvements should be linked to the EU accession process, which currently involves three countries.

Cooperation in the management of the basin's resources has brought significant economic, social and environmental benefits in the past and will bring more in the future, although the decisions and actions taken will influence the extent of these benefits. There are still many opportunities to strengthen cooperation: the development of connectivity and trade in electricity, and waste management and wastewater treatment are just two examples of many potential topics identified. By building trust, cooperation will also bring a number of additional benefits in terms of regional economic integration for peace and security.

## 4.4 Summary of the Nexus Assessment in the North-Western Sahara Aquifer System[86]

**The North-Western Sahara Aquifer System (NWSAS)[87]is the main groundwater resource in the region, with an estimated reserve of about 40,000 billion cubic meters of water that is largely non-renewable. The aquifer water is in great demand for drinking and, in particular, for irrigation. In addition to the gradual decline in groundwater levels as depletion occurs, there are risks associated with the quantity and quality of groundwater due to deficiencies in wastewater and irrigation drainage water management, as well as in oil and gas exploration.**

The challenges of ensuring the sustainable use of the region's water resources shared by Algeria, Libya and Tunisia sharing aquifers were the focus of two transboundary workshops[88] on assessing the water-food-energy-ecosystem nexus in the North-Western Sahara aquifer system, held in 2017 and 2019, as well as two national consultations[89]. The workshops were part of an ongoing process to enhance transboundary cooperation for NWSAS management and capacity building.

The purpose of the first workshop was to present and discuss three interrelated topics:

- understanding the nexus approach for water, food, energy and ecosystems and its application on the transboundary NWSAS level;

- characteristics of the stakeholders involved in the NWSAS management;

- defining the boundaries of the direction of sustainable socioeconomic development in the NWSAS Basin, which can serve as the basis for a common vision of its water resources management.

More than 50 participants from Algeria, Libya and Tunisia, representing various sectors of energy and agriculture, water and utilities, and environmental organizations, gathered in Algeria for a two-day event.

The workshop provided a timely opportunity to assess current and future aquifer management at national and transboundary levels, including sectoral policies in the three countries. The participants identified the linkages between strategies and plans, laying the foundation for enhanced cooperation, outlining a range of useful governance, policy and infrastructure actions that could be taken.

In particular, the participants highlighted the importance of food security, which is increasingly at risk due to climate change, and predicted an increase in the occurrence of extreme hydrological events, calling for rationalization of water use and improved irrigation efficiency. The region is also currently planning a significant development of renewable energy sources (in particular solar energy) with various motives, including diversification of energy sources and reduction of dependence on imports. The “nexus assessment” launched aims to systematically analyze these

[86] Assessment launched to reinforce cooperation between Algeria, Libya and Tunisia in managing shared groundwater resources. Published: 20 July 2017. http://www.unece.org/?id=46340

[87]NWSAS – The North-Western Sahara Aquifer System Project – is part of the United Nations Environment Program (UNEP) and is funded by the Global Environment Facility (GEF).

[88] First Regional Consultation Workshop: Assessing the Water-Food-Energy-Ecosystems Nexus in the North-Western Sahara Aquifer/ 18 - 19 July 2017. https://www.unece.org/environmental-policy/conventions/water/meetings-and-events/water/workshops-water-convention-and-protocol-on-water-and-health/2017/first-regional-consultation-workshop-assessing-the-water-food-energy-ecosystems-nexus-in-the-north-western-sahara-aquifer/doc.html

[89] Reconciling resource uses: Assessment of the water-food-energy-ecosystems nexus in the North Western Sahara Aquifer System, Part A - "Nexus Challenges and Solutions. Published: September 2020. http://www.unece.org/index.php?id=55154

trends and opportunities, and to bring the authorities and stakeholders responsible for these natural resources together at the dialogue table.

The workshop participants urged timely monitoring of available water resources, application of demand management measures (including through appropriate pricing), reorientation of economic development towards higher cost production that does not require abundant water supply, and revision of tariffs. The potential of renewable energy sources for pumping and treating water was also recognized, as well as issues related to environmental considerations and water needs for energy production. The participants also foresaw the need for significant investments in modernization and expansion of infrastructure to address the identified problems.

Revision and enhancement of the NWSAS Coordination Mechanism were also among the opportunities identified during the workshop, which could be reported in an upcoming intersectoral study prepared by the workshop organizing partners.

The workshop also provided an opportunity for interested parties to learn more about strengthening cooperation under the UNECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention). The Convention is of interest in the water-stressed region of the Middle East and North Africa due to the fact that it is open for accession to all UN member states in 2016. The provisions of the Convention pay particular attention to cooperation through agreements and designated institutions that also support countries' implementation of the 2030 Agenda for Sustainable Development by promoting transboundary cooperation in water resources management.

## 4.5 Summary of the Nexus Assessment in the Drin River Basin[90]

**The nexus assessment of the Drin River Basin (shared by Albania, North Macedonia, Montenegro and Kosovo[91]) contributed to the Basin's Transboundary Diagnostic Analysis (TDA) and to the development of the Strategic Action Program (SAP), a policy document providing the basis for deepening transboundary cooperation, approved in April 2020. Phase I consisted primarily of a qualitative description of nexus issues in the nexus thematic report for the TDA. The nexus assessment and subsequent analysis of the priority nexus issues (Phase II) provide additional support for SAP implementation, in particular with regard to synergies with economic sectors and justification for wider participation of all sectors in strategic action. During Phase II, the following 2 components are analyzed:**

1) **the potential impact of increased cooperation on the two hydropower cascades with regard to flood management, and,**
2) **economic, environmental and social implications of renewal and modernization of the cycle from production to marketing of woody biomass in the framework of sustainable forest management.**

Phase I ended in 2019 and Phase II is scheduled to be completed in late 2021[92].

The assessment in Phase I showed that there are at least three areas where improved intersectoral governance can have a significant positive impact on the basin, namely:

- **Energy and water** due to the dominant role of hydropower operators in flow regulation and flood and drought management;
- **Energy, forestry and water resources** to improve the management of forests in the basin and, in turn, better manage erosion and bottom sediments while improving the chain from production to marketing of woody biomass;
- **Agriculture and water resources**, including irrigation techniques, crop selection and potential for trade.

In accordance with the results of the Phase I report, to further analyze the benefits of cooperation in the basin, a quantitative assessment of the Phase II assessment for the Drin Basin is being developed, which will focus on hydropower and flood issues, as well as biomass and sustainable forest management.

The overall objective of the Hydropower and Floods interface study is as follows:

- To understand the potential impact on flood management of enhanced cooperation along and between the two cascades of hydropower plants on the Drin River;
- To quantify the costs and benefits of transition to a cooperative hydropower operation in the basin, taking into account floods;
- To identify the key management changes that are needed for this transition;
- To clarify the profitability of new hydropower in the basin compared with the expected impacts of climate change and other renewable energy sources.

To achieve this purpose, the existing detailed hydrological model of the basin will, where possible, be linked to a multi-country power system model to be developed on a case-by-case basis. A

[90] Nexus Assessment of the Drin River Basin – Phases I and II. Lucia de Strasser, UNECE, 8th Expert Working Groups Meeting. 17th Meeting of the Drin Core Group. Pristina, May 2019. https://www.gwp.org/globalassets/global/gwp-med-files/list-of-programmes/see-nexus/drin-nexus-policy-dialogue/steering-committee-meetings/17th-drin-core-group-2nd-steering-committee-meeting/de-strasser_pristina_ewgdcg-may-2019.pdf

[91] References to Kosovo shall be understood to be in the context of UN Security Council Resolution 1244 (1999).

[92] Nexus Assessment of the Drin River Basin – Phases I and II. Lucia de Strasser, UNECE, 8th Expert Working Groups Meeting. 17th Meeting of the Drin Core Group. Pristina, May 2019. https://www.gwp.org/globalassets/global/gwp-med-files/list-of-programmes/see-nexus/drin-nexus-policy-dialogue/steering-committee-meetings/17th-drin-core-group-2nd-steering-committee-meeting/de-strasser_pristina_ewgdcg-may-2019.pdf

cascade of hydroelectric power plants (HPPs) on the Drin River (2 HPPs in North Macedonia and 3 HPPs in Albania) is a physical link between hydrological and energy system models, forming an integrated water-energy model.

The integrated model includes the use of 5 key scenarios, as well as their combinations:

- Current situation (BAU – business as usual).
- New Dam (ND) reflecting the impact of the construction of a new hydropower plant on the Drin River in Skavitsa, Albania on power generation and flood control.
- Climate change (CC), reflecting the effects of rising temperatures and decreasing precipitation.
- Flood Protection (FP) to assess the impact on power generation under the HPP operating scenario to optimize flood management.
- Hydropower Cascade Optimization (HCO) to assess the impact on flood risks according to the HPP operating scenario in order to optimize power generation.

