

WORLD SMALL HYDROPOWER DEVELOPMENT

REPORT 2019

Case Studies

GREEN SMALL HYDROPOWER



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1. GREEN SMALL HYDROPOWER DEVELOPMENT IN CHINA



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China's small hydropower development process

China's first small hydropower plant (SHP), the Shilongba SHP in Yunnan Province, started generating electricity in 1912 with an initial installed capacity of 480 kW. Since then the country has gone through the following four main stages of SHP development:

- In the initial stage, from 1949 to 1980, the speed of SHP development was slow and the scale small, though it played an important role in solving the issue of no power supply in mountainous and rural areas.
- During the slow development stage, from 1980 to 2000, the Central Government encouraged the local governments and farmers to set up SHP projects themselves to aid in rural electrification.
- The rapid development stage, from 2001 to 2010, driven by the reform of the national investment system and electric power system, saw the growth of social capital and all-round development of the rural economy and society.
- From 2011, SHP development has entered the environmental reform stage. Restricted by resources and environmental factors, the recent focus is to improve SHP quality and increase efficiency. This will promote people-orientated, safe, green and harmonious SHP construction and development.

'The recent focus is to improve SHP quality and increase efficiency, while vigorously promoting people-orientated, safe, green and harmonious SHP construction and development.'

By the end of 2017, China had built over 47,000 SHPs, with the total installed hydropower capacity exceeding 340 GW. Of this figure, SHP exceeds 79 GW and accounts for 23 per cent of China's total hydropower generation. Over 62 per cent of China's SHP potential has been exploited, rising to a development rate of 82 per cent in some central and eastern provinces.

China's commitment to green SHP

In recent years, the Government's attitude towards SHP has changed from vigorous advocacy to strict regulation. However, there remains a strong commitment to "green hydropower", defined by the Chinese Ministry of Water Resources as "environmentally friendly, socially harmonious, with standardized management and meeting economic rationality criteria".

With increasing hydropower development in China, the environmental impact of the sector has become more prominent including the change in the hydrological features of the rivers. Partial river channels have dried up, river ecosystems and the downstream water for living and production have been affected, and gate-dams have reduced river connectivity. Also, the natural environment of migratory fish and other aquatic organisms are affected.

Presently, China's new rural hydropower resources are mainly located in remote areas, where the environmental conditions are fragile and the demand for electricity is low.

Further, some of China's older SHPs are considered unsafe for the environment and their electromechanical equipment is either ageing or obsolete. Units with obsolete design and manufacturing standards often compete for water with the rivers' ecosystems. In this light, green SHP development is a significant step towards maintaining China's environmental safety. It offers a strategy to maintain harmony between human water usage and the promotion of aquatic ecology, while helping to rapidly transform the SHP development approach by improving quality and increasing efficiency.

Green SHP research and practice

Academic research and seminars underpin China's development of green SHP. For example, in 2012, ICHSP conducted research on the influence of green hydropower on the environment of river systems in the south-western, south-eastern, north-eastern and north-western regions of China. It also analysed major influencing factors, screened key elements to evaluate green hydropower development and convened academic seminars to assess the effects of SHP projects on the environment.

Box 1. Changes and stages in small hydropower in China

Changes in investment mechanisms

The power consumption of Chinese society soared in the 1990s following economic reforms and the opening-up of the Chinese economy. Realizing the great potential of SHP development, the Chinese Government took the lead in changing the SHP investment mechanism and led a reform of feed-in tariffs, while encouraging private-sector investment in the SHP industry, greatly alleviating power supply problems. Subsequent investment in SHP via shareholding mechanism thrived, bringing considerable income to investors. During this period, the proprietary rights of SHP moved from the state and collective ownership to private (or share) ownership.

Changes in benefit distribution

The advantages of developing via shareholding mechanisms stimulated the rapid exploitation of China's SHP resources, enriching specific groups and individuals. The 1990s saw intensive development, and good-quality SHP resources were concentrated with vested interests. Overall, the SHP profits were distributed to the shareholders rather than to the general public.

