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Abbreviations

ADB – Asian Development Bank

CIS – Commonwealth of Independent States

EBRD – European Bank for Reconstruction and Development

EDB – Eurasian Development Bank

EU – European Union

EurAsEC – Eurasian Economic Community

GW – gigawatt

HPP – hydropower plant

IBRD – International Bank for Reconstruction and Development

IFC – International Finance Corporation

IRENA – International Renewable Energy Agency

kWh – kilowatt-hour

MW – megawatt

TWh – terawatt-hour

UNDP – United Nations Development Programme

Main Conclusions

Small hydroelectricity potential is usually assessed from the point of view of whether the use of watercourses is efficient. Small hydroelectric power plants (HPPs), as other power generating facilities, have their advantages and disadvantages.

The economic, environmental and social advantages of small hydropower are the saving of fossil fuels and construction materials, minimal environmental impacts and relatively short payback periods. Small HPPs are effective for small and medium–sized businesses, the services and tourism sectors, agriculture and industrial production.

The disadvantages of small hydropower that can affect its efficiency include unstable power generation because of the hydrological conditions of small rivers, the possibility of accidents during high water periods, and the quick silting of reservoirs near plants' dams. Common problems surrounding small hydropower in the CIS are the lack of knowledge about hydrological and flow conditions of small watercourses; the lack of mass production of equipment and maintenance services for it; and relatively high unit costs (in some instances). Regulations and specifications governing design, construction and installation are not sufficient.

For these reasons, better economic conditions are needed to launch high–tech production and maintenance facilities for small hydroelectricity generating equipment. The legislation on renewable energy sources needs to be further improved and standardised. New technical regulations are needed to provide small hydropower plants and other renewable energy facilities with access to power systems, and these should be based on best international practice. Special guaranteed tariffs on electricity produced by small HPPs are deemed expedient, as is an obligation for power grids to buy this energy or its surplus not consumed by the plant owner. Research and engineering work needs to be financed and private investment should be attracted in the sector. In addition, professional training needs to be arranged.

Introduction

World energy consumption has risen by 70% since 1971 and continues to increase at an average world rate of about 2% a year (with some slowdowns during economic crises in developed and developing nations). Renewable sources account for 16% of world energy generation. Hydropower is the most advanced and flexible source of renewable energy, accounting for 87% of its output (World Energy, 2007).

The first decades of the 20th century were a period of grand hydropower projects. Large hydroelectric power plants (HPPs) were launched in the United States, the former USSR, China, India, Turkey, Iran, Iraq, Canada, Africa, and Latin America. Latin America, North America and Europe have significant hydro potential, a large part of which has been already utilised. In East and South Asia and Africa hydropower is an underdeveloped sector.

Russia ranks fifth in terms of installed hydroelectricity capacity and generation after China, Canada, Brazil, and the United States. Norway, Iceland and Canada are the top three countries ranked by per–capita hydroenergy production. In Norway, HPPs generate 98–99% of the country's entire energy output. In addition to fully satisfying its home energy needs, Paraguay exports 90% of energy produced by its HPPs to Brazil and Argentina.

	Electricity generation in 2008 (billion kWh)	Electricity generation in 2009 (billion kWh)	Installed capacity (GW)	Hydroelectricity share in country's total energy production (%)
China	522.4	548.9	196.8	22
Canada	369.5	363	88.9	61
Brazil	365.8	387	69	85
U.S.	254.8	272.1	78.1	6
Russia	167.5	176	47.4	21
Norway	138.1	124.9	27.5	98
India	113.1	104.4	33.6	16
Venezuela	86.7	85.8	14.6	69
Japan	75.4	75.1	27.2	7
Sweden	68.3	64.4	16.2	44

Table 1.
Hydroelectricity output by country

Source: Russian Hydropower in 2011–2015: Technical Conditions of Hydroelectricity Power Plants and Investment Projects. Industry Survey

In more than 60 countries HPPs account for at least 50% of total energy consumption. They also help fight floods and provide water for irrigation. In 2006, the installed capacity of the world's largest HPPs reached 770 GW and their energy output 2,725 TWh.

Hydroelectric power plants differ by head and capacity. «Head» refers to the difference in height between the water's source and its outflow. Each country uses its own classification and the parameters we provide in this report are sometimes just reference figures. In terms of the maximum head, HPPs can be high–head (over 60 m), medium–head (25 to 60 m), and low–head (3 to 25 m). In terms of installed capacity, they can be large (250 or more MW), medium (10–50 to 250 MW), and small (1–10 MW or, in some cases, up to 50 MW).

1. Modern Trends in Developing Small Hydropower

According to the International Energy Agency's (IEA) World Energy Outlook 2008, the average annual growth of electricity generation by large HPPs in 2007–2030 is predicted to be 2%. By 2030, hydroelectricity generation by large HPPs is expected to exceed 4,380 TWh, but the proportion of large HPPs' contribution to world electricity generation is expected to decrease to 12.4% (World Energy Outlook, 2008). From 2001 to 2006, the average growth of the world's small HPPs' capacity was 7%. By 2006, their installed capacity had reached 73 GW and power generation 250 TWh.

In 2006, the world's total investment in small hydropower was approximately $6 billion. The average cost of construction of small HPPs varied from $1,500 to $2,500 per kW of installed capacity.

Small HPPs account for 8.3% of electricity generation in Switzerland, 2.8% in Spain, almost 3% in Sweden, and 10% in Austria. China has the largest small hydro capacity (47 GW), followed by Japan (4 GW), the United States (3.4 GW), Italy and Brazil.

Table 1.1.
Share of hydropower (including small hydro) in world electricity generation

Source: World Energy Outlook, 2008

Energy source	Electricity generation (TWh)		Share (%)		Growth rate (%)
	2006	2030	2006	2030	2007–2030
Large plants	2,725	4,383	14.4	12.4	2
Small plants	252	778	1.4	2.2	4.7

The development of hydropower has long-term economic advantages, which include the diversification and more efficient, multipurpose use of the hydropower potential of big and small rivers. Developed and developing countries are advancing this sector, in particular in rural areas and regions that are badly linked to energy systems. The construction of small HPPs is considered promising for regions with transboundary river basins. Small hydropower is free from many of the disadvantages of large HPPs and is one of the most economical and environmentally friendly ways of generating electricity, in particular when small watercourses are used.

The advantages of small hydropower include: alleviation of the impacts of global climate change due to lower CO_2 emissions; technological advancement; minimal flooding and construction; local and regional development; assistance in maintaining river basins; electrification of rural areas; and a short payback period. The construction and operation of small hydropower plants does not affect the landscape and exerts almost no pressure on the ecosystem. Other advantages, compared to fossil fuel plants, are the low cost of energy and low operational costs, relatively cheap equipment, longer lifetime (40 to 50 years), and the comprehensive use of water resources (electricity generation, water supply, navigation, land development, water conservation and fishery).

At present, there is no worldwide accepted definition of small hydropower. Many countries classify plants by installed capacity. As a rule, small HPPs have a capacity of up to 10 MW (up to 50 MW in some countries).

The investment costs of large hydropower plants range from $1,750 per kW to $6,250 per kW, with an average of about $4,000 per kW (in 2008). The investment costs of small (1–10 MW) and mini (≤1 MW) hydropower plants may range from $2,000 to $7,500 per kW and from $2,500 to $10,000 per kW, respectively, with average figures of $4,500 per kW and $5,000 per kW. Operation and maintenance costs of hydropower facilities are between 1.5% and 2.5% of investment costs per year. The resulting overall generation cost is between $40 and $110/MWh ($75/MWh on average) for large HPPs, between $45 and $120/MWh ($83/MWh) for small HPPs, and from $55 to $185/MWh ($90/MWh) for mini HPPs.

Table 1.2 provides key and forecast data for small hydropower.