In order to provide policymakers with meaningful information, the technical analysis of hydropower operation and cooperation in the Drin River Basin will be accompanied by a (simplified) assessment of the socioeconomic costs and benefits associated with the various scenarios, as well as the definition of clear responsibilities related to water-energy cooperation at the level of governance and institutions to overcome obstacles to better cooperation.

The overall objective of the study on sustainable biomass and forest management is to assess the economic, environmental and social impacts of modernizing the woody biomass value chain as part of sustainable forest management, focusing on the benefits in terms of rural population, diversification, improved health, mitigation the impacts of climate change, protecting biodiversity, combating erosion, managing sediment, promoting gender equality and the empowerment of women. For these purposes, the analysis will be based on a comprehensive overview of relevant governance, markets, intersectoral policies, and consumption and trends. Based on the analysis results, a map will be created of intersectoral impacts, trade-offs and synergies associated with the use of biomass analysis and sustainable forest management within the water-food-energy-ecosystems nexus, as well as in conjunction with measurable key indicators that will support the identification of areas where further policy action is needed, some of which will help to quantify the economic, environmental and social benefits of sustainable biomass. The analysis will also be used to propose a package of solutions for institutionalization, information, instruments, infrastructure and international cooperation.

## LIST OF THE USED INFORMATION SOURCES


1. Kazakh lake 'could dry up'. BBS News, 15 January 2004. http://news.bbc.co.uk/2/hi/asia-pacific/3397077.stm
2. Water resources of Kazakhstan in the new millennium. New York: United Nations Development Programme. UNDP, 2004.
3. Environment and Development Nexus in Kazakhstan. A series of UNDP publication in Kazakhstan, #UNDPKAZ 06, Almaty, 2004. https://www.thegef.org/sites/default/files/ncsa-documents/2147-22347.pdf
4. World Bank, 2007, Drought Management and Mitigation Assessment for Central Asia and the Caucasus: Regional and Country Profiles and Strategies. https://reliefweb.int/report/argentina/drought-management-and-mitigation-assessment-central-asia-and-caucasus-regional-and
5. Natural Disaster Risks in Central Asia: A Synthesis. Michael Thurman, UNDP/BCPR, Regional Disaster Risk Reduction Advisor, Europe and CIS. 11 April 2011. http://www.undp.org/content/dam/rbec/docs/Natural-disaster-risks-in-Central-Asia-A-synthesis.pdf
6. Second Assessment of Transboundary Rivers, Lakes and Groundwaters. Published: August 2011. http://www.unece.org/env/water/publications/pub/second_assessment.html
7. Economic Commission for Europe Meeting of the Parties to the Convention on the Protection and Use of Transboundary Watercourses and International Lakes. Sixth session, Rome, 28–30 November 2012. http://www.unece.org/fileadmin/DAM/env/water/mop_6_Rome/Official_documents/ECE_MP.WAT_2012_L.1_e.pdf
8. Lessons learned from the preparation of the Second Assessment and plans for future assessments under the Convention. 2012. http://www.unece.org/fileadmin/DAM/env/water/mop_6_Rome/Official_documents/ECE_MP.WAT_2012_2_e.pdf
9. A proposed approach to assessing the Water-Food-Energy-Ecosystems Nexus under the UNECE Water Convention Discussion paper. 4 April, 2013. https://www.unece.org/fileadmin/DAM/env/documents/2013/wat/Nexus_mtg/NexusAssessment_DiscussionPaperOnApproach_final_forWeb.pdf
10. Бассейн реки Алазани/Ганых. Оценка взаимосвязи между водой, продовольствием, энергией и экосистемами. Подготовлено Королевским технологическим институтом (КТН, Стокгольм) под руководством секретариата Конвенции по трансграничным водам ЕЭК ООН. Первый проект отчета для комментариев со стороны соответствующих государственных органов. 19 июня 2014 г. https://www.unece.org/fileadmin/DAM/env/documents/2014/WAT/09Sept_8-9_Geneva/Alazani_Ganikh_River_Basin_Water-Food-Energy_-Ecosystems_Nexus_assessment_RUS.pdf
11. Working Group on Integrated Water Resources Management Tenth meeting Geneva, 24 and 25 June 2015 Item 8 of the provisional agenda, Thematic assessment of the water-food-energy-ecosystems nexus. https://www.unece.org/fileadmin/DAM/env/documents/2015/WAT/06Jun_24-25_IWRM_Geneva/Informal_doc_10_outline-nexus-stock-taking-report.pdf
12. Third meeting of the Task Force on the Water-Food-Energy-Ecosystem Nexus. 29 April 2015. http://www.unece.org/index.php?id=38157
13. Reconciling resource uses in transboundary basins: assessment of the water-food-energy-ecosystems nexus (chapter 5) ─ Summary nexus assessment of the Alazani/Ganikh River Basin. Published: June 2016 http://www.unece.org/index.php?id=42935

14. Reconciling resource uses in transboundary basins: assessment of the water-food-energy-ecosystems nexus in the Sava River Basin. 2016. https://www.unece.org/fileadmin/DAM/env/water/publications/GUIDELINES/2017/nexus_in_Sava_River_Basin/Nexus-SavaRiverBasin_ECE-MP.WAT-NONE-3_WEB_final_corrected_for_gDoc.pdf
15. Water Energy Food Environmental Nexus in Central Asia From Transition to Transformation. December 2017. DOI: 10.1007/698_2017_180 In book: The Handbook of Environmental Chemistry (pp.1-18)Chapter: Water Resources in Central Asia: International Context Publisher: Springer International Publishing AG Editors: S.S. Zhiltsov et al. https://www.researchgate.net/publication/321673745_Water-Energy-Food-Environmental_Nexus_in_Central_Asia_From_Transition_to_Transformation
16. Reconciling Resource Uses in Transboundary Basins: Assessment of the Water-Food-Energy-Ecosystems Nexus in the Syrdarya River Basin. Published: January 2017. https://www.unece.org/environmental-policy/conventions/water/envwaterpublicationspub/water/envwaterpublicationspub74/2017/reconciling-resource-uses-in-transboundary-basins-assessment-of-the-water-food-energy-ecosystems-nexus-in-the-syr-darya-river-basin/doc.html
17. First Regional Consultation Workshop: Assessing the Water-Food-Energy-Ecosystems Nexus in the North-Western Sahara Aquifer/ 18 - 19 July 2017. https://www.unece.org/environmental-policy/conventions/water/meetings-and-events/water/workshops-water-convention-and-protocol-on-water-and-health/2017/first-regional-consultation-workshop-assessing-the-water-food-energy-ecosystems-nexus-in-the-north-western-sahara-aquifer/doc.html
18. Assessment launched to reinforce cooperation between Algeria, Libya and Tunisia in managing shared groundwater resources. Published: 20 July 2017. http://www.unece.org/?id=46340
19. Disaster Resilience Scorecard for Cities. Preliminary level, Detailed Level Assessment. May 2017. https://www.unisdr.org/campaign/resilientcities/toolkit/article/disaster-resilience-scorecard-for-cities
20. Assessment of the water-food-energy-ecosystems nexus and benefits of transboundary cooperation in the Drina River Basin. January 2017. file:///C:/Users/Admin/Downloads/UNECE2017-Drina_final_report.pdf
21. The UNECE Nexus Assessment of the Drin River Basin. https://www.energy.kth.se/energy-systems/current-projects/the-unece-nexus-assessment-of-the-drin-river-basin-1.976513
22. Water in Kazakhstan, a Key in Central Asian Water Management. Aibek Zhupankhan, Kamshat Tussupova and Ronny Berndtsson. Published online: 22 Mar 2018. https://www.tandfonline.com/doi/full/10.1080/02626667.2018.1447111#:~:text=Thus%2C%20the%20total%20water%20resources,Kazakhstan%20in%20the%20new%20millennium
23. Methodology for Assessing the Water-Food-Energy-Ecosystem Nexus in Transboundary Basins and Experiences from its Application: Synthesis. UNECE. 2018. http://www.unece.org/fileadmin/DAM/env/water/publications/WAT_55_NexusSynthesis/ECE-MP-WAT-55_NexusSynthesis_Final-for-Web.pdf
24. The Water-Energy-Food Nexus: A systematic review of methods for nexus assessment. Tamee R Albrecht, Arica Crootof, and Christopher A Scott. Environmental Research Letters, 13 (2018) 043002. https://doi.org/10.1088/1748-9326/aaa9c6
25. Nexus Assessment of The Drin River Basin – Phases I and II. Lucia de Strasser, UNECE, 8th Expert Working Groups Meeting, 17th Meeting of the Drin Core Group. Pristina, May 2019. https://www.gwp.org/globalassets/global/gwp-med-files/list-of-programmes/see-nexus/drin-nexus-policy-dialogue/steering-committee-meetings/17th-