Changes in energy structure status

Since the 1990s, China has undergone 30 years of rapid development and based on this growth, various other energy technologies were developed including wind, solar and nuclear power. Other alternative energy construction projects were initiated too. In fact, the installed capacity of China's wind and solar power constructed over the past 10 years exceeds the installed SHP capacity, which was developed over the last 60 years. Meanwhile, SHP proportion of China's energy structure is decreasing with every passing year.

Changes in demand

The high-speed development of China's society and economy has continuously improved the living standards and production levels, and the basic demands of people have been transformed from simply wanting a resolution of power supply issues to water resource utilization at a higher level. For example, people around SHPs expect to share the economic benefits of generated power. Moreover, people's demand for water resources has changed too. Earlier, water was primarily used as a tool for generating electricity, whereas now, drinking, environmental protection, and tourism are being prioritized.

Changes in the Government's attitude towards SHP

The Government has established many environmental protection zones, natural reserves, biosphere reserves, soil and water conservation areas, and even conservation areas for drinking water. An increasing number of SHPs, established early in China's SHP development cycle, find themselves located in various reserves. Additionally, environmental issues related to their operation are increasingly visible. The Government has refurbished, used either punitive measures or shut down such SHPs in an attempt to address environmental issues. Overall, the Government's attitude towards SHP has changed from vigorous advocacy to strict regulation.

The Standard for Evaluation of Green Small Hydropower, which stipulates the definition and construction standards of green SHP, was formulated based on this research. Moreover, ICSHP is currently formulating "Guidelines for Control Techniques for Downstream Flow Reduction of Small Hydropower Stations" to help standardize the construction requirements for newly built or refurbished SHPs. Similarly in 2016, the Ministry of Water Resources released Guidelines for Promoting the Development of Green Small Hydropower. The current aim is to establish a standard management system for green SHP, develop incentive policies, and build a batch of green SHPs before the end of 2020. It is envisaged that the green SHP concept will be fully embraced by 2030.

The guidelines identified seven key tasks to promote green SHP, namely, strengthening planning constraints and optimizing the layout of development; scientifically designing, constructing and advocating for green development; implementing, upgrading and transforming, and promoting ecological operation; perfecting the monitoring network, safeguarding the demand of ecological water and promoting cascade cooperation; improving technical standards and playing a good leadership role; and accelerating technological breakthroughs and promoting technological innovation.

In 2017, the Ministry issued the Notice on the Establishment of Green Small Hydropower Stations, detailing the certification process and procedures, which require all SHPs to abide by the laws and regulations, meet the requirements of downstream water, have no water disputes and have basic conditions of Standard for Evaluation of Green Small Hydropower.

ICSHP has also led the development of the Green Hydropower Management Information System, with a view of improving the efficiency of green hydropower management and information collection, to standardize work procedures, improve overall management of green hydropower departments, and increase publicity and transparency. The system integrates digital technology with green hydropower and promotes smart management to help the system become the "Internet+" of green hydropower.

In 2017, following voluntary application, preliminary validation, verification and publication, 44 SHPs passed the assessment and were accredited as the first batch of green SHPs in China. Over 400 hydropower stations were registered and applied in 2018, of which 121 were accredited as green SHPs.

Implementing measures for green hydropower

The requirements for development layout, development scale, development method, construction and operation of hydropower resources must be clarified through planning, and spatial control should be carried out in the development stage. SHP development is strictly prohibited in ecologically fragile and important eco-functional areas, while areas with higher development level must be optimized for development. Development planning should be continually evaluated.

In the design and construction stage, full use should be made of existing topography and landforms to arrange SHP facilities so as to minimize disturbances to river morphology and ecosystems. Moreover, green SHP projects should keep away from sensitive development areas such as nature reserves, national key scenic areas, centralized drinking water sources, and reduce the impact on land vegetation and soil disturbance. Green SHP should also avoid river canalization, which changes the boundary conditions of rivers, adversely affecting the upstream, downstream and both banks of the river. Further, the ecological flow of the river must be scientifically verified and the discharge measures should be identified. The ecosystems' demand for river water should be guaranteed, and the impact on the hydrological situation should be minimized.