Technical performance	International classification of HPPs							
Technology	Mini HPPs (up to 1 MW)			Small HPPs (1–10 MW)			Large HPPs (>10 MW)	
Efficiency (turbine) (%)	Up to 92			Up to 92			Up to 92	
Construction time (months)	6–10			10–18			18–96	
Technical lifetime (years)	Up to 100							
Load (capacity) factor (%)	40–60 (50)			34–56 (45)			34–56 (45)	
Max (plant) availability (%)	98			98			98	
Environmental impact								
CO_2 and other greenhouse gas emissions (kg/MWh)	Negligible							
Construction costs (in 2008 prices, $)								
Investment cost, including construction costs ($/kW)	2,500–10,000 (5,000)			2,000–7,500 (4,500)			1,750–6,250 (4,000)	
Operation and maintenance cost (fixed and variable) ($/kW)	50–90 (75)			45–85 (65)			35–85 (60)	
Economic lifetime (years)	30							
Total production cost ($/MWh)	55–185 (90)			45–120 (82.5)			40–110 (75)	
Data projections	2010			2020			2030	
Investment cost, including construction costs ($/kW)	5,000	4,500	4,000	4,500	4,000	3,600	4,000	3,600
Total production cost ($/MWh)	90	82.5	75	81	75	67.5	73	67.5
Market share (% of global electricity output)	16–17			18–20			20–21	

Table 1.2.
Key and forecast data for hydropower technology

Source: ETSAP, 2010

World energy technology development scenarios predict hydropower capacity to more than double (up to 1,700 GW) between now and 2050, and hydroelectricity production to reach some 5,000–5,500 TWh per year by 2050. However, future hydropower production could be affected by climate change, both negative and positive, which requires corresponding

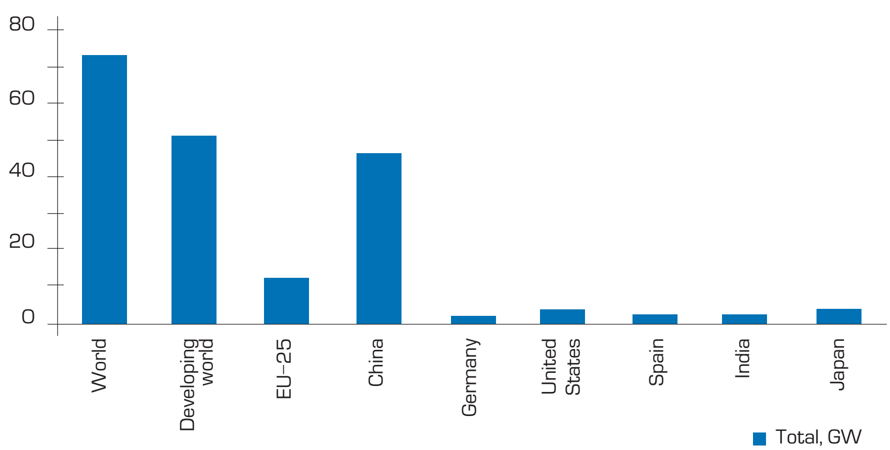

Figure 1.1.
Small hydropower capacity in some countries

Source: REN21, 2008

Note: China is included in developing countries' capacity investigation and adaptation measures. A key obstacle to hydropower advancement in developing countries' transboundary river basins is the lack of agreements on joint use of water. However, this is primarily a concern for large hydro projects.

In China, small hydropower includes plants with a capacity from 1 to 50 MW. They play an important part in ensuring energy supply to rural regions. A total of 45,000 small HPPs generate 70 billion kWh for 300 million rural inhabitants. China has plans to expand its small hydropower: $16.5 billion will be invested in the sector in the forthcoming years. The number of districts with small HPPs will increase from 300 to 782. A significant portion of these include irrigation facilities. The advancement of small hydropower in China and the dissemination of experience in this field are supported by the International Centre for Small Hydropower established by the country's government, as well as UNIDO and UNDP in Hangzhou, Zhejiang Province in Eastern China. The China Township Electrification Programme until 2005 has electrified 1,000 villages, with small HPPs in particular. The China Village Electrification Programme, launched in 2006, planned to electrify 10,000 villages by 2010, including investing in the construction of small HPPs.

China plans to raise its hydropower capacity to 190 GW in 2010 and 300 GW in 2020. It is becoming a global leader in terms of the use of renewables and a leading producer of equipment for small HPPs, accounting for a significant portion of the global output.

Table 1.3. Small hydropower advantages

	Factors	Advantages
1.	Economic	Cost of electricity production is 2–2.5 times lower than at large hydropower plants
		No need for dams and large flood zones; no need to withdraw fertile land from agriculture
		Proximity to consumers and no need for expensive power transmission lines, in particular in hard-to-reach areas
		Possibility to attract investment from the population, medium and small businesses
		Additional opportunities to develop new areas
		Shorter electricity generation periods
2.	Technical and technological	No need for heavy machinery and roads for the transportation of machinery and materials to construct dams and other facilities
		Easy operational control
		Possibility to use low-duty vehicles in the construction of small HPPs
3.	Environmental	No flood zones and preservation of natural landscapes (no salinisation and erosion), forests, flora and fauna
		Maintenance of the environmental balance
		Preservation of the quality of water used for utility systems and irrigation
4.	Social	Electrification of localities that are remote from main communications
		Job creation and involvement of workforce to develop new production and improve the efficiency of existing plants
		Improvement of social and household conditions of the population

Other countries also pay significant attention to developing small hydro. The EU planned to increase its small hydropower capacity to 14 GW by 2010. The average cost of 1 kWh of electricity produced by small HPPs in Europe was approximately $0.03 in 2005.

The unit cost of small HPPs construction, when they are designed and constructed to individual projects, is often higher than that of large plants. However, these costs can be lowered if standardised designs and equipment and local materials are used. The EU countries use this approach to expand the utilisation of small rivers.

The scale and growth rates of small hydropower depend on the availability and sophistication of technology, and on generating costs. Although large HPPs generate cheap electricity, their expansion has slowed down in the past years. The reasons for this are the need for significant long-term investment, high restoration, environment protection and social costs, long construction times, and the depletion of technically available and economically feasible hydro potential.

The large hydropower market comprises several equipment manufacturers and many suppliers of auxiliary components and systems. At the same time, the market for small hydro comprises more sophisticated equipment, allowing the use of a variety of structures and new materials. Experts say that the demand for small HPPs has grown significantly. Many countries produce cutting-edge standardised equipment for small hydro, including Francis, Kaplan and Pelton turbines. The size of a turbine depends on head and flow rate and requires individual design in certain cases.

Small hydropower plants have a lifetime of approximately 50 years without the need for any significant replacements of equipment. The investment costs of HPPs differ significantly between developed and developing countries. Civil work is cheaper in developing countries because of the low-paid workforce. With relatively equal equipment and installation costs, the construction of a HPP in developing countries may be more economically feasible than in developed ones.

With the world's limited hydro potential, the growth rates of small hydropower can be expected to go down by 2030; however they will be higher than those of large hydro. With a growth rate of 4.5–4.7%, small HPPs will generate 770–780 TWh of electricity a year by 2030, accounting for 2% of the world's energy output. Therefore, we can expect that small hydropower will remain one of the most important and competitive sources of renewable energy in the near future.

2. Developing Small Hydropower in the CIS

Most countries have programmes to develop small hydropower as a renewable energy source. The share of small hydro is growing in the majority of developed nations and in many developing countries because of continuous improvements of small hydro technologies and the corresponding reduction in generating costs, as well as government support. This growth is boosted by the extended use of renewable energy caused by the need to adapt to global climate change, to decrease costs, and to save fossil resources.

The CIS member states also have programmes to develop small hydropower and provide support to the sector. A number of abandoned small plants have been restored and existing irrigation facilities have been used to construct small plants. Private capital is also interested in small hydro. The domestic plants' payback periods are four to five years, while increases in wholesale and retail electricity prices can reduce this time, over a relatively short period, by 33%, which is an advantage for medium and small businesses.

However, the CIS countries face some common and individual challenges that impede the advancement of this sector. First, they lack long-term financing to construct small HPPs. Their owners are usually regional and municipal authorities and medium-sized businesses. As a rule, state budgets do not fund these projects. Banks and lease companies are usually not very interested in them because of long (from the point of view of banks) payback periods and insignificant capital expenditure. The procedures for allocating land for building small HPPs and approving designs are too complicated and can take up to five years. In some CIS countries, national grids set steep requirements for hooking up small HPPs to their networks.

For these reasons, the various CIS countries pursue different approaches to expanding the sector. Russia, in accordance with its Energy Development Strategy 2020, plans to increase the share of renewables to 4% in the next 10 years, which is approximately five times lower than their potential that could be utilised given the current level of economic development.

Kazakhstan is in a similar situation. The Kazakh government has passed a law to support renewable energy; however it does not provide real mechanisms to promote this sector beyond a mere legislative framework. The share of renewables should reach 2.5% by 2020. This suggests that renewable energy, including small hydropower, will grow at a low pace. Some experts believe that inattention to this sector is a result of prevailing stereotypical attitudes, namely that the country's huge fossil fuel reserves make other energy sources unnecessary.