drin-core-group-2nd-steering-committee-meeting/de-strasser_pristina_ewgdcg-may-2019.pdf
26. Куда «уходит» Капшагай? На поверхности водохранилища показался затопленный поселок. Сентябрь 2020. https://spik.kz/kuda-ukhodit-kapshagay-na-poverkhnosti-vodokhranilishcha-pokazalsya-zatoplenniy-poselok-iliysk?fbclid=IwAR0lHy4nkHY7_KQlDDRnjANIvWHuZN8wvdWfUle_kPeoLlGyNDoBNE8hfxQ
27. Towards Sustainable Renewable Energy Investment and Deployment: Trade-offs and Opportunities with Water Resources and the Environment. Published: April 2020. http://www.unece.org/index.php?id=54348
28. The Nexus Methodology. https://www.unece.org/environmental-policy/conventions/water/areas-of-work-of-the-convention/envwaternexus/the-nexus-methodology.html
29. Концептуальная записка. Целевая группа по взаимосвязи между водой, продовольствием, энергией и экосистемами. Шестое совещание. Дворец Наций, Женева, Швейцария/виртуальное участие через платформу Interpfy. 22–23 октября 2020 г. http://www.unece.org/fileadmin/DAM/env/documents/2020/WATER/09Sep30-2Oct_15th_IWRM/INF.12_6th_Nexus_TF_ConceptNote_final_RUS.pdf
30. Project Reconciling Different Uses of Water - Work on the Nexus in Transboundary Basins, 19 December 2016. https://www.water-energy-food.org/fr/resources/project-reconciling-different-uses-of-water-work-on-the-nexus-in-transboundary-basins
31. Water-Food-Energy-Ecosystems Nexus - Assessment of The Isonzo/Soča River Basin (Italy, Slovenia). December 2016. https://www.minambiente.it/pagina/water-food-energy-ecosystems-nexus-assessment-isonzosoca-river-basin-italia-slovenia
32. Water, Energy and Environment. The SPECA Working Group on Water, Energy and Environment. https://www.unece.org/speca/wer.html
33. Report. United Nations Special Programme for the Economies of Central Asia (SPECA)
34. 23rd Session of the Working Group on Water, Energy and Environment
35. (2 October 2019, Tashkent, Uzbekistan). https://www.unece.org/fileadmin/DAM/env/Projects_in_Central_Asia/Report_23rd_Session_SPECA_WG_WEE_2019_Tashkent_final_ENG.pdf
36. Концептуальная записка. Целевая группа по взаимосвязи между водой, продовольствием, энергией и экосистемами. Шестое совещание. Дворец Наций, Женева, Швейцария/виртуальное участие через платформу Interpfy. 22–23 октября 2020 года. http://www.unece.org/fileadmin/DAM/env/documents/2020/WATER/09Sep30-2Oct_15th_IWRM/INF.12_6th_Nexus_TF_ConceptNote_final_RUS.pdf
37. Пустили на самотек. Почему водные ресурсы никого не волнуют в Казахстане. 9 Октября, 2020. https://holanews.kz/news/77463/?fbclid=IwAR3kj6w6_ellhyyPV8R1dcLuhDPYFPWegLjnuVhSLAiHtuz5U5VqQayPfXo
38. Управление ресурсами подземных вод трансграничных водоносных горизонтов (Проект ГГРЕТА). ОБЗОР И РЕЗУЛЬТАТЫ ОЦЕНКИ (2013-2015 гг.). https://groundwaterportal.net/sites/default/files/3650_15_GGRETA%20Brochure_Ru_PRINTED.pdf
39. Water–Energy–Food Nexus Framework for Promoting Regional Integration in Central Asia. Olimjon Saidmamatov, Inna Rudenko, Stephan Pfister, and Jacek Koziel. Article in Water, July 2020. https://www.researchgate.net/publication/342666282_Water-Energy-Food_Nexus_Framework_for_Promoting_Regional_Integration_in_Central_Asia
40. Проект «Центрально-Азиатский Диалог по использованию возможностей многосекторального финансирования путем усиления взаимосвязи «вода-энергия-

продовольствие». Идеи ВЭП Нексус проектов. Инвестиционный портфел. Октябрь 2019. https://carececo.org/main/ckh/publications/idei-vep-neksus-proektov-investitsionnyy-portfel/
41. Расширение возможностей для возврата инвестиций посредством применения подхода нексус: примеры передовой практики подхода нексус. 05.12.2019. Авторы: Джеймс Далтон, Ребекка Уэллинг , Кристин Майер , Мария Карреньо Линделин, П.Дж. Ридделл. https://carececo.org/main/ckh/publications/increasing-returns-on-investment-opportunities-by-applying-a-nexus-approach-best-practice-nexus-case/
42. БЮЛЛЕТЕНЬ НЕКСУС №1. РЭЦЦА. 04.12.2019. https://carececo.org/main/ckh/publications/byulleten-neksus-1/
43. Проект «Центрально-Азиатский диалог по использованию возможностей многосекторального финансирования путем усиления взаимосвязи «вода-энергия-продовольствие». Понимание подхода взаимосвязи водной-энергетической-продовольственной безопасности. Аналитическая записка. Июнь 2019 г. https://carececo.org/main/ckh/publications/analiticheskaya-zapiska-1-pochemu-neksus/
44. Проект «Центрально-Азиатский диалог по использованию возможностей многосекторального финансирования путем усиления взаимосвязи «вода-энергия-продовольствие». От «идеи» к «общим выгодам». Аналитическая записка. Июнь 2019 г. https://carececo.org/main/ckh/publications/analiticheskaya-zapiska-2-ot-idei-k-obshchim-vygodam/
45. Есекин Б.К., Водное партнерство для Центральной Азии, Монголии и Кавказа. ПЕРЕДАЧА ОПЫТА И ЗНАНИЙ. Экология и промышленность Казахстана. 2 /66/ 2020. https://drive.google.com/file/d/1_cwpph9VA9weNZjCd9lK8Cm7UrHU5ehX/view?fbclid=IwAR1WJKI6wd30HUuIBbl-ICa32XTPOxNWV-2231I3Ubl4FuA-ksnbXCKvqUU
46. ПАНЕЛЬ: «ЗЕЛЁНОЕ ВОССТАНОВЛЕНИЕ В ЦЕНТРАЛЬНОЙ АЗИИ». Презентация. Анна Кириленко. Экологическое Движение БИОМ. https://docs.google.com/presentation/d/1hm76RVpUcrKDK0cVRqYipH9gehHiL7yxswk83romg38/edit#slide=id.p1
47. Коксарайский контррегулятор - достижение независимости и гарантия безопасности южного региона. 30 декабря 2011. inform.kz https://www.inform.kz/ru/koksarayskiy-kontrregulyator-dostizhenie-nezavisimosti-i-garantiya-bezopasnosti-yuzhnogo-regiona_a2430103
48. Экологи оценили последствия изменения климата в Центральной Азии. 3 апреля 2019. https://uz.sputniknews.ru/society/20190403/11143924/Ekologi-otsenili-posledstviya-izmeneniya-klimata-v-Tsentralnoy-Azii.html
49. Reconciling resource uses: Assessment of the water-food-energy-ecosystems nexus in the North Western Sahara Aquifer System, Part A - "Nexus Challenges and Solutions. Published: September 2020. http://www.unece.org/index.php?id=55154

# ANNEX 1. CASE STUDIES FOR TRAINING

This Annex presents six case studies for training with the aim of practical training of students in nexus assessments after learning the theoretical foundations outlined in this manual "Water-Energy-Food-Ecosystems Nexus in the Context of Central Asia".

Students will use the nexus assessment methodology described in subsections "3.3. Goals, Key Principles and Limitations of the Nexus Assessment Methodology for Water, Food, Energy and Ecosystems" and "3.4. Methodological Approaches to Nexus Assessment", as well as additionally use and study the necessary information from the "List of the Used Information Sources" of this textbook.

Practical sessions will be conducted in small groups of 5–10 people, where students will participate in the assessment, acting as different interested countries, sectors and organizations of the represented model macroregion. The results of the model assessments will be presented by the groups in plenary session to discuss and compare different approaches for nexus assessment.

Before starting work in groups, students should choose a moderator, a speaker and develop agreed rules of work, such as:

- Do not ask everyone in the group to immediately participate in the discussion. Give all students an opportunity to familiarize themselves with tasks of assignment and description of case study and understand the problem.
- Do not set any restrictions so that everyone in the group could freely express any opinion.
- Do not immediately reject proposed ideas. Do not criticize! Create a friendly environment so that everyone in the group could freely express their opinions.
- There are no right and wrong ideas! Collect all proposals.
- During the discussion, write down absolutely all the proposals, without exception, on a flipchart!
- Provide an opportunity for students to add their ideas after working in a group, for example during a plenary presentation.