As far as renovation and refurbishment measures are concerned, ecological flow features prominently in green SHP development, focusing on eight specific areas (Box 2). One potential measure to be considered is the use of a weir. If the river, on which a hydropower station is located, is wide, shallow and flows slowly, a fixed or movable weir

can be built. It should be located at an appropriate part of a dried-up river section that has little impact on flood control for upstream villages. This will allow the section to maintain a certain water depth and meet the requirements of longitudinal connectivity of the river.

Further, sluices can be built at appropriate points in the dried-up river section if there is a need for flood-and-erosion control during the rainy season. A typical sluice used for this purpose is a flap gate at the bottom foundation that has discharge holes. At the lowest water level, the flow discharge capacity of the discharge holes shall not be less than the minimum discharge flow. Floodgates can be opened to release flood water at high water level during the flood season.

It should be noted that if the main river channel where a hydropower station is located is stable, the inflow is low during the dry season, the river is wider and the evaporation capacity is larger. Given that certain fish and other aquatic organisms may have certain water depth requirements, it may be necessary to build a longitudinal deep pool at an appropriate point on the dried-up river section to restore water.

In terms of operation and management measures, for hydropower stations that have a significant influence on the hydrological situation of rivers during low water periods, the generation-dispatching mode should be changed. Along with that, seasonally restricted operations should be implemented, which will allow water to flow directly back to the river during the low water period.

It is also recommended to coordinate the operation of cascade hydropower plants using a centralized control system. Such a system should utilize the hydrological survey

information and water situation forecast results of the basin to guarantee the continuous discharge of water for improving river ecology.

Another operational measure is to establish an ecological flow monitoring network. This involves establishing monitoring sites at each discharge outlet of hydropower stations in the basin to monitor the discharge. Alternatively, river sections near the downstream part of the dam site of a hydropower station can be selected for installing flow-measuring devices.

The ecological flow monitoring technology should match with the conditions of the monitoring section, flow characteristics and discharge method. It is mainly based on real-time online monitoring and supplemented by other artificial comparison measurement so as to reflect the discharge flow objectively and accurately. Common measurement methods include traditional flow meter, Doppler (ADCP) flow measurement, real-time radar wave flow measurement, electromagnetic flow meter measurement, water meter measurement and hydraulic structure measurement.

Construction of green hydropower demonstration zone in Zhejiang

Target

The main aim is to undertake a comprehensive restoration of hydropower systems based on basins and regions, aiming to eliminate or alleviate environmental problems, such as drying-up of water or water reduction in river courses caused by hydropower stations. This is achieved through

Box 2. Ecological flow release

Use water diversion system

- For hydropower stations that adopt channel diversion, build a side weir by leaving an opening or bury drainage pipes in an appropriate place after the channel passes the dam to discharge the flow into the river channel.
- For hydropower stations that adopt tunnel diversion, utilize the original constructed adit tunnel near the dam to retrofit or excavate a new drainage tunnel. In this case, drainage pipes can be used to discharge the flow into the downstream river channel.
- For technically and economically feasible projects, “ecological generator units” can be installed in the outlet of drainage pipes.

Use spillway sluices with small opening

- For a gate-dam (sluice-dam) hydropower station, a one-hole or multiple-hole sluice gate can be closed incompletely, allowing for the control of discharge into the downstream river channel. After calculating and determining the sluice gate discharge opening using the sluice hole discharge formula, it can be controlled via a sluice gate stroke controller or by setting a limit pier (cement pier) on sluice floor slab.

Use spillway sluice

- According to the actual situation of the layout of a hydropower station, the operating gate (service gate) of spillway can be renovated. The middle gate or flap gate can be set and a hoist can be added to discharge the flow downstream.