There is no significant growth predicted in the use of renewables, including small hydropower, in other CIS countries. For this reason, it would be expedient to set up an intergovernmental function within the existing CIS integration structures to develop renewable energy and provide research and technical support to this sector.

2.1. Armenia

Armenia is a mountainous country: over 75% of its territory is 1,500 m and more above sea level. The country has over 200 small rivers with a length of over 10 km. River flow averages 6.25 km^3 a year, including 3.03 km^3 formed by springs and groundwater. Hydrographically, the country has 14 river basins. Hydropower is the most explored mode of renewable energy. The country's hydro potential is estimated at 21.8 billion kWh a year. Its HPPs generate about 1.5 billion kWh, or 20% of the annual energy output.

In 2009, the Armenian government approved a blueprint for developing small hydropower. This document will regulate the construction of plants and the provision of design and construction licences and water use permits.

Armenia classifies plants with a capacity of less than 10 MW as small plants. Most HPPs have a capacity of less than 1 MW, although there are plants with higher capacity. Most of them use water diversion. In 2011, the country had 108 small plants with a total capacity of 130 MW and an annual output of 450 million kWh. Another 65 plants are under construction.

The investment programme provides for the reconstruction of existing plants, the construction of new large plants (275–300 MW total), and the utilisation of the economically feasible hydro potential of small rivers (260 MW total).

The International Energy Corporation plans to launch an investment programme to upgrade hydro assets, including seven plants on the Sevan Razdan cascade on the Razdan River. The cascade's installed capacity is 561.4 MW and its average annual output 500 million kWh. The first plant was commissioned in 1936, the last one in 1962. The average age of equipment exceeds 50 years and it is obsolete and in an unsatisfactory condition. The programme intends to replace some equipment in order to reduce operation and maintenance costs and improve the plants' reliability and safety.

All small plants in Armenia were built by private companies. Another source of funding is loans from banks, including foreign institutions. The World Bank has provided $5 million in investment loans to the power sector. The European Bank for Reconstruction and Development (EBRD) has provided $7 million and Cascade Universal Credit Organisation has invested $3 million. The Global Environment Fund (GEF) has provided a $3 million grant to study the potential of renewable energy sources and attract private investment.

2.2. Belarus

Belarus has over 20,800 rivers and streams with a total length of 90,800 km. Their total annual flow averages 58 km^3. The potential capacity of all watercourses reaches 850 MW, including 520 MW of technically feasible capacity and 250 MW of economically feasible capacity. The Neman, Western Dvina and Dnieper river basins in the Grodno, Vitebsk and Mogilev Oblasts have the highest hydro potential. A feasibility study to construct hydropower cascades on these rivers has been prepared.

In 1950–1960, about 180 HPPs were built in Belarus with a total capacity of 21 MW and an annual output of 88 million kWh in an average water year. Small hydropower plants (with a capacity of less than 100 kW) operated by collective farms accounted for about 20% of power supplies to the agricultural sector during that period. With the development of centralised power supplies, most of these plants have been decommissioned.

At present, Belarus has 41 HPPs with a total capacity of 16.1 MW, which is approximately 3% of the available potential. Twenty two plants (9.4 MW in total) represent about 60% of the total hydropower capacity. The country's largest Osipovichi plant (2.175 MW), was commissioned in 1953. The country's total hydroelectricity output was 39 million kWh in 2008 and 44 million kWh in 2009.

In accordance with the state hydropower construction programme for 2011–2015, which was adopted in 2010, Belarus plans to construct and reconstruct 33 HPPs with a total capacity of 102.1 MW and an annual output of about 463 kWh. The programme is aimed to improve the country's energy security by replacing fuel and energy imports with renewables and alleviating the environmental impact of the fuel and energy sector.

The programme is financed by the central and local budgets, private companies, private loans, foreign investments, and other sources. Its expected outcomes are up to 0.51 billion kWh of energy output a year by 2015 and annual fuel and energy savings of 120,000 tonnes of equivalent fuel compared to 2009. The amount of financing and its distribution by type of renewables will be adjusted after tenders for equipment suppliers are completed.

The construction costs average about $6,000 per kW of installed capacity. The construction costs of small hydropower plants can be cut down if domestically-made horizontal hydro units (100–1,500 kW each) are used. These units are designed to use the potential of small rivers and channels with a head height of 2–20 m and a turbine flow of 1 to 10 m^3 per second. As distinct from conventional hydropower plants, this equipment does not need buildings, hence shorter construction times and lower construction and reconstruction costs.

Belarus' plain landscapes allow for developing hydropower using low-head watercourses. The state programme classifies HPPs by installed capacity as follows:

- Large plants: ≥ 10 MW;
- Small plants: 1–10 MW;
- Mini plants: 100 kW – 1 MW;
- Micro plants: < 100 kW.

The construction costs of micro, mini and small plants can be cut down if design, manufacture, construction and installation take place simultaneously. Commissioning periods can be decreased to 15–18 months and construction costs, according to some estimates, can be paid back within five to six years.

The generating cost is expected to average $0.07 per kWh. Land lease accounts for the largest portion of this figure. If land rentals to local budgets are abandoned, the generating cost may be cut down by more than 50%.

The state programme is being implemented through sector-wide and regional energy saving programmes and other non-conventional and renewable energy development programmes.

The law requires that the environmental impact of HPPs be assessed at the design stage when feasibility studies are prepared.

The design and construction/reconstruction of plants on transboundary watercourses and water bodies should also be planned in compliance with the Convention on the Protection and Use of Transboundary Watercourses and International Lakes (1992). Intergovernmental cooperation agreements on the protection and efficient use of transboundary watercourses and other international treaties are also taken into account during plant planning by riparian countries.

Designers and developers evaluate the feasibility of new constructions by taking into account the environmental and economic factors recommended by the Central Research Institute for Complex Use of Water Resources, the recommendations and guidelines for substantiating the environmental security of new hydropower plants, and the assessment of the economic hydropower potential of Belarus' rivers, approved by the Ministry of Natural Resources and Environmental Protection and Belenergo.

The Grodno hydropower plant (17 MW, which is more than the total capacity of all HPPs in the country) was completed in 2010. The Grodno plant will generate about 87.6 million kWh a year on average, saving 28,000 tonnes of equivalent fuel.

Two other large plants, the Neman plant (20 MW) and the Vitebsk plant (40 MW), are planned to be commissioned before 2016. In 2016–2019, the following large plants will be commissioned on the Dnieper and Western Dvina rivers:

- Beshenkovichi (30 MW) in 2016;
- Orsha (5.7 MW) in 2017;
- Rechitsa (4.6 MW) in 2018;
- Upper Dvina (20 MW) in 2018;

- Shklov (4.9 MW) in 2018; and
- Mogilev (5.1 MW) in 2019.

In November 2010, the Eurasian Development Bank (EDB) provided $99.8 million to construct the 21.75 MW Polotsk hydropower plant on the Western Dvina River. Its annual output is expected to reach 112 million kWh. The total project cost is $142.7 million. This is a ten-year loan which covers design, construction, equipment and component supplies and installation, start-up, testing, commissioning and training. This project will help reduce the energy dependence of GDP and improve the country's overall energy security as it will use local renewables. It will also help reduce generating costs and save up to 35,100 tonnes of fossil fuel a year.

2.3. Kazakhstan

Kazakhstan has a significant hydropower potential of 170 billion kWh, of which 30 billion are economically feasible to utilise. There is uneven distribution of hydro resources, with most of them concentrated in eastern and south-eastern regions. Northern and central regions account for a mere 1.7% of the country's hydropower resources.

Kazakhstan's hydropower plants have a total capacity of 2,068 MW and generate 8.32 billion kWh of electricity a year (12% of overall generating capacity and energy output). The country has several large and medium plants: Bukhtarma, Ust-Kamenogorsk and Shulba on the Irtysh River, the Kapchagay plant on the Ili River, the Shardarya plant on the Syr Darya River, and the Moinak plant on the Charyn River.

The potential of small hydro is also significant. The country has 2,174 rivers over 10 km long whose total length exceeds 83,200 km. This comprises 1,889 rivers from 10 to 50 km long (86.9%), 130 rivers from 50 to 100 km long (6%), and 155 rivers more than 100 km long (7.1%). Small rivers represent almost 90% of all watercourses and are economically feasible for small hydropower.