It should be noted that any coincidence of the description in the below presented case studies with any real geographic objects is accidental and does not imply the expression of any opinion on the part of the authors regarding the legal status of any state (territory or region), its authorities or regarding delimitation of its borders or territory.

**Case study No. 1. Description of the situation in the water, food, energy sectors and ecosystems of the hypothetical macroregion of the Saltlake-Kopsu Basin.**

**The objective of this case study**:

To show how ineffective water management, poor infrastructure and water crises are primarily the result of a governance crisis, a lack of coordination between stakeholders and imperfect legislation. To explain that the prevention of these problems by joint efforts in the dialogue between countries can prevent an environmental catastrophe and help to avoid the deterioration of the political and socioeconomic conditions for development in a hypothetical macroregion.


**Figure 6. Hypothetical map of the Saltlake-Kopsu Basin macroregion.**

Saltlake is a drainless freshwater lake with no outlet to the ocean, located in a natural basin in the southeast of the state of Saland. The lake is divided into two parts by the strait. Saltlake covers an area of approximately 16.5 thousand km² and is the only large freshwater lake in Saland. Saltlake is located at an altitude of approximately 340 m above sea level and has an elongated oval shape. Its length is about 600 km, its width varies from 10–20 km in the eastern part to 75 km in the western part. The length of the lake's coastline is 3000 km.

The climate in the area of the lake is desert. About 80 % of the territory of Saland has an average annual wind speed of 4–6 m/s. The average maximum temperature in July is about +30 C, in January – about -9 C. Average precipitation is 131 mm per year. The duration of the sunshine in Saland is very long – about 2500–3100 hours per year on average. The relative humidity is 55–60%. The lake freezes every year, and ice usually stays from November to early April, and the ice from the eastern part goes away with a delay of 10–15 days. Saltlake is located in semi-desert areas. To the north of the lake is a vast hummock, to the west is the Dala steppe, and to the south are the Su-Kopsu mountains, the Takdast and Sartat sands.

The lower reaches of the Saltlake-Kopsu Basin are home to almost 20% of Saland's residents (3.1 million people), including residents of Sivercity, the largest metropolis of Saland. The largest settlement on the shore of the lake is Saltlake City with 90 thousand inhabitants. The city is located on the northern shore of the lake, its backbone enterprise is the Saltlake mining and metallurgical plant, which uses the water of the lake. The plant is the largest polluter in the Saltlake region.

The lake is filled with 4 large rivers. There are also several small rivers, but all of them are mainly fed by snow, and therefore become shallow and dry up in May.

From the south, the largest of the above 4 rivers flow into the lake – the transboundary Kopsu River, which gives 80% of the inflow. Therefore, everything that happens on the bed of this river will directly affect Saltlake. The Kopsu River originates in the Su-Kopsu mountains in the neighboring state of Bigstan at an altitude of 3540 m. The climate and natural conditions in the vast areas of Bigstan adjacent to the border are very similar to those in Saland.

Saland and Bigstan are good neighbors, and the people of both countries reckon with each other. Bigstan is interested in the rich energy resources of Saland, which is very important for the growing demand of Bigstan for energy (especially oil and gas) in the future. Saland is interested in Bigstan's investment and technology. Of these two countries, only Saland has acceded to the "Convention on the Protection and Use of Transboundary Watercourses and International Lakes" (Water Convention).

The development of the transboundary Kopsu River is not actively discussed between the bordering parties and the signing of a limited number of bilateral agreements ultimately led to the fact that until today there is no agreement between the countries regulating the ecological flow of transboundary rivers and their tributaries.

In the north, from the Saland side, on the Kopsu River, the Kopsu HPP dam was built, which formed the Kopsu reservoir (60 km from Sivercity). Its maximum width is 20 km and maximum depth is 45 m. The waters of the reservoir are used for electricity generation and agriculture, and the coast of the reservoir is used for recreation.

At the same time, over the past 30 years, on the other southern side of the upper reaches of the Kopsu River in Bigstan, as a result of active development, there has been a sharp increase in the number of people in the Kopsu River basin, which required a significant increase in the area for cotton and grain crops, the construction of new canals, dams, reservoirs and energy sources on this transboundary river. Currently, Bigstan is already irrigating over 500 thousand hectares of land and 7 large mountain deep-water reservoirs have been built on its territory, filled by the Kopsu River and its tributaries originating in the territory of Bigstan.

As a result, Saland has faced a sharp shortage of water flow downstream, which caused the process of drying up of Salt Lake (out of 15 lake systems, only 6 remained), a decrease in crop yields and an increase in the process of desertification of the territories adjacent to the lake. The Kopsu reservoir was also threatened with drying out. In addition, the issue of water pollution in the transboundary river has become acute. On the Saland side, there was a massive death of fish. The hydro chemical study of bottom sediments at the section between the countries showed the presence of 32 pesticides and herbicides and their metabolites in the water. The flora and fauna of Saltlake, which is on the Ramsar Convention's list, are also endangered. There are about 19 fish species in the lake, more than 119 bird species on the territory of the reservoir 14 of which are listed in the Red Book. There are up to 65 species of unique plants growing on land and in water.

**Test questions:**

- What is the reason for the lack of dialogue between the countries on these water resources despite the good neighborly relations between these countries?
- What are the main reasons for the shallowing of Saltlake?
- What are the main policy questions that this nexus assessment should answer?
- How could the countries in the macroregion sharing a transboundary basin benefit from a nexus approach and how to root the possible opportunities on the current policies?
- What is the institutional and governance structure on the national level and the mechanisms for intersectoral coordination?
- What institutional and governance structures are needed on the macroregion/transboundary basin level to improve intersectoral coordination mechanisms?
- How can the various interlinkages be assessed and ranked by order of importance?
- What trade-offs can be offered to the countries in this situation? How could this be done?
- Compare with existing examples of assessments[93] aimed to foster transboundary cooperation by identifying intersectoral synergies and determining measures that could alleviate tensions related to the multiple needs of the riparian countries for common resources. Find which components of the assessment might be general and which might be specific to this case study?
- Are there prospects in these countries for the development of alternative energy sources and is there a potential for this?
- What additional gender problems or problems of youth and socially vulnerable groups can be solved by promoting the nexus approach?

[93] See Section 4. PERFORMED NEXUS ASSESSMENT WITH THE FOCUS ON ITS VARIOUS COMPONENTS

**Case study No. 2. Description of the situation in the water, food, energy sectors and ecosystems of the hypothetical macroregion of the Alpha transboundary river basin.**

**The objective of this case study:**

To show the importance of considering different climate predictions and development recommendations when making decisions in long-term and short-term planning. To show the interlinkages between different sectors of the economy, which may not be obvious, but affect each other. Students can refer to the description of examples in sections 4.1 and 4.2.

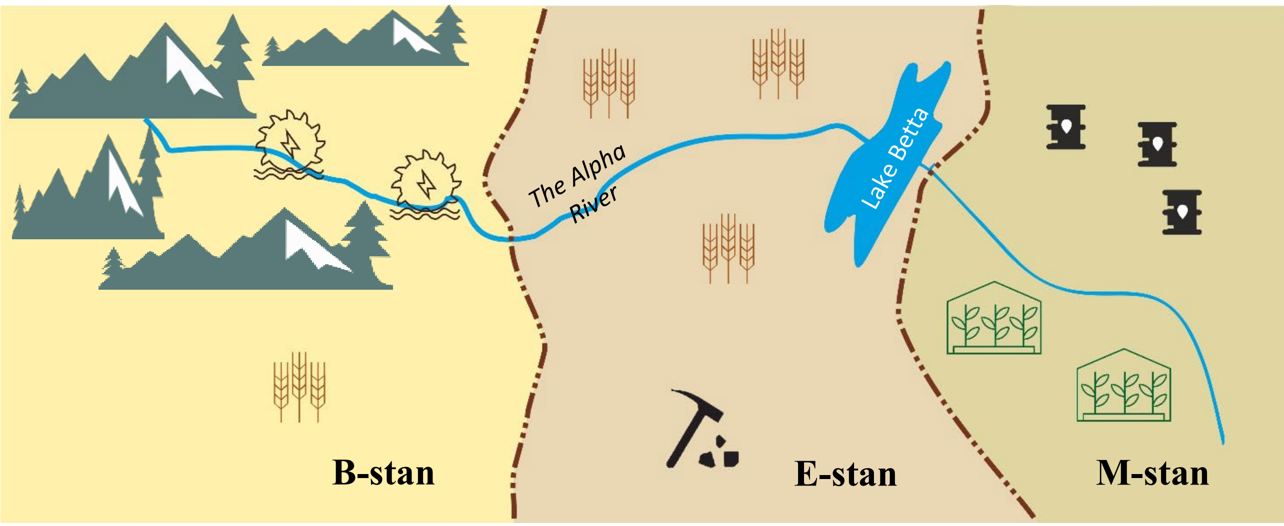



**Figure 7. Hypothetical map of the Alpha transboundary river basin macroregion.**

The Alpha transboundary river flows through the region, which covers three countries called B-stan, E-stan and M-stan, feeding all countries in the region. The river flow is formed in the B-stan mountains and passes through the fertile valleys of E-stan, ending up in the densely populated areas of M-stan.