Use dam-emptying facilities

- Utilize the original bottom outlets of the dam (such as the diversion bottom outlet, sediment orifice, reservoir emptying hole, flood discharging tunnel, spillway tunnel), add sluice gate control system, adjust dispatching and operation mode.

Set ecological base load or use reverse regulation

- For a dam-type hydropower station, which can meet the ecological flow requirements via electricity generation, it is unnecessary to set up special discharge facilities. According to the upstream water inflow condition, adjust the capacity of the reservoir and the characteristics of the generating unit of the hydropower station, optimize the dispatch and operation of the reservoir, and ensure continuous operation of at least one generating unit. Dispatch discharge flow through base load or reverse regulation and try to reduce the amplitude of variation of the downstream channel in one day as far as possible.

Install an ecological generating unit

- Besides the large generating unit, install the ecological generating unit, which can be set up separately, run for a long term and undertake the task of ecological discharge.

Release discharge by using bypass pipe of generating unit

- Open holes on the bypass pipe of water inlet valve of the generator unit and connect the drainage pipes, and discharge flow downstream after transformation by making use of the original water diversion facilities of the hydropower station.

Add dam water release facilities

- Add inverted siphon, water pumping system, spillway and other facilities at appropriate locations in the dam area to continuously take water from the upstream of the reservoir. After that, get water to pass through the dam and then release it into the downstream channel of the dam to meet ecological flow requirements.

both engineering and non-engineering measures designed to maintain and improve the ecological condition of rivers, optimize the allocation of water resources and scientifically utilize hydropower resources.

Activities

For some old diversion-type hydropower stations, especially those diverting water across the basins, water discharge facilities should be increased through technical refurbishment to maintain the ecological flow of the channels downstream of the hydropower stations.¹ Ecological weirs, rolling dams and landscape weirs should be built in dried-up or water-reduced river sections affected by hydropower dams and cascade hydropower stations. In this way, both the water supply for production and domestic use in the downstream can be safeguarded, and the water landscape of the river can be improved.

¹ If condition allows, small ecological units can be added.

Moreover, the minimum ecological flow and control principle of a hydropower station shall be identified according to the characteristics of different rivers in different basins, while ecological flow monitoring facilities must be installed to dynamically manage the ecological flow.

Starting with the actual condition of hydropower stations, an ecological operation mode will be established, the operation and scheduling will be improved, and the optimal scheduling of water resources in the reservoir will be strengthened. In addition, the downstream flow in dry seasons should be effectively improved by accumulating stored water during the rainy season.

Depending on the level of local economic and social development, hydropower stations will be multifunctional, not only generating electricity but also facilitating water supply and flood control. Hydropower stations deemed unsafe, not environment-friendly and uneconomical will be gradually abandoned and dismantled.

Promoting process

Runoff investigation and evaluation were conducted between the powerhouse and the dam. Moreover, an evaluation was done of the water-reduced and dried-up sections of 849 SHPs in Zhejiang Province, which had an installed capacity of above 500 kW. An assessment was made of the water environment and ecological degradation caused by water-reducing and dried-up river sections. Other process-promoting activities include:

- Active implementation of pilot projects in green hydropower demonstration zones in Lin'an, Anji and Kaihua. The total investment was over US\$ 3 million; 8 green hydropower demonstration zones and 15 ecological restoration hydropower stations were built; and 5 hydropower stations were dismantled. The demonstration effect and ecological benefits were outstanding.
- Compilation of Technical Guidelines for Ecological Hydropower Construction. Further clarification of technical requirements and methods for green hydropower construction, as well as technical measures for ensuring the ecological flow of downstream of hydropower stations, environmental protection, restoration of dried-up sections and the continuous environment improvement of hydropower stations.
- Compilation of the implementation plan for green hydropower construction during the 13th Five-Year Plan period (2016–2020). Organization and compilation of the implementation plan for the construction of green hydropower demonstration zones in Zhejiang (2016–2020), and integration of the content of green hydropower construction into the 13th Five-Year Plan for water conservancy development in Zhejiang Province. During the period, Zhejiang Province plans to build 50 green hydropower demonstration zones in 39 counties (cities, districts) and complete the restoration of 300 hydropower stations.