Small hydropower plants represent the largest share of renewables in Kazakhstan. With a total capacity of 97.6 MW, they generated 379.6 million kWh of electricity in 2009.

As in other CIS countries, many small HPPs in Kazakhstan were decommissioned after the country developed centralised power supplies. The existing small plants require reconstruction and upgrades.

A cascade of nine small diversion plants is located on the Bolshaya Almatinka River. This facility needs a technical upgrade and strengthening of its main structures. Its total installed capacity is 43.7 MW and average annual output 203.2 million kWh. The largest plants of the cascade are the upper HPP-1 and HPP-2.

Existing small plants in southern regions are being reconstructed to cover power shortages. Reconstruction has been completed in the Fabrichny village of Almaty Oblast (600 kW) and continues at the Issyk plant.

The Almaty cascade is situated in Almaty Oblast, on the Bolshaya and Malaya Almatinka rivers. It comprises 11 small HPPs (49.15 MW total), which were commissioned in 1944–1954, and is owned by Almaty Power Plants JSC. The cascade can be extended with another two small plants (5 MW total).

The Leninogorsk cascade is situated in East Kazakhstan Oblast, on the Gromotukha and Tikhaya rivers. It includes two functioning plants (11.78 MW) and several idle facilities, which were commissioned in 1928–1949. The cascade is owned by Ridder HPP, LLC.

The Karatal cascade is situated in Almaty Oblast, on the Karatal River. It comprises four operative plants and several plants which are still in the design stage. If the cascade achieves full capacity, it will comprise 10 plants.

Karatal hydropower plant. The construction of this plant began in 1950. The plant was launched in 1953 and completed in 1954. Its capacity is 10.08 MW and average output 50 million kWh.

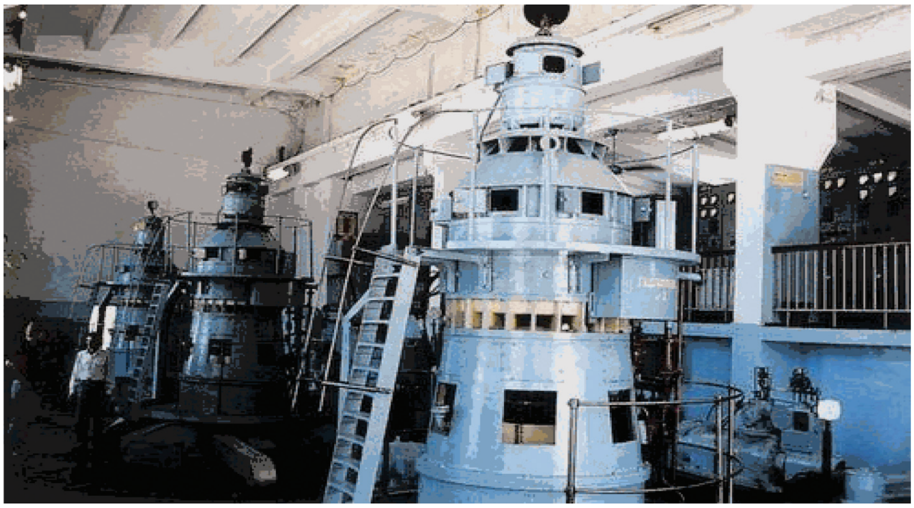

Figure 2.1.
Turbine hall of the Karatal hydropower plant

The plant building hosts three vertical units with Francis turbines designed for a head height of 46.2 m. The turbines are run by 3.36 MW hydraulic generators made by Ganz, Hungary. The owner is Kazzinc JSC.

Karatal–2. Construction of this plant began on April 31, 2007 and was completed on September 19, 2008. This is a diversion plant located downstream from the Karatal hydropower plant and takes in water from its discharge canal. The plant's capacity is 4 MW and average annual output 19.5 million kWh. The building includes two 2 MW units designed for a head height of 19.8 m and a water flow of 25 m/sec. The equipment supplier is SA Mecamidi, France. The owner is Karatal HPP Cascade, LLC.

Karatal–3. Construction of this plant began in February 2009 and was completed on December 22, 2009. The plant is located downstream from Karatal–2 and takes in water from its discharge canal. This is a diversion plant which includes an intake chamber, a 1,255 m diversion canal, a head bay, power conduits, a building, a discharge canal, a discharge pipe, and idle discharge. The building includes three hydro units (4.4 MW total). The equipment was supplied by Shanli, China. The owner is Karatal HPP Cascade, LLC.

Karatal–4. The plant was commissioned on June 28, 2008 and has a capacity of 3.5 MW. The owner is Karatal HPP Cascade, LLC.

The Issyk cascade is situated in the Yenbekshi–Kazakh district of Almaty Oblast. It includes three plants: Issyk–2 has been commissioned and is functioning, Issyk–1 is under construction, and Issyk–3 is in the design stage. The cascade is owned by Energoalem, LLC.

Issyk–2 was commissioned on November 3, 2008. It is situated 0.7 km downstream from the Lake Issyk dam in the Ile–Alatau national nature park. Its capacity is 5.1 MW and average annual output 25 million kWh. The project cost $4.3 million.

The Talgar hydropower plant on the Talgar River has a capacity of 3.2 MW. It comprises three units manufactured by Uralmash in 1959. The owner is Almaty Power Plants JSC. The plant is waiting for reconstruction which will raise its capacity to 6 MW.

The Sergeyev plant on the Ishim River uses water from the Sergeyev dam. It has a capacity of 2 MW and comprises two 1 MW turbines.

Merke-3 is situated on the Merke River, in the Merke district of Zhambyl Oblast. It has a capacity of 1.5 MW and an average annual output of 6.5 million kWh. The project cost 237 million tenge and was commissioned on December 28, 2010.

Other small HPPs include Zaisan (2 MW), Aksu (2 MW, commissioned in 2008 after reconstruction), Uspenka (2.5 MW), Antonovka (1.6 MW with two hydro units made by Uralmash in 1960), Georgiyevka (1.7 MW), and Urjar (0.175 MW).

The Kazakh government has approved the power sector development programme for 2010–2014, which includes small hydro. New plants are planned to be built in regions with hydropower resources. In Almaty Oblast these are: a cascade of small hydropower plants on the Koksu River (42 MW total, to be commissioned in 2012); a small plant on the Baskan River (4.37 MW, 2011); a plant on the Issyk River (5 MW, 2011–2012); a plant on the Shelek River (30 MW, 2014–2015); and a plant on the Lepsy River (4.8 MW, 2012). In South Kazakhstan Oblast, small HPPs will be built on the Keles River (10 MW, to be commissioned in 2011–2014).

The modern small river and watercourse utilisation technologies allow for building small and mini hydropower plants into the existing hydro facilities. This is another advantage of small hydropower. Kazakhstan has canals with depth drops which can be used for these purposes. Studies suggest that small plants built on drops should be of an open-flow intake type.

The significant underutilised hydro potential of large irrigation canals and water reservoirs allows for developing hydropower on irrigated lands that lack power supplies.

2.4. Kyrgyzstan

Kyrgyzstan has significant potential to develop hydropower. It ranks third among the CIS countries in terms of amount of water resources. The country has 252 large and medium rivers, with a potential capacity of 18.5 million kW and a potential output of more than 140–160 billion kWh of electricity, of which less than 10% are utilised.

The hydropower potential has been determined for almost all rivers. The Naryn, Sary-Jaz, Kekemeren, Chatkal, Tar, Chu, Kara-Darya and Chon-Naryn rivers have average river slopes between 5 and 20 m per km of length and an average specific capacity between 2,227 and 5,322 kW/km.

The country has 17 power plants with a total installed capacity of 3.68 million kW, including two thermal plants (0.73 million kW) and 15 HPPs (2.95 million kW). The Naryn hydropower cascade provides over 80% of total energy output.

The economic potential of Kyrgyzstan's hydropower is significantly higher than that of all other renewables. The estimated potential of small rivers and watercourses is 1.6 million kW, with potential output reaching 5–8 billion kWh a year.

About 90% of small watercourses are the upper and middle parts of rivers. They are mostly located in rural and mountainous areas with a dispersed population that is in acute need of electricity. Small and medium hydropower is one of the most efficient means of advancing the power sector. Small plants, in particular in mountainous areas, will help develop small and medium businesses in the agricultural, industrial and tourism sectors and improve the living conditions of people occupied in distant-pasture animal breeding, the seasonal processing of agricultural produce, and the production of building materials. Small and medium hydropower will strengthen the country's energy security and supply electricity to remote and hard-to-reach areas.