The area of B-stan is 300 thousand km2, E-stan – 500 thousand km2, M-stan – 1.5 million km2. At the same time, the largest population lives in the territory of M-stan. The share of the urban population in M-stan is 60%, the share of the rural population is 40%. In the countries of B-stan and E-stan, on the contrary, the rural population predominates.

Climate change is projected to accelerate in this region due to continuing global warming. Although the methods used by hydrometeorological services differ between the mentioned countries, the general idea is that the temperature is expected to rise by about 1–2 degrees Celsius by 2030. Recent manifestations of climate change are actively affecting the melting of the B-stan glaciers, which in subsequent years will lead to a decrease in river flow. B-stan is a mountainous country with increased vulnerability to the climate change effects.

In the territory of E-stan, close to the M-stan border, on the Alpha River connecting the countries, there is Lake Betta, which is a place of attracting tourists from all three countries, but due to climate change, the ecological situation in the lake is close to catastrophic. In an attempt to save the lake, E-stan is building an additional dam to raise the water level. This leads to a reduction in the river flow for the summer period in the agricultural regions of B-stan and E-stan for M-stan located downstream. The reduction in the flow is forcing M-stan to introduce new resource-saving technologies and negotiate with the countries upstream the Alpha River about the water apportioning regime. All negotiations on water apportioning are carried out on the basis of existing agreements, which were signed more than 60 years ago, when the river flow was 30 % higher. It is important to note that B-stan is not a member of the UN Conventions on Climate Change and the Convention on the Protection and Use of Transboundary Watercourses and International Lakes. E-stan has accepted but not ratified both conventions, while M-stan is a party to both Conventions.

At present, greenhouse gas (GHG) emissions in B-Stan are low. The contribution of B-stan to global GHG emissions from fossil fuel combustion for one-year averages 0.05%, i.e. the volume of GHG emissions per capita in B-stan is more than three times lower than the world average. The indicators of E-stan are higher due to developed agriculture and imports of products not only to neighboring countries, but also to other countries and the presence of several mineral deposits. M-stan, being a more developed country due to the presence of a large number of oil and gas fields, has the highest GHG emissions in the region.

B-stan has a large number of hydroelectric power plants on the Alpha River. However, the expected climate change in the next 10 years will lead to a decrease in water flow and to a reduction in the potential of hydropower resources. As a result, even with an annual GDP growth of 5%, the hydropower potential of B-stan will be exhausted in a few decades.

B-stan is a country with a low average per capita income of $ 200. For E-stan, it reaches USD300, and for M-stan – USD500. To meet the needs, the economies of all countries will develop, and GHG emissions will also increase. The increase in greenhouse gas emissions is expected to be much faster than in developed countries. Despite this, the long-term goal of B-stan and E-stan is to reduce GHG emissions by 10 % compared to 1990 in the context of the 'below 2 C target, while M-stan has set a goal to reduce greenhouse gas emissions by 15 %.

Since the first submission of Nationally Determined Contributions (NDCs)[94] in 2015, the countries have worked on the plans to implement NDCs, and some countries have further developed mitigation measures for different sectors. At the same time, the countries are improving their databases and building capacity to prepare the 2020 NDC submission. NDC development is an intermittent process, with NDC submissions required every few years. Throughout the process, dialogue with stakeholders will be essential for all sectors of the economy within the nexus approach. As the countries move forward, it will be necessary to consider more ambitious actions with each new NDC[95] and take into account the nexus perspectives for the development and use of the macroregion's resources.

**Test questions:**

- Which sectors of the economy are most important for each country at this stage and in the future?
- Which sectors of the economy are most vulnerable to climate change and why?
- Which sectors of the economy should be targeted for adaptation measures, and which sectors should be targeted for mitigation measures to climate change?
- What are the possible ways to support the areas of the economy that will bear the burden of reducing greenhouse gas emissions?

[94] What will change when Nationally Determined Commitments (NDCs) replace Intended Nationally Determined Contributions (INDCs)? 5 first insights. https://infoclimate.org/chto-izmenitsya-s-prihodom-natsionalnyih-obyazatelstv/
[95] "... It is encouraging that most of the new climate commitments go beyond measures previously submitted by countries, setting more ambitious targets and increasing transparency, and taking into account the latest advances in science and technology."

- What is the potential for the representatives of the responsible structures to understand the relationship of climate change with the main sectors of this macroregion?
- What specific steps can be taken in the first stages?
- What are the prospects the nexus assessment for water, food, energy and ecosystem resources?
- What is the potential for dialogue: previous experience, political ties, existing agreements on water distribution, common power grids, etc.? Where can the countries find connections and trade-offs for agreement?
- Compare with existing examples of assessments aimed to foster transboundary cooperation by identifying intersectoral synergies and determining measures that could alleviate tensions related to the multiple needs of the riparian countries for common resources? Find which components of the assessment might be general and which might be specific to this case study?

**Case study No. 3. Groundwater resources management: an aquifer in a transboundary context.**

**The objective of this case study:**

To show how ineffective management of groundwater resources leads to unbalanced exploitation of complex resources (in terms of quantity, quality and interaction with surface waters), and how important it is to take into account the interactions of a transboundary aquifer with other aquifers and surface waters in its management.

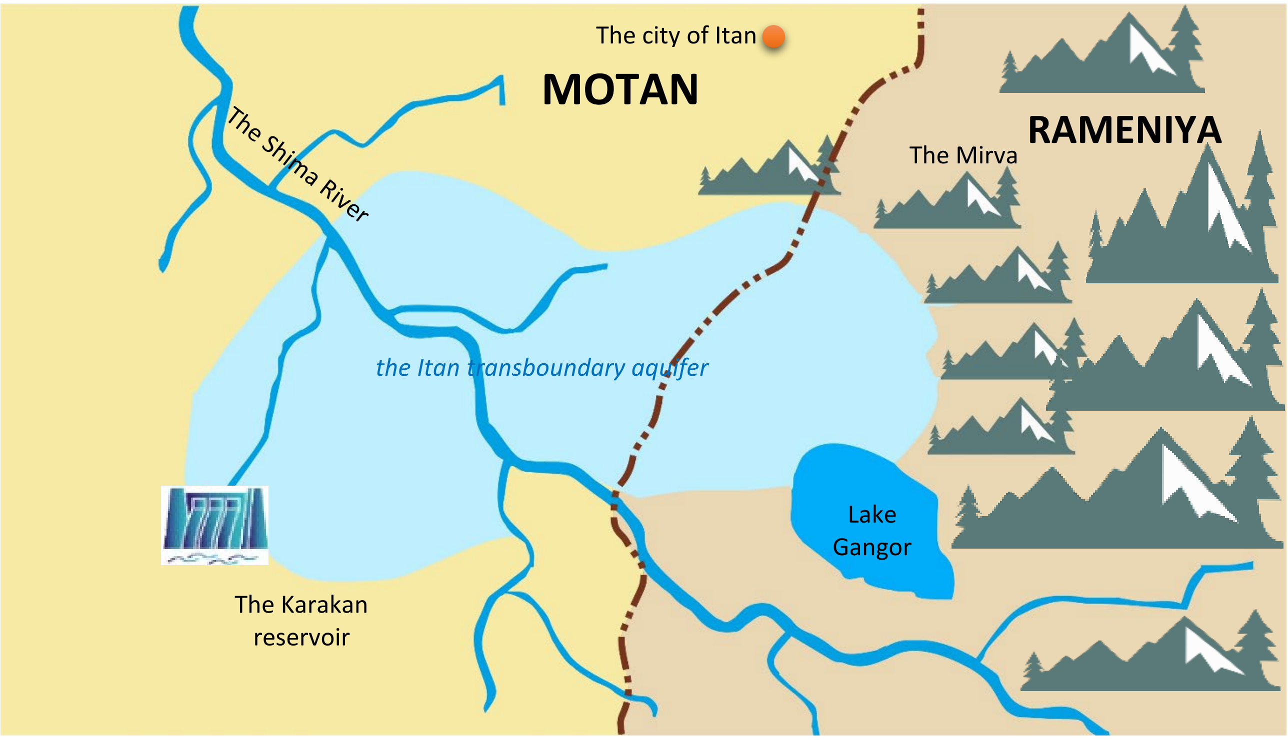



**Figure 8. Hypothetical map of the Itan international transboundary aquifer (ITA) basin macroregion.**

The Itan international transboundary aquifer[96] (ITA) is located within two states – Motan and Rameniya. This is the largest aquifer in the region, which contains fresh water reserves and is artesian, it is characterized by the free flow of water from wells. The area of the aquifer in Motan is 950 km2, and in Rameniya it is 605 km2.