Guarantee measures

The rules for the construction and management of green hydropower demonstration zones in Zhejiang Province were established. These rules cover the definition, content, procedures, implementation of the procedures, and project applications of the green hydropower demonstration zone. They also delineate responsibilities for different levels of water administrative departments and project owners.

The management regulations for existing hydropower stations were issued. More specifically, in June 2015, the Province issued the Compensation Principles for Dismantling Existing SHPs in Anji County, which can implement the compensation process according to the dismantling of hydropower stations and restoration of the environment.

The construction of a green hydropower demonstration area was included into the project segmentation contact system, the daily supervision and inspection system and the monthly work notification and report systems. It was also included in the “one thousand people and ten thousand hydraulic projects” on-site guidance and the service work and provincial assessment on “treating sewage and flood control water and drainage, ensuring water supply and grasping water saving”.

Construction funds were raised through multiple channels including the Central Government, Provincial Government, the Global Environment Facility, private funds and bank loans. The fundraising channels for the project construction in the demonstration area were broadened to ensure the smooth implementation of the project. Moreover, the power generation loss was also measured and classified for the reimbursement in Jinhua and other cities (regions).

In terms of raising public awareness, a consensus on the promotion of the green hydropower demonstration area was gradually built from the higher level of government to grassroots hydropower stations through publicity, training and guidance.

Achievements in numbers

Overall, a total of 24 green hydropower demonstration areas have been identified, 53 hydropower stations have been refurbished, 24 rivers have been restored, 25 km of dried-up river sections have been restored, 3 discharge sluice holes ensuring ecological flow have been newly built and reconstructed and 37 weirs for maintaining ecological flow have been newly built.

Lessons for future SHP development

Lesson 1: Strengthen publicity, training and technological knowledge.

Lesson 2: Conduct basic investigation and clarify problems and working conditions.

Lesson 3: Set requirements, identify objectives clearly and formulate scientific layouts.

Lesson 4: Formulate standards and issue guidelines for promotion.

Lesson 5: Implement pilot projects, typical models, accumulate experiences and promote best practice.

Lesson 6: Conduct research on supporting policies, establish and improve incentive and guarantee mechanisms.

Box 3. The green SHP certification mechanism**Institution building**

In terms of future development, a key aim is to set up a certification institution for green hydropower. This institution will gain policy supports in relevant laws and regulations, finance, price and other fields, set scientific certification standards and adopt transparent certification procedures. Scientific research institutes and industry associations can participate or provide appropriate technical support and consultation.

Green power certificate for SHP

SHPs that have passed the green hydropower certification shall be awarded certificates by the competent department of hydropower resources. Enterprises of power generation and sales can voluntarily purchase the green power certificates. Megawatts hour of power generated is equivalent to a green certificate, which is marked with the type, serial number, production date and other information of the eligible renewable power. The green power certificate supports the quota system of SHP generation, that is to say, it is compulsory to stipulate a certain proportion of green SHP power output from power generation enterprises or power grid.

Green power tariffs

Power supply companies shall set green tariffs separately for the power companies with a green certificate, and consumers shall be free to choose a suitable proportion of green power according to their electricity consumption. A certain additional price is charged per kilowatt hour to make up for the higher cost of green power.

Green certificate market

A new competitive market, which allows the trade of green SHP electricity and has a different pricing system from that of the conventional power market, shall be created. This is called the green certificate market. The trading mechanism of green certificate not only opens up a sales channel for green power, but also ensures its optimized allocation and reasonable supply.



Figure 1. Shilongba SHP in Kunming, Yunnan Province
Note: China's first SHP, with installed capacity of 240 kW, is still operating.