Before large plants were launched, the country had about 200 small plants, almost all of which have now been decommissioned. At present, there are only 10 operative small plants in Kyrgyzstan.

Figure 2.2.
A small hydropower plant on the Alamedin River

Source: Assessment of Regional Cooperation Opportunities in Renewable Energy Source Use in the Central Asian Countries (The Case of the Kyrgyz Republic)

In 2005–2008, Kyrgyzstan received significant assistance from the UNDP. The project assessed the potential of micro hydropower plants, established existing obstacles, and determined the institutional and regulative frameworks for using such plants and their serial production in the country. Thirteen micro power plants from domestic and foreign suppliers have been installed in Issyk Kul Oblast to test the technology for later application in rural mountainous areas. A local company has been consulted on launching mass production of single-phase 1.5 kW micro plants and three-phase 5 kW plants. A project to connect small plants to power grids has been developed. The information booklets, materials and posters about micro plants have been distributed in other regions of Kyrgyzstan.

The country has a government programme in place until 2012 to develop small and medium hydropower. Its primary objectives are to implement state policy in the sphere of small and medium hydropower and to create conditions for attracting investment. To this end, the state supports the allocation of land for power facilities and their design, construction and operation; facilitates sale of electricity; helps create conditions to transit electricity, including exports; and protects investments.

The programme is open for all permitted forms of financing including the following:

- Build-Operate-Transfer (BOT): a private investor designs, finances and builds a new facility under a long-term concession agreement and operates it within the period of this agreement. When the agreement expires, ownership is transferred to the state unless it has already passed to the state because of the project's completion.
- Build-Own-Operate (BOO): a private investor finances, builds, owns and operates a facility or provides services on the terms of lifetime ownership or lease. Government restrictions are set forth by the original agreement and by the permanent regulatory body.
- Build-Own-Operate-Transfer (BOOT): a private investor obtains a franchise to finance, build and own a facility (and to receive payments for its use) for a limited period of time, on expiry of which ownership is transferred to the state.

A total of 41 small and medium plants, including 12 in Issyk Kul Oblast, are planned to be built before 2012. Another four plants are expected to be launched at the existing hydro facilities and nine small plants are planned to be reconstructed.

Kyrgyzstan has the research and technical base to develop small hydropower. The Energy Research and Technical Centre designs micro and small hydropower plants, which were previously exported to Cuba and Mongolia.

2.5. Russia

Hydropower is the most promising power sector in Russia. It is one of the largest suppliers of system–wide services: power and capacity generation, and the maintenance of frequency and voltage in the Unified Energy System of Russia. In addition, hydropower helps attain other important goals: the creation of potable and industrial water supply and irrigation systems for agriculture; the development of navigation and fishery; and the control of river flows in order to prevent floods and protect the population. Hydropower provides infrastructure for the operation and development of some very significant sectors and the country as a whole.

Russia's total hydro potential is estimated at 2.900 billion kWh of annual output or 170,000 kWh per km^2 of the country's area. The total installed capacity of Russian hydro facilities is approximately 46 GW, making it the world's fifth largest producer of hydroelectricity. In 2010, HPPs generated 165 billion kWh of electricity or 20% of Russia's total energy output.

Russia has 102 hydropower plants with capacity of over 100 MW each and one pump–storage hydropower plant (Zagorsk HPP).

The Zaramag, Kashkhatau and Gotsatli hydropower plants and the Zelenchuk pump–storage HPP are under construction in the North Caucasus. The Irganai and Agvali power plants are planned to be expanded and the Kuban cascade and Sochi power plants are being developed. Small hydropower is being created in North Ossetia, Dagestan and Siberia (expansion of the Boguchany, Vilyuy HPP–3 and Ust–Srednekansk plants and design of the South Yakutia hydropower complex and the Evenki plant). A hydropower complex is being developed in Russia's central and northern European regions and along the Volga. Compensating facilities are being constructed in the largest consuming regions.

The hydropower reform has created the Hydro OGK Federal Hydrogenerating Company (now RusHydro), which has combined a significant part of the country's hydro assets. RusHydro comprises 15 federal power stations.

At the same time, Russia's large hydropower faces territorial, infrastructure and hydrographical challenges. These include the remoteness of most of the hydropower potential, which is concentrated in Central and Eastern Siberia and the Far East, from the main consumers. Large distances and significant transportation costs make the cost of fuel and energy so high that the use of small rivers and other non–conventional renewables becomes economically feasible.

Electricity produced by some renewables can be cheaper than that of diesel generators. In addition, there is no need for fuel supplies. Potential consumers of renewable energy include forest and fishery businesses, weather, communications and geological stations, and offshore oil and gas platforms. Decentralised power supplies to rural areas, including remote localities, family farms and private country houses, is another promising market for small hydro.

Small hydropower is considered one of the promising modes of supplying power to remote regions which do not have connections to common grids. According to recent estimates, the technically feasible potential of small hydro is 357 billion kWh a year and the economically feasible hydro resources of small rivers exceed 200 billion kWh a year. Small rivers prevail in the hydrographical network in terms of both their number and total length (small watercourses account for 94% of the length of the river network). About 90% of the rural population and up to 44% of the urban one are concentrated in or near small river basins.

Small hydropower is expected to develop primarily in Siberia and the Far East. In Russia's European regions, small HPPs are planned to be built in the North Caucasus.

The first hydropower plant in Russia, designed by a mining engineer Nikolai Koksharov, was built on the Berezovka River in the Altai region in 1882. This was a four–turbine plant with a capacity of 180 kW, which produced electricity for dewatering pumps at the Zyryanovsk mine. This plant operated for 50 years and was closed in 1932 due to deterioration of equipment.

On May 11, 1903, the Belyi Ugol plant (700 kW) was launched on the Podkumok River near Yessentuki in the Caucasus. It was designed by Mikhail Shatelen, a professor at the St. Petersburg Polytechnic Institute, and Genrikh Graftio, a well-known power engineer. This plant supplied energy to four resort towns, which had 400 street lamps and 3,000 electrified houses. It also powered pumps to supply mineral water to health resorts and provided electricity to the Pyatigorsk and Kislovodsk trams.

In 1910, the Porogi hydropower plant with two 550 kW turbines was commissioned. In 2010 it celebrated its 100th anniversary. The plant was designed by Boris Bakhmetev, a graduate of the St. Petersburg Transportation Institute, hydraulic engineer and professor of the St. Petersburg Polytechnic Institute and Columbia University. This plant still uses the original equipment whose operational life has proven to be very long. The arch-gravity dam was designed by Bakhmetev and built of cemented stone under the supervision of Alexander Shuppe, a mining engineer. It is also still in operation, although in need of repair. The plant's equipment (supplied from German, Swiss, Austrian and Russian factories) and efficient layout make it a valuable part of the technical heritage of Chelyabinsk Oblast. It has also been nominated for inclusion on the UNESCO World Heritage list.

By 1917 Russia had 78 hydropower plants with total capacity of 16,000 kW. The largest of them was Murgab HPP (1,000 kW). In addition, the country had up to 2,000 small power-driven hydro units with a total capacity of about 90,000 kW and about 40,000 waterwheel mills with an average capacity of about 10 hp (horsepower) each. All plants were financed by the private sector and were owned either by joint stock companies or equity partnerships.

The situation did not change after the country introduced its new economic policy. In 1919, 47 small plants (1,600 kW total) were built. The 48 kW Yaropoletsk plant, one of the five stations in the cascade on the Lama River near Moscow, was one of the first rural power plants.

There were two stages in the development of small hydropower in Russia:

- 1919–1945: construction of plants with capacity of several dozen kW and small plants at collective farms in rural areas. Approximately 950 plants with total capacity of about 32,000 kW (an average of 35 kW) were built before 1941; and
- 1945–1969: construction of large state plants (with capacity between 1,000 and 10,000 kW) within local energy systems. In 1951–1953, 111 public plants (440 kW on average) were built in rural areas and 116 plants (300 kW on average) for collective farms. By 1954, there were 6,614 small HPPs with total capacity of 322,000 kW which produced 24% of power supplies to rural localities.