This aquifer occurs at a considerable depth within the foothill and alluvial[97] plains. The Itan ITA in the north-east and east of Motan borders on the spurs of the Mirva mountains, and in the south and west on the territory of Rameniya it borders on the Karakan reservoir (area of 830 km2). The Karakan Reservoir is a wetland of national importance and is known for its rare and endangered species of waterfowl.

[96] "Aquifer" means a permeable water bearing geological formation underlain by a less permeable layer and the water contained in the saturated zone of the formation. This definition is taken from UNGA Resolution A/RES/63/124 on the Law of Transboundary Aquifers and the draft articles contained therein (2008).

[97]The alluvial plain (from the Latin alluvialis) is a plain that arises as a result of the accumulative activity of large rivers. Especially vast alluvial plains arise when rivers wander in areas of tectonic subsidence. From the surface, they are formed by river sediments (most often sands of various sizes), the thickness of which can reach several hundred meters.

In the territory of Rameniya there is a small lake Gangor, and a large transboundary river Shima flows in the area where the Itan ITA is located in the territory of both countries. The Shima River is fed by melting snow, its average annual flow is 39 km3. The region is characterized by an arid continental climate with hot summers. In general, the climate in this area is characterized by low humidity and low rainfall.

Within Motan, the territory of the Itan ITA is one of the most densely populated, including the population of the capital of Motan, the city of Itan. The population at the beginning of 2019 was 650 thousand people, of which 24 % were urban and 76 % rural. Analysis of population dynamics showed that the region is experiencing significant population growth.

The main industries in the ITA are agriculture, mining, traditional (non-renewable) energy. In winter, the inhabitants of the region, due to the limited supply of electricity and the lack of central heating, use firewood from the nearby forest belts for heating and cooking. A decrease in the number of trees due to such cutting leads to land degradation and disruption of filtration processes. 80 % of the total water intake is used for agricultural purposes, and most of the rest is used for domestic and drinking water supply. Within the territory of the ITA, there are 900 thousand hectares of agricultural land, 63% of which is located in the territory of Motan. From 1970 to 2019, there was an increase in the area of agricultural land by 1.8 times due to an increase in the area of pastures.

The increase in the population in the territory of the transboundary aquifer has led to an increase in the volume of water withdrawal for domestic and drinking water supply, both from surface and groundwater. The poor irrigation infrastructure and poor agricultural practices in the Motan region threaten water and land resources.

Although Lake Gangor is also used for irrigation and domestic needs, rising temperatures in the region have led to a marked decrease in the water table in Rameniya. Scientists expect this trend to continue and believe the lake will no longer be used for recreational activities within 6-7 years and will no longer be able to provide water to communities around the shores of Lake Gangor by 2030. Moreover, it added an additional burden to the use of groundwater.

Consequently, in the future, the demand for water resources will grow due to (a) demographic growth, (b) economic development and (c) possible climate change. The main problem associated with the Itan ITA is the inevitable depletion of groundwater reserves as a result of their withdrawal and the weak legislative framework of the law on environmental impact assessment in both states.

According to experts, intensive industrial and agricultural activity over the past 40–50 years has had a negative impact on the state of fresh groundwater, has led to the depletion and reduction of its reserves by 40 %, including due to uncontrolled selection by various economic entities building unauthorized wells. Inefficiency of irrigation systems and irrational organization of drainage systems for irrigation purposes, in turn, have led to an increased level of salinization of water and soil and a general deterioration of the environment. In the next ten years of operation, the current gushing wells will lose their artesian character and water from them will have to be pumped, and in the long term, the groundwater level may drop below the level that is minimally necessary for operation from a technical or economic point of view.

At the same time, the existing network of observation wells for monitoring groundwater in the territory, consisting of 1,100 points, does not allow timely and full identification of the development of negative processes that cause pollution of aquifers, depletion of reserves and flooding of urban areas.

Obviously, when managing the Itan ITA, its interaction with other aquifers, as well as with surface waters, should be taken into account, and therefore an integrated approach to water resources management is required. Both states – Rameniya and Motan, taking into account this situation, decided to pay special attention to expanding the network of observation points for state monitoring of groundwater in the zones of their formation and exploited deposits, in the territories of transboundary aquifers, as well as within industrial and urban agglomerations, large hydraulic structures and irrigation and drainage systems. It was also decided to strengthen the administrative and operational management of groundwater resources.

A key element of the Constitutions of Rameniya and Motan is the provision that "every citizen has the right to a clean and healthy environment and to adequate access to food and water". The Motan Law on Water Resources and Security provides for the inclusion of water security issues in the national environmental plan for 2020–2030, as well as in national plans for adaptation and mitigation of climate change.

Your group is tasked with defining how the areas of the current legal environmental situation in Rameniya and Motan should be addressed. You should also make suggestions for possible recommendations on how to better codify water resources and water security in the legislation and policies of both countries, and identify the most important areas requiring attention. What are your recommendations?

**Test questions:**

1. What are the main reasons that can lead to the exploitation of groundwater?
2. Why is it necessary to organize monitoring and assessment of transboundary groundwaters?
3. What should be taken into account when managing the Itan ITA?
4. What levels cover the administrative and operational management of groundwater resources?
5. What institutional and governance structures are needed on the transboundary aquifer level to improve intersectoral coordination mechanisms?
6. What additional local measures can reduce the pressure on groundwater use?
7. How can the nexus approach contribute to solving problems in the macroregion?
8. What are the milestones to be considered when introducing the nexus approach in the region?
9. Compare with existing examples of assessments aimed to foster transboundary cooperation by identifying intersectoral synergies and determining measures that could alleviate tensions related to the multiple needs of the riparian countries for common resources. Find which components of the assessment might be general and which might be specific to this case study?

## Case study No. 3. Description of the situation in the water, food, energy sectors and ecosystems of the hypothetical Landland-Uzeriya macroregion

### The objective of this case study:

To show how man-made disasters arising from ineffective land use management and the poor state of the infrastructure of a transboundary watercourse lead to flooding and a decrease in the area of agricultural land, destruction of infrastructure, deterioration of quality, pollution and degradation of soil, cause material damage to the population and worsen quality of life of the population.

To explain that the prevention of these problems by joint efforts and in dialogue between countries can improve safety on transboundary watercourses and help to avoid man-made disasters and deterioration of political and socioeconomic conditions for development in the hypothetical macroregion. Students can refer to the description of examples in section 4.2.


**Figure 9. Hypothetical map of the Landland-Uzeriya macroregion and the scale of flooding from the Bordogul reservoir**

Sunny region is the southernmost region of Landland. The region is surrounded on three sides by the territory of Uzeriya, and on the fourth side it adjoins the Great reservoir from the Landland side. The Great reservoir is located in Landland, it has a length of 80 km, a width of 25 kilometers, an area of 783 sq. km, the total volume is 5.7 cubic km, useful volume – 4.2 cubic km. In some years it was reported that the critical maximum volume reached 5.5 cubic km. A low-pressure run-of-river hydroelectric power plant is also located in the Great reservoir (the hydroelectric power plant is part of the pressure front). In dry years, the water level can drop below the “dead storage capacity”, but with a decrease in volume to 0.5 cubic km there is “dirty goo”. Water consumption: long-time average annual – 626 cubic meters per second, summer minimum – 56.3 cubic meters per second, winter minimum – 137 cubic meters per second, through all 4 turbines at a design head – 780 cubic meters per second. Locks were installed to control the water level in the reservoir. Once there was already a strong flood in the Great reservoir, the sluices were opened, since the capacity of the hydraulic units was not enough. As a result, 21 cubic km of water (almost 60 % of the annual flow of the Kul Dariya River) was directed from the Great reservoir to the lowland in Jumak region of Uzeriya. As a result, Lake Sharmankul was formed. Over the next two years, another 7 cubic km was discharged. The increase in discharges was associated with the transfer of the Bordogul reservoir to the energy regime and a significant increase in winter passes. The volume of water in Sharmankul exceeded the usable capacity of the Great reservoir by 10.5 times.

The Bordogul reservoir, located in Uzeriya, was built near the Kul Dariya River, a few tens of kilometers from Landland. The Bordogul reservoir holds 922 million cubic km and is intended for irrigation of agricultural land in Kul Darya and the neighboring Jumak region of Uzeriya. Also, in the future, it is planned to build a hydroelectric power plant with a capacity of 15 MW. A recreation area will be created on the territory adjacent to the reservoir. The construction of this one of the largest hydraulic structures in the country was supervised by the Prime Minister and President of Uzeriya. According to media reports, over 82 million euros have already been spent on the facility. This year the construction of a small hydroelectric power plant with a capacity of 10.7 MW has begun at the Bordogul reservoir. It is planned to spend 21 million euros on the project.