Figure 2. Qingxi SHP in Guizhou



Figure 3. Jinkeng Ling SHP in Zhejiang (1,250 kW)



Figure 4. Hengjin First Cascade in Zhejiang Province (9,750 kW)

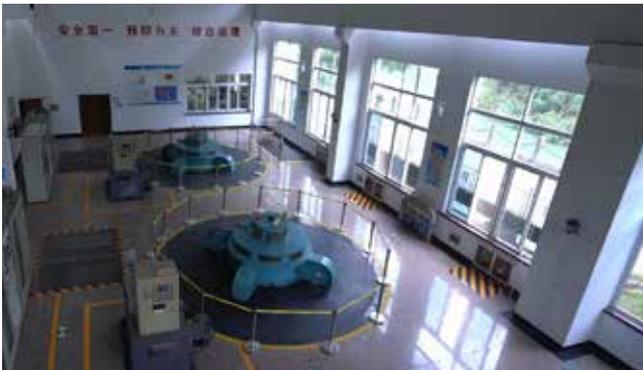


Figure 5. Anming First Cascade in Songyang, Zhejiang Province
Note: Total capacity is 2×6.3 MW, reservoir storage capacity is 3.32 million m^3 , an 80 cm pipe was installed at the bottom of the reservoir for ecological flow discharge.

2. GREEN SMALL HYDROPOWER IN AUSTRIA IN THE CONTEXT OF THE EU WATER FRAMEWORK DIRECTIVE



Source: Google Maps

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Pacific) for Small Hydro Power/
National Research Institute for
Rural Electrification

Small hydropower (SHP) as a renewable energy source plays an important role in Austria's energy sector, although balancing the need for hydropower development and river conservation continues to present a considerable challenge. In an attempt to square this circle, Austria has increasingly turned its attention towards green SHP, its policy and practice endorsing effective measures to promote ecological flow and river restoration, in particular.

The backbone of the Austrian energy mix, hydropower, accounts for over 60 per cent of Austria's electricity generation. Moreover, Austria has more than 3,000 existing hydropower plants with a catchment area larger than 100 km². Despite the fact that the country's hydropower potential is already developed to 68 per cent, the current Austrian Climate and Energy Strategy aims to further increase hydropower production based on the EU Renewable Energy Directive.

One potential consequence of such development is that hydropower initiatives may have a negative impact on river ecosystems, in turn hindering the accomplishment of the aims of the EU Water Framework Directive (WFD) and the Habitats Directive. WFD takes a pioneering approach to protecting natural geographical formations, such as, river basins. Overall WFD requires EU member states to reach 'good status' objectives for waterbodies based on a six-year cycle. For surface water, it consists of a general requirement for ecological protection ('Good Ecological Status' or GES) and a low level of chemical pollution ('Good Chemical Status' or GCS). GES is defined in terms of the quality of the biological community, the hydromorphological characteristics and the chemical and physicochemical characteristics.

Hydromorphological alterations (changes in the natural flow regime and structure of surface water) due to hydropower are among the top pressures emerging from the WFD analysis. In an attempt to balance both the hydropower development and the environment conservation, Austria has taken effective measures to guide the new development and ecological restoration of rivers impacted by existing hydropower plants. The specific successful practices employed by Austria, which may be of relevance to stakeholders in other countries facing similar or related issues, are discussed next.

Ecological flows policies for SHP with legal binding

Ecological flows (Eflows) as a hydrological regime consistent with GES shall ensure the good functioning of the ecosystem according to river type-specific biological conditions. The Austrian Water Act of 1990 requires that water abstraction has to be restricted so that an ecological minimum flow to achieve GES is guaranteed. In 2010, the Eflows to achieve good status (base flow and dynamic aspect) were defined in the ordinance on quality objectives for rivers and lakes. Requirements covering ecological minimum flow, ecological continuity (fish pass) and hydro-peaking are stipulated in the ordinance in detail with legal binding.



Figure 1. Dabalada ramp offering possibility of ascent for fish

Moreover, the Austrian National River Basin Management Plan stipulates that an ecological minimum flow must also be restored in existing hydropower plants that were awarded permits before 1990. Restoration will be undertaken incrementally until 2027 via an ecological prioritization approach.