In 1954, rural consumers were permitted to connect to centralised power grids and the construction of small plants stopped. Many operative plants were abandoned due to the low price of electricity in centralised grids, which made small plants non-competitive. In addition, many plants were poorly designed and lacked qualified construction workers, equipment suppliers and operational personnel. There were no specialised producers of equipment for small plants. These factors have prevented the further advancement of this sector.

The majority of Russia's small hydropower plants at that time:

- underused the river flow in Russia's central regions (just few of them had a river flow utilisation factor of 0.3–0.4 outside high water periods while the demand coverage factor was 0.6–0.7);
- shut down completely during high water periods because water levels in the upper and lower pools became equal; and

- were unstable and had abrupt voltage and frequency changes during load fluctuations.

The Master Plan of Power Facilities until 2020 describes the long-term development of Russia's power sector.

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Small HPPs	1,672.6	2,586.5	2,429.5	2,276.7	2,738.2	2,788.1	2,548.5	2,659.2	3,178.5
Total electricity output	8,778,000	8,913,00	891,300	916,300	931,900	953,100	931,381	1,008,256	1,033,327
Share of small HPPs (%)	0.19	0.29	0.27	0.25	0.29	0.29	0.27	0.26	0.31

Table 2.1.
Electricity generation by Russia's small hydropower plants (million kWh)

Source: Shkradyuk, 2010

In 2009, the Russian government adopted a new Energy Strategy until 2030, which paid significant attention to the development of alternate energy sources. According to it, the share of non-conventional renewables in the country's power balance should reach at least 10% by 2030 and at least 5% by 2020. By the end of this period, renewables are predicted to generate up to 80–100 billion kWh, an increase of more than 10 times from 2009. At present, Russia has about 300 small hydropower plants with total capacity of approximately 1.3 million kW.

Indicator	Value
Project cost (million roubles)	25–30
Project time (months)	8–10
Payback period (years)	3–5
Average lifetime (years)	25
Warranty on main hydro equipment (years)	3

Table 2.2.
General technical and economic characteristics of a standard small hydropower plant project

Source: Yenov, 2010

In March 2010, the Small Hydropower Association was set up in Russia. This organisation unites Russian companies that are interested in developing small hydropower and develops programmes and mechanisms to attract Russian and foreign investors.

RusHydro plays an important part in developing small hydropower. The New Energy Fund was set up to operate RusHydro's small hydro development programme and construct small plants. Its founders are RusHydro, the Energy Carbon Fund and the Non-State Pension Fund of the Electric Power Industry. The fund's programme provides for building 275 small plants in Russia by 2020, with total capacity of 1.86 GW.

Table 2.3.
Small hydropower plants commissioned by 2010 under the New Energy Fund's small hydro development programme

2007	2008	2009	2010
5 MW	20 MW	125 MW	150 MW

Source: Shkradyuk, 2010

Small power-generating enterprises are planned to be established at small hydropower plants. These projects are preliminarily named joint projects and will be implemented within 10–15 years.

A technology park and an investment fund to finance energy efficiency and energy saving programmes are planned to be set up in Bashkiria. At the initial stage, the technology park's investment fund will total 2–4 billion roubles. RusHydro will own 51% of the fund and Bashkiria 49%.

RusHydro and Alstom (France) agreed to create a joint venture in Bashkiria to manufacture equipment for small hydropower plants. The plant will be built in cooperation with Alstom. It will produce equipment for small plants with a capacity of up to 25 MW as well as control and safety systems. Production of these systems will be launched in 2011; the first hydro units will appear on the market in 2013. In the future, the plant is expected to manufacture turbines for medium plants with a capacity of up to 150 MW.

There is a growing supply of equipment for small plants with good operational characteristics and automated controls. It is designed and manufactured by MNPO INSET, RAND, Gidroenergoprom (St. Petersburg), MAGI–E (Moscow), Tyazhmash (Syzran), NPO TsKTI (St. Petersburg), MNTO INSET (St. Petersburg), Elsib (Novosibirsk) and Strela (Orenburg), among others. These manufacturers produce equipment for mini and small HPPs with installed capacity of between 45 kW and 30 MW, which suits almost all types of head heights and water flows existing in the country. In addition, this equipment is produced in modular configurations to reduce installation and operation costs.

A broad range of modern hydro units has been developed. They have various types of wheels and improved performance for many types of head heights (from 1.5 to 400 m) and water flows.

The significant progress in developing small hydro opens new opportunities for this sector. The new equipment meets high technological requirements, can work autonomously or be connected to local grids, is fully automated, does not need 24–hour attendance, and has a long lifetime of 40 years (with up to five years between overhauls).

However, the development of small hydropower requires upgrades of the mechanical engineering base, job creation and significant local and foreign investments.

2.6. Tajikistan

Tajikistan has several hydrographical regions formed by its two largest rivers, Syr Darya and Amu Darya. The country's northern regions are located in the Middle Syr Darya basin, which has an area of 13,000 km^2 or one tenth of the country's total area. Almost all other regions lie in the Amu Darya basin, which is divided by mountain ridges into large river basins with different head heights, degrees of glaciation, river network development, flow formation conditions and runoff systems. The north–eastern Pamir is the only area that does not contribute to these two great rivers (the basins of Karakul Lake and the Markansu River).

Tajikistan's hydrographical network comprises over 25,000 rivers with a total length of 69,200 km, including 947 rivers 10 to 100 km long, 16 rivers between 100 and 500 km long, and four rivers of more than 500 km. Geographically, the river network includes the large basins of the Zeravshan, Surkhandarya (Karatag and Sherkent), Kafirnigan, Vakhsh, and Panj (Gunt, Bartang, Yazgulem, Vanj and Southern Kyzylsu) rivers.

Tajikistan's largest rivers are the Panj (521 km), Vakhsh (524 km), Bartang (528 km), Kafirnigan (387 km), Zeravshan (310 km; full length 877 km), and Syr Darya (180 km within Tajikistan). The average annual water flow is 56.2 km^2. The main source of water is seasonal snow. Most rivers in the country originate from glaciers. For this reason, one of the main differences between Tajikistan's mountainous rivers and its lowland watercourses is the long deluge periods in the mountains, during which rivers carry 70–90% of their annual flow.

Tajikistan's developed hydrological network includes large and small rivers and is a good basis for the development of hydropower, in particular in mountainous areas.

The Vakhsh cascade (285 MW total) was built on the Vakhsh River; the Varzob cascade (25 MW total) on the Varzob River; the Kairakkum hydropower plant (126 MW) on the Syr Darya; and the Khorog and Pamir HPPs (22.7 MW total) on the Pamir. According to Gidroenergoproekt, the following small plants were built in 1994–2000 to electrify hard–