But one day, early in the morning, one of the dams of the Bordokul reservoir broke through. As a result, several settlements were flooded, roads were destroyed, and about 70,000 residents of nearby areas were evacuated. Large water covered the villages of Sunny region of Landland, where more than 1,030 houses, three schools, five kindergartens, four medical facilities and a community center were damaged. More than 30 thousand people were evacuated from 14 localities, 9 thousand hectares of sown fields were flooded. The Government declared the man-caused emergency. In Uzeriya itself, a water spill also occurred and flooded a settlement in Kul Dariya region. About 90 thousand people were evacuated, 4 people died, one went missing as a result of the flood.

The General Prosecutor's Office opened a criminal case on the fact of the incident. According to the authorities, the cause of the man-caused accident was a stormy wind, which caused a powerful wave, which destroyed part of the dam. At the same time, meteorological services deny the presence of strong winds at the specified time. Reconstruction work continues at the site of the emergency. A government commission has been created to eliminate the consequences of the flood. The operational headquarters is personally led by the president of the country of Uzeriya. In addition, an intergovernmental Uzeriya-Landland group was created to eliminate the consequences of the emergency and resolve all issues. According to the media information of Uzeriya, during the construction of the Bordogul reservoir, significant violations and thefts were committed, which affected the quality of the materials used.

As a result of the incident, according to media information, it became known that about 3,601 hectares of crops had already been flooded. On the route of international importance in Kul Dariya region, water reached the surface of the highway, and the road from the capital to other cities was temporarily closed. According to the most conservative preliminary estimates, the damage amounted to 800 thousand euros.

The most affected areas are the villages of Landland. The houses built of adobe suffered the most – they turned into a clay mess. All household plots of villagers in the flood zone were flooded. The least damage was done to houses made of brick. In Uzeriya, it turned out that 85 % of the flooded area is cotton, the rest is alfalfa and corn fields. Currently, 95 specialists are taking inventory of flooded arable land and livestock losses. There is still little opportunity to fully assess the damage to the value of arable land and livestock in Sunny region. Today, the evacuation of livestock in villages with the risk of flooding in Sunny region continues. 3,115 heads of cattle, 1,100 horses, 585 sheep and 35 camels have already been evacuated from 8 settlements affected by the floods of Sunny region. The number of drowned animals is still unknown, the water level is still high. Residents of the affected areas were evacuated; during the emergency, a temporary tent camp was created for them for more than a thousand people.

**Test questions:**

1. How do you assess the status of reservoir safety monitoring and analysis of lessons learned in the past?
2. What is the reason for the lack of dialogue between the countries on these water resources despite the good neighborly relations between these countries?
3. What are the main reasons that could lead to the destruction of the dam of the Bordogul reservoir? Which organizations and officials are responsible for this situation?
4. How can neighboring territories formulate an agreement to prevent hazards in transboundary watercourses?
5. In such situations, how can local farmers secure themselves in order to preserve their agricultural land and continue their food production activities with little loss?
6. What are the main policy questions that this nexus assessment should answer?
7. How could the countries in the macroregion sharing a transboundary macroregion benefit from a nexus approach and how to root the possible opportunities on the current policies?
8. What is the institutional and governance structure on the national level and the mechanisms for intersectoral coordination?
9. What institutional and governance structures are needed on the transboundary macroregion level to improve intersectoral coordination mechanisms?
10. How can the various interlinkages be assessed and ranked by order of importance?
11. What trade-offs can be offered to the countries in this situation?

**Case study No. 5. Description of the situation in the energy, water and food sectors and ecosystems of the hypothetical macroregion of the Darmiya transboundary river basin.**

**The objective of this case study:**

To show the need to foster transboundary cooperation by identifying intersectoral synergies and determining measures that could alleviate tensions related to the multiple needs of the riparian countries for common resources. Also, to show what should be considered when conducting nexus assessments in transboundary basins. Their multidisciplinary experience should be taken into account and attention should be paid to rebuilding the regional network and revitalizing the energy market; in particular, increasing the efficiency of generation, transmission and consumption of energy. It is also important to improve the efficiency of water use in agriculture.

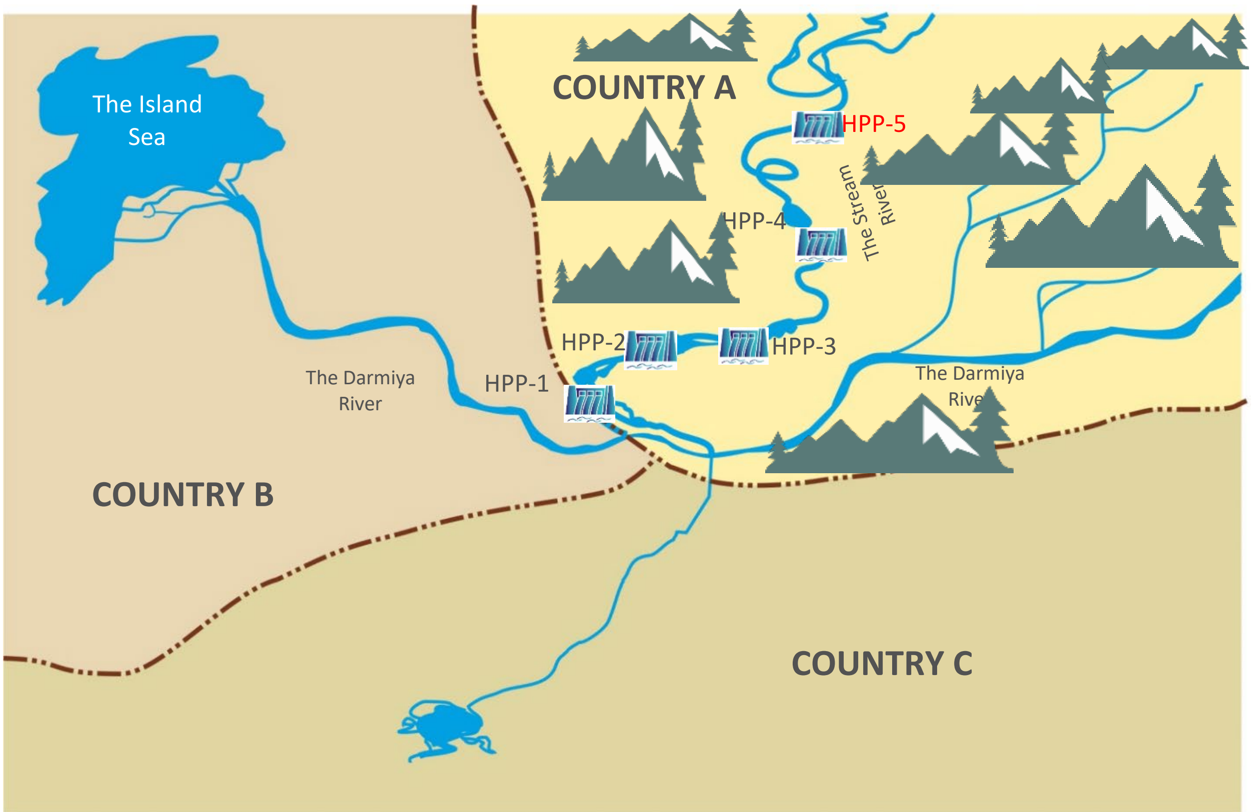



**Figure 10. Hypothetical map of the Darmiya transboundary river basin macroregion.**

The Stream River, which forms on the territory of Country A, makes a significant contribution to meeting the water needs of Country B and Country C located downstream. The Stream River is the largest tributary of the large transboundary river Darmiya, which flows through Countries B and C and fills the Island Sea in Country B. The Stream River accounts for 25 % of the Darmiya Basin runoff and about 50 % of the hydropower potential of Country A. Currently, 4 hydroelectric power plants have already been built on the Stream River (HPP-1, HPP-2, HPP-3, HPP-4), generating about 15 billion kWh of electricity per year. In the future, Country A may build another large HPP-5 (3600 MW) on the Stream River. On the one hand, the construction of a whole cascade of hydroelectric power plants increases the possibilities of long-term flow regulation in the interests of all states of the river basin. On the other hand, there is a risk of deterioration of relations with neighboring countries in the event of an increase in the operation of the cascade of reservoirs in the energy regime in the interests of the energy system of Country A. As it known, Country A, located upstream, is interested in discharging the maximum volumes of water in winter, when the demand for electricity reaches its peak, while Countries B and C, located downstream, need maximum volumes of water in summer during the irrigation period.

Under certain conditions, the project of a new hydroelectric power plant can have a significant impact on the regulation of the Stream River flow and, accordingly, on the volume and regime of use of water resources received by neighboring countries. As it is known, in accordance with the norms of international law, the absolute sovereignty of the upstream country over the available water resources is unacceptable. The current agreement on water apportioning, adopted by these countries, does not automatically imply the approval of the riparian countries for the creation of any hydraulic structures on transboundary rivers. In this regard, it is extremely important for the countries of the region to establish close cooperation to prevent possible negative consequences of the construction of hydropower facilities for the downstream countries. The obligation to cooperate is a general obligation of all states within the framework of customary international law, including in relation to transboundary water resources.

Large hydropower plants are designed to play an important role in the economic development of states (creation of new jobs, regional and industrial development with an increase in export potential). At the same time, in recent years, the understanding of the significant impact of large hydraulic structures on society and the environment has also increased throughout the world. In assessing options for dam construction, the social and environmental aspects of the project should be given the same, if not more, importance as the technical and economic factors. Taking into account that under the previous conditions the ecological role of water resources, including the water requirements of ecosystems from the standpoint of their sustainability, was not considered at all, the requirement for an ecological examination of hydropower projects, especially of such large-scale ones, seems to be extremely urgent. The main water management problems are concentrated in the lower reaches of the Darmiya River in Countries C and B, where there is an acute shortage of water during normal or dry years. This results in a lack of flow to maintain the wetland ecosystem, natural habitats and maintain the level of the Island Sea. Soil salination increases due to water losses in irrigation channels and cultivation of unstable monocultures.

There is a possibility that unilateral actions of Country A regarding the construction of HPP-5 and uncoordinated regulation of the regime of the transboundary river Darmiya could push gas-rich Countries B and C to restrict and even stop supplies of gas and mineral fertilizers to Country A and reorient export flows to other markets. In particular, the gas of Countries B and C can be in demand on the markets of other countries, and the export of fertilizers, most likely, can be carried out to other countries of Asia and far abroad.

At the same time, all three countries are trying to build good economic and political ties and have adopted multilateral regional agreements and bilateral agreements on the use of water resources of international watercourses and even created an Interstate structure to regulate water flows in the Darmiya River basin.

The scale of the new HPP project requires the attraction of external investments in conditions of limited financial possibilities for solving the problem of developing the hydropower potential of Country A. The common interest of the countries of the region in the implementation of the new hydropower plant project and attracting foreign investment can become one of the main factors in achieving mutually beneficial agreements on water use. But how can this be achieved?

**Test questions:**

- How do you understand the risk of deterioration in relations with neighboring countries downstream in the event of the operation of a cascade of reservoirs in the energy regime in the interests of the energy system of one country located upstream?
- What is the reason for the lack of dialogue between the countries on these water resources despite the good neighborly relations between these countries?
- Compare with existing examples of assessments aimed to foster transboundary cooperation by identifying intersectoral synergies and determining measures that could alleviate tensions related to the multiple needs of the riparian countries for common resources. Find which components of the assessment might be general and which might be specific to this case study?
- What are the main policy questions that this nexus assessment should answer?
- How could the countries in the macroregion sharing a transboundary basin benefit from a nexus approach and how to root the possible opportunities on the current policies?
- What is the institutional and governance structure on the national level and the mechanisms for intersectoral coordination?
- What institutional and governance structures are needed on the macroregion/transboundary basin level to improve intersectoral coordination mechanisms?
- What alternatives and trade-offs can be offered in this situation?

**Case study No. 6. The Mogrul reservoir and hydroelectric power plant as an example of a complex search for consensus on water and energy resources management between the countries upstream and downstream of the Anduin River basin**

## The objective of this case study:

To show the overall situation with the management of water and energy resources of the model macroregion using the example of the use of the Mogrul reservoir and hydroelectric power plant. To help solve the widespread problem of water use for electricity and irrigation in agriculture in the region, taking into account the different approaches to the use of water resources in the countries upstream and downstream of the Anduin River. Students can refer to the description of examples in section 4.2.


**Figure 11. Hypothetical map of the Anduin transboundary river basin macroregion.**

The Saryn River is a tributary of the transboundary Anduin River. Their total length reaches 3,019 km. The Anduin River originates in Moria and flows through the neighboring countries of Gondor and Isengard to the Great Sea in the country of Eribor. The territory of the two upstream countries, Moria and Gondor, is predominantly mountainous, and in the two countries downstream of the Anduin, Isengard and Eribor, steppe and semi-desert zones prevail. The climate of the region is severely continental, in the downstream countries it is desert-steppe, arid – with severe frosts in winter and hot summers.

The flow of water into the Anduin River and its tributary Saryn is mainly regulated by the Mogrul reservoir, which is formed by a high-pressure dam with a dam building of the Mogrul hydroelectric power plant on the Saryn River in the mountains in Moria. The surface area of the reservoir is 284 km. The maximum water level in the reservoir is 19.5 billion cubic meters, the normal level is 17.3 billion cubic meters, and the useful volume of water is 14 billion cubic meters, which allows for long-term flow regulation. The so-called "dead" volume leading to the shutdown of the hydroelectric power plant is 5.5 billion cubic meters. The installed capacity of the power plant is 1,200 MW, the design average annual power generation is 4,400 million kWh. The waterworks facilities are located in a narrow mountain gorge. Due to the obsolescence of the equipment after 40 years of operation, the Mogrul HPP is being modernized to increase the plant's capacity to 1,440 MW.

Over time, violent conflicts began to arise between the countries lying along the Anduin over water apportioning. While the upstream countries (Moria and Gondor) constantly face energy shortages in winter, the downstream countries (Erebor and Isengard) experience summer water shortages for irrigation purposes. The downstream countries appeal to the original agreement that "the main purpose of the Mogrul reservoir is the long-term compensatory regulation of the Saryn River flow in order to increase the water availability of irrigated agriculture in the Anduin River basin. The use of the reservoir for energy purposes is secondary." The upstream countries claim that Moria can use the Mogrul reservoir exclusively for its own purposes, since the hydroelectric power plant provides 70 percent of the electricity for the entire country and, accordingly, is a strategic facility.

Initially, the countries managed to negotiate and use the reservoir both in "irrigation" and "energy" regimes. The upstream countries, receiving electricity from hydroelectric power plants, practically do not have their own hydrocarbon resources, and they have to purchase them. The downstream countries, on the contrary, are rich in hydrocarbon resources, especially oil and gas, and have a population that is 4 times larger than that of the upstream countries and is mainly engaged in agriculture. All four countries are members of the Common Economic Community. During this period, the riparian countries preferred to regulate water apportioning based on bilateral agreements. Such agreements were signed between Isengard and Moria, Eribor and Moria. These agreements stipulated the volume of water releases from the Mogrul reservoir, Isengard and Eribor received electricity from Moria, which was excessively generated at this hydroelectric plant. And in the winter, they supplied Moria with energy, providing coal and gas. A new agreement is concluded every year.

However, until now the countries have not come to an agreement on the regimes of operation of the reservoir. On the contrary, the problem serves as a constant source of tension in relations between these countries. And the degradation of the environment, climate change, including an increase in dry years, and population growth, can cause new outbursts of tension around the issues of water apportioning, which, in turn, will increase the possibility of an armed conflict in this macroregion. For example, power outages in Moria (as it was not possible to use the Mogrul reservoir for energy production during the winter) led to frequent rolling blackouts and contributed to growing public discontent and a sharp exacerbation of the socioeconomic situation and changes in the country's leadership in Moria.

Attempts have been made on several occasions to regulate water apportioning through regional agreements and regional water management institutions. But, although these agreements and institutions were created in the best traditions of good neighborliness, as in previous times, their real effect leaves much to be desired.

At the same time, in all countries there is a growing understanding that actions to adapt to climate change should be integrated into development and planning policies at all levels of the territory: region, district, village. The countries agree that low water level and water scarcity are not an isolated case, but the result of the onset of climate change, and it is necessary to start planning all socioeconomic and economic activities taking into account adaptation measures. The countries are aware of the need to improve the technical condition of water management systems, increase the level of implementation of new irrigation technologies, train farmers in effective water use and agricultural technology, expand the use of rational water-saving irrigation methods and agricultural techniques that contribute to the efficient use of water and land resources.

Your group has the task of finding ways and compromises that satisfy all the indicated model countries to address basic water conservation issues in the region.

**Test questions:**

- What are the main reasons leading to a decrease in the water level of the Mogrul reservoir?
- Under what basic (climatic, etc.) conditions were attempts made to find an optimal solution for the hydropower use of the reservoir?
- What attempts have countries made to find a compromise?
- What is the reason for the lack of regular dialogue between the countries on these water resources despite the good neighborly relations between these countries?
- How can the upstream and downstream countries of the Anduin Basin share a transboundary basin benefit from the nexus assessment, and what policy steps are needed for this?
- What are the existing mechanisms for coordinating actions between countries, have the appropriate structures been established?
- What institutional and governance structures are needed on the macroregion/transboundary basin level to improve intersectoral coordination mechanisms?
- What solutions could be proposed for the countries in this situation and how could this be done?