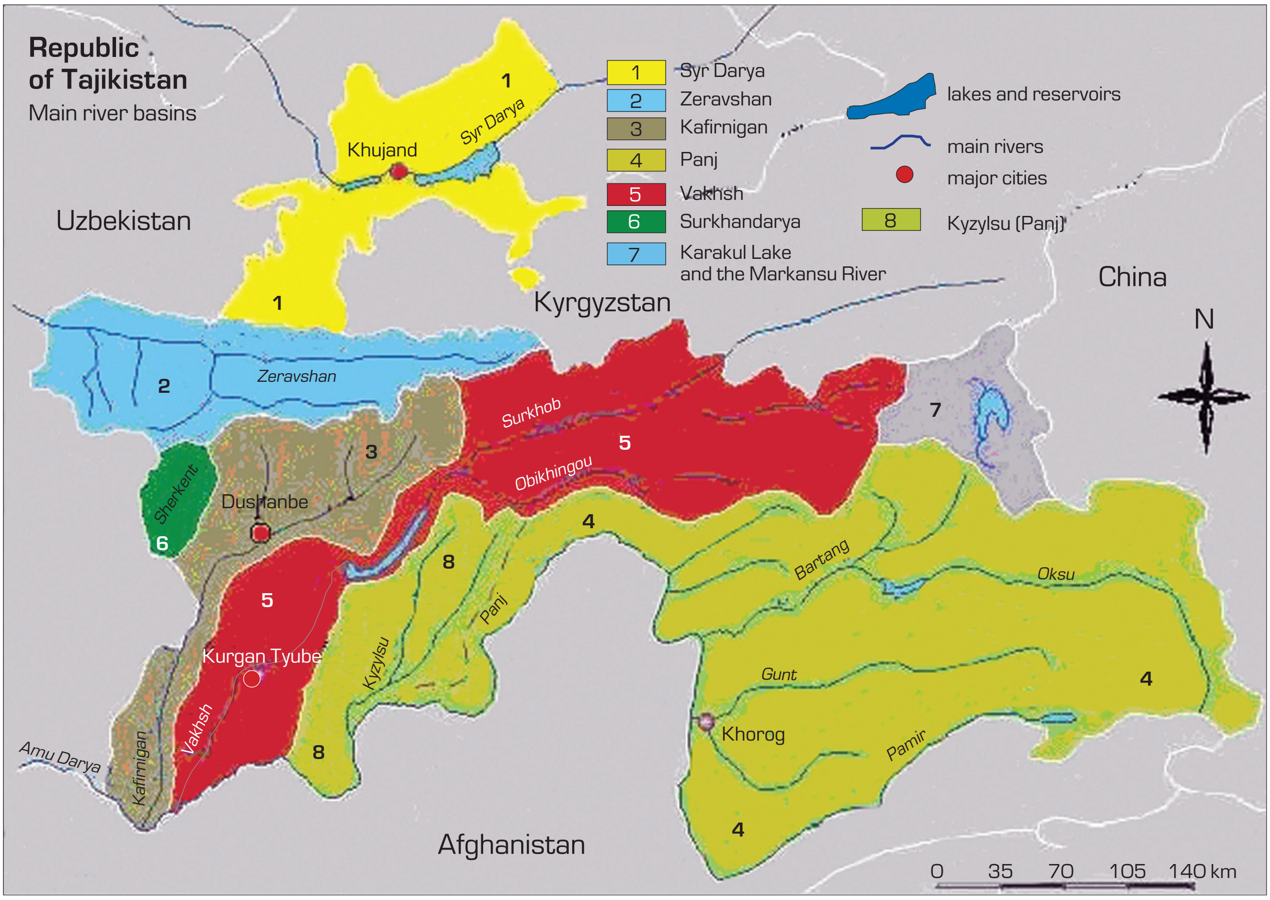

Figure 2.3.
Tajikistan's main river basins

Source: MEPRT, 2003: 3

to-reach mountainous settlements: Tekharv (360 kW, Gorno-Badakhshan Autonomous Province, 1994); Khistevars (630 kW, Sughd Province, 1996); Khazara-1 and Khazara-2 (250 kW, Regions of Republican Subordination, 1998–1999); Kyzyl Mazar (70 kW, Khatlon Province, 1998); and Anderbag (300 kW, Gorno-Badakhshan Autonomous Province, 1999). These projects were financed by Tajik government and Barki Tojik state energy holding. Over 25 small plants (100 to 1,500 kW) and over 40 mini plants (5 to 100 kW) were commissioned in mountainous regions.

In July 2009, the Sangtuda-1 hydropower plant was commissioned. It has four units with total installed capacity of 670 MW. This is the fifth plant on the Vakhsh cascade and one of Tajikistan's largest hydropower plants, along with Nurek (3,000 MW) and Baipaza (600 MW). Sangtuda-2 (220 MW) was completed in 2011, bringing the country's total hydro generating capacity to 5,000 MW.

The use of small rivers is a priority for Tajikistan's power sector. The small hydropower potential of small and medium rivers exceeds 30 million kW, allowing generation of about 100 billion kWh. Experts believe that small rivers can provide remote regions with all the electricity they require, or at least to a significant extent.

Tajikistan has government programmes for long-term hydropower development, including its small sector. In accordance with the Law #587 dated January 12, 2010 On the Utilisation of Renewable Energy Sources, small hydropower includes micro (up to 100 kW), mini (101 to 1,000 kW) and small (1,001 to 30,000 kW) hydropower plants.

In accordance with article 6 of the law, the priority areas for renewables are:

- areas without centralised power supplies where the construction of conventional power plants and high-voltage transmission lines is economically unfeasible or impracticable because of the low density of the population;
- areas with centralised power supplies that experience frequent power outages due to the poor condition of grids or the lack of capacity or energy, which cause significant economic damage and negative social consequences; and
- populated areas, countryside and places of people's temporary residence with heating, power and water supply problems.

In order to find solutions to these energy, social and economic problems, all the country's renewables and the respective power generating units are subject to registration, which is carried out by an authorised body in charge of the power sector (article 9). The relationships between renewable energy producers and grid operators, as well as with legal entities and individuals who buy this energy for resale are governed by contracts (article 11).

Government support to renewables includes: ensuring efficient pricing of renewable energy to foster its production and consumption; regulating tariffs on renewable energy supplies to consumers, including subsidies; guaranteeing the connection of renewable energy producers to power grids; and promoting investment and new technologies, including by creating favourable conditions for national and foreign investors (article 14).

Interstate, state, sector-wide and regional research and technical programmes may be adopted to manage the development of this sector (article 15).

In accordance with the Blueprint for Fuel and Energy Sector Development in 2003–2015, which was approved by the Tajik government, the main task is to balance the utilisation of fuel, energy and water resources and to ensure stable power and fuel supplies for the country. As for the power sector, the blueprint provides for the creation of favourable conditions for investors; the electrification of remote regions through the construction of small and mini hydropower plants; and the creation of research laboratories to study the potential of renewables.

Tajikistan's fuel and energy sector will be developed in stages. To ensure energy security, its priorities in 2003–2015 include the construction and commissioning of a number of small hydropower plants (RT, 2007: 115).

In 2006, the Centre for Power Projects, a state-run enterprise, was set up to coordinate projects irrespective of sources of financing, and the Long-Term Programme for Small Hydropower Plant Construction in 2007–2020 was adopted. This programme was revised and used to prepare the Long-Term Programme for Small Hydropower Plant Construction in 2009–2020.

The programme has three stages:

- short term (2009–2011): 66 plants with total installed capacity of 43.53 MW and an estimated cost of $51.593 million;
- medium term (2012–2015): 70 plants with total installed capacity of 32.85 MW and an estimated cost of $39.38 million; and
- long term (2016–2020): 53 plants with total installed capacity of 26.801 MW and a cost of $32.161 million.

The programme is planned to be financed by attracting local and foreign investors. Enterprises will receive benefits if they build small hydropower plants for their own needs. Their electricity will be cheaper than that purchased from the energy system. The price of electricity produced by small plants owned by enterprises will not exceed its prime cost. Tajikistan's experience of constructing small HPPs shows that the unit cost of construction is within $1,100–1,200 per kW.

The investment needed for all three stages is $123.1 million. These funds will be provided by international financial institutions. The Islamic Development Bank, the Asian Development Bank, the International Finance Corporation, the UNDP, and Iran are financing the construction of 23 small plants.

In addition, there is a pilot project to build and commission two or three wind power plants with a capacity of 20 to 100 kW.

Tajikistan has the necessary research and production resources to manufacture small and very small hydropower plants. The Chkalov Mechanical Engineering Plant and Tajiktekstilmash have the technology to produce equipment for small hydro. The small units they offer are manufactured using foreign technologies and equipment.

When local production is established, the unit cost of small plant construction and operation will decrease by 20–30%, making small plants more affordable for the population and farms. Small HPPs, whose production could be easily launched in Tajikistan, have many applications. Micro plants with a capacity of 5 to 50 kW can provide light to remote villages. More powerful plants can be used to supply electricity to processing farms (mini factories) and for heating.

2.7. Ukraine

Ukraine has over 63,000 small rivers and watercourses with a total length of 135,800 km, of which about 60,000 (95%) are very small (less than 10 km) running for a total of 112,000 km (1.9 km on average). A total of 87% of small rivers with a length of less than 10 km have drainage basins between 20.1 and 500 km^2. Western Ukraine's rivers have the highest flows.

The development of small hydropower in Ukraine began in the early 20th century. Eighty-four small HPPs (4,000 kW total) were in operation in 1924. In 1929, their number grew to 150 (8,400 kW). These plants included Buki (570 kW, 1929), Voznesensk (840 kW, 1929) and Sutiski (1927, capacity raised to 1,000 kW in 1935). In 1934, the Korsun-Shevchenkovskyi plant (1,650 kW) was built; it is still operative today. In 1935–1937, the Shumsk (120 kW), Potush (32 kW), Pisarevka (160 kW), Belousovo (88 kW), Berezovka (108 kW), Kleban (64 kW) and other plants were constructed. Dozens of water mills with small, 5–25 kW generators worked on some rivers in Western Ukraine. These were very simple small hydropower plants that provided electricity to nearby localities.

A total of 956 small plants operated in Ukraine by 1950 and construction continued. About 30 small plants were built in Transcarpathia: Ust-Chornaya (400 kW), Uglya (250 kW), Turya Remeta (360 kW), Dil, Keretski and Stavnoye. Uzhgorod (1,900 kW) and Onok (2,650 kW) plants were reconstructed. The Korsun-Shevchenkovskyi (1,650 kW), Steblyov (2,800 kW) and Dybno (560 kW) plants formed the very first rural energy system in Ukraine, which also included the Yurkovo thermal power plant (2,000 kW). The Ladyzhin and Glyboch small hydropower plants (7,500 kW each) and other facilities were constructed.

The proportion of small hydropower has sharply declined with the development of large thermal and nuclear energy. Centralised power supplies and low prices for fuel and electricity for authorities and enterprises that owned small hydropower plants made these plants economically unfeasible. As a result, almost all small plants have been decommissioned and disassembled. The construction of small plants at irrigation systems has also been stopped. Small plants had been expected to be built at 100 irrigation reservoirs, but construction was never started.

Ukraine has preserved only 150 small plants, including 49 operative. The functioning plants have obsolete hydropower, technological and electrical equipment, defective waterfront facilities (which can cause accidents and failures), silty reservoirs, high water intake for non-generation purposes, and washed-out downstream discharge facilities and shores. The negative consequences of Ukraine's refusal to develop its small hydropower include the loss of design, production and construction experience.

Small hydropower plants have again become economically feasible with the increases in energy prices, the appearance of new forms of ownership and business, and the development of private business. The revival of small hydropower began in 2000–2006 with very little government financing. The following small plants were reconstructed and commissioned: Korsun-Shevchenkovskyi (1,650 kW), Snyatin (800 kW), Sandrakskaya (640 kW), Yurpole (550 kW), Gordashevskaya (400 kW), Korzhevka (400 kW), Kuntsevo (400 kW), Ostapovka (375 kW), Sukhobarovskaya (330 kW), Galzhbiyevka (250 kW), Petrashivka (250 kW), Sednev (230 kW) and Lisyanka (200 kW). Construction has begun on new facilities, primarily micro plants.

Work is underway to determine the country's economically feasible hydro potential, including that of the existing water reservoirs and wastewater recovery facilities at water supply and discharge systems. In accordance with the Energy Strategy of Ukraine until 2030, the country has the following plans in the sphere of small hydropower:

- Reconstruction of small plants (135 MW total);
- Construction of new plants on the Tisza River and its feeders (400 MW total);
- Construction of new plants on the Dniester River and its feeders (560 MW total); and
- Construction of new decentralised plants on small watercourses (45 MW total).

By 2030, the generating capacity of Ukraine's small hydropower plants is expected to reach 1,140 MW and annual output 3.75 billion kWh. The advancement of small hydropower will help decentralise the country's energy system and electrify remote and hard-to-reach rural areas. This will help resolve many economic, environmental and social problems in rural regions. Small hydropower plants can contribute significantly to energy supply available to Ukraine's western regions.

The country's research and design institutions have the necessary potential to produce equipment for small hydropower. Turboatom, Kievenergomash (turbines and generating units), the Poltava Turbine Plant (lifting equipment for hydro units), the Nezhin Repair and Mechanical Plant (sluice gates), the Sumy Frunze Mechanical Engineering Research and Production Association (turbines and generating units), Elektrotyazhmash (powerful hydraulic turbine generators), Yuzhelektromash (generators), Elektronmash and Khartron (control systems) can launch mass production of modern hydropower equipment for small plants of Ukraine and for export to the CIS.

3. International Technical Assistance to Small Hydropower

The International Bank for Reconstruction and Development (IBRD) is the main credit institution of the World Bank Group. The Bank finances only 30% of a project's cost and specifically targets infrastructure: power, transportation and communications. Since the mid-1980s the IBRD has raised the share of loans to agriculture (to 20%), and to healthcare and education. Industry receives less than 15% of the Bank's loans.

The International Finance Corporation (IFC) is an international financial institution of the World Bank. The IFC provides loans and equity investments, structured finance and risk management products, as well as consultancy to promote the growth of the private sector in developing countries. As distinct from the IBRD, the IFC does not require state guarantees for financing. In 2010, the IFC's Russian division launched a programme to finance renewable energy projects. Loans are provided through Russian banks.

The World Bank provides significant support to hydropower not involving the use of transboundary watercourses. The Bank promotes efficient water management to meet the growing demand for water, provides additional support to hydropower, promotes adaptation to climate change and mitigation of its impacts, and strives to mitigate the risks of hydropower projects.

The European Bank for Reconstruction and Development (EBRD) is an investment mechanism established in 1991 by 60 countries and two international organisations to support market-oriented economies and democracy in 27 countries, from Central Europe to Central Asia. The EBRD is the largest investor in the region. In addition to providing its own funds, the Bank attracts significant foreign direct investment. Although its shareholders are governments, the ERDB invests primarily in private enterprises, as a rule together with its commercial partners. The ERDB provides project finance to banks, enterprises and companies and invests in new and existing production. It also works with state-owned companies to promote their privatisation and structural reorganisation and to improve their public services. In accordance with the agreement establishing the EBRD, all its activities are aimed to promote environmentally friendly and sustainable development.

The Asian Development Bank (ADB) provides significant support to its developing member states in the creation of priority sectors, including hydropower and environmental policy integration. The ADB is eager to provide financing for the development of small hydropower in the CIS and offers loans for these purposes on acceptable conditions.

The Eurasian Development Bank (EDB). In 2010, the EDB approved a programme to support and develop small and medium-sized businesses by providing targeted loan facilities to financial institutions. This programme can support small hydropower in the Bank's member states. Its purpose is to create favourable conditions for the sustainable development of small and medium-sized businesses in the member states, expand the infrastructural and institutional basis of the market-oriented economy, and provide financial support to small and medium-sized businesses. Loans are provided through banks of the EDB member states.

The United Nations Development Programme (UNDP) provides significant support to developing countries in advancing renewables, including small hydropower. In Central Asia, the UNDP has fulfilled some pilot projects to ensure the utilisation of small rivers' hydropower resources. It holds regular regional conferences in Central Asia and the CIS to share experience and promote cooperation in the sphere of renewables. In April 2011, the UNDP and the EDB signed a memorandum of understanding, which provides the basis for cooperation in the area of energy efficiency and energy saving, environmental protection and food security, water management and rural development. The common interests of the EDB and the UNDP include projects to advance renewables in Central Asian rural localities, with small hydropower as a priority, and to study the issues of joint management of hydropower resources of the Central Asian transboundary rivers.

The International Renewable Energy Agency (IRENA) is a new international institution established on January 26, 2009 in Bonn. The statute of IRENA has been signed by 148 states (Russia, Ukraine and Belarus are not signatories). IRENA has its headquarters in Abu Dhabi, United Arab Emirates. The organisation states that renewables are one of the key solutions to the power sector's problems. However, despite their significant potential, the current utilisation of renewables is still limited. Obstacles include lengthy permit procedures, customs duties on imports, technical barriers, risks associated with these projects, and the lack of understanding of their potential. IRENA's main objective is to help find solutions to these problems and to promote all types of renewables and respective policies at local, regional and national levels, taking into account environmental concerns. IRENA intends to hold regular consultations and to cooperate with organisations and networks that have already been working in the sphere of renewables in order to strengthen its cooperation potential.

Conclusions

The experience in developing the hydro potential of small rivers in the CIS shows that the construction of small hydropower plants has the following patterns:

- construction of small plants within larger hydro facilities;
- reconstruction of the existing or abandoned plants with modern automated equipment; and
- construction of new autonomous small hydropower plants.

Since the cost of equipment for small plants can be as high as 50 or even more percent of construction costs, the following should be ensured:

- equipment should be standardised;
- equipment should be fully automated and operative without 24–hour attendance;
- equipment should have simple design and high reliability and should be made with modern materials;
- mass–production generators and boosters should be used;
- control systems should be standardised and control of the hydraulic units should be tied to the automated hydropower plant; and
- modern technology should be used to improve operational reliability and lifetime, and reduce maintenance costs.

To improve the economic feasibility of small hydro construction, projects should use cutting–edge design and engineering solutions and standardised construction processes. Equipment for small hydropower plants should be modular and include standardised units and devices. The creation of a maintenance and repair service is another important condition for ensuring the reliable operation of small hydropower plants.

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- Development banks' operations and activities in the CIS countries and issues of cooperation.

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