The Austrian Water Act 2011 also stipulates that it is obligatory to guarantee ecological continuity at all the barriers, for example, hydropower plants or obstacles due to flood protection measures. Fish passes are, therefore, required for all hydropower plants that are situated in rivers with natural fish habitats. This also means that flow conditions have to allow fish migration (regulations for minimum depth and minimum flow velocity). Standards for the construction of fish passes, necessary for GES, have been developed and were published in 2012.

Implementation via an orderly prioritization approach

In Austria, the first National River Basin Management Plan (2009) prioritizes river stretches with middle-distance migratory fish. Furthermore, in 2011, the Governor of Upper Austria issued an ordinance for mitigation measures in the priority river reaches – and this ordinance enforces the establishment of river continuity at 310 barriers, 100 of which are hydropower plant barriers. Permit holders were obliged

Box 1. Requirements for a good hydromorphological status of a waterbody

Indicators	Requirements
Minimum flow	Natural mean annual flow $\leq 1 \text{ m}^3/\text{s}$ Natural mean annual flow $> 1 \text{ m}^3/\text{s}$
	$> \text{natural lowest daily minimum flow}$
	$> 50 \text{ per cent mean annual low flow}$ $> 33 \text{ per cent mean annual low flow}$
Dynamic flow	20 per cent of actual flow (recommended)
	Seasonal character of the natural bed-sediment relocation and thus a substrate composition is ensured
	Sufficient current/flow is ensured in times of spawning migrations
	Different habitat demands of individual age classes of key organisms are considered during different times of the year
Water depth and flow velocity	Minimum water depth and minimum flow velocity in the natural fish habitat
Hydro-peaking	For large rivers, anthropogenic fluctuations in water flow shall be assessed on a case-by-case basis.
	For all other waterbodies, they shall not exceed a ratio of 1 to 3 between downsurge and surge, and the water covering of the riverbed shall, during downsurge, account for at least 80 per cent of the riverbed surface covered in times of surge.
Fish migration	Anthropogenic migration barriers occurring in the natural fish habitat must be passable for fish all year long



Figure 2. Fish lift in Runserau



Figure 3. Fish pass and residual turbine at the Opponitz hydropower plant

to submit projects related to river continuity and ecological minimum flow, and the measures had to be licensed and implemented according to strict timelines.

Meanwhile, a technical paper addressing barriers in the Danube River Basin has been issued to the countries through which the Danube River flows. The paper outlines existing technical solutions to restoring river connectivity for fish migration, summarizes measures for ensuring fish migration at transversal structures and provides a rough orientation for the construction of fish passes.

It also evaluates types of fish passes, and covers upstream and downstream migration. Measures to restore the river continuum are classified as removal of the barriers, rough ramps or river bottom sills, nature-like bypass channels or nature-like pool-type fish passes, technical fish passes and special constructions (e.g., fish locks, fish lifts). Two approaches for the assessment of fish pass functionality are also discussed – evaluation based on indirect parameters (abiotic) and evaluation based on ecological investigations into the ecological impact on fish. Based on the evaluation of the waterbody condition, measures are also stipulated in the National Water Management Plan (NGP) that are required

in NGP I in the priority waterbodies (catchment area greater than 100 km²).

Specific measures

Until 2013, the Dabalada dam was an impassable hurdle for fish upstream of the entry to the Ill River into the Rhine River and it was the only migration obstacle before the subsequent renaturation stretch. To create connectivity, the previous Dabalada dam was replaced by a riverbed ramp in the trough-step-pool system, which covers the entire width of the waterbody. With this ramp, fish can now travel upstream unrestricted (Figure 1).

Moreover, a fish lift is used as a fish pass at the existing Runserau weir on the Inn River due to the lack of space and the extremely variable headwater levels. The downstream waterside is connected to the Inn by means of a vertical slot fish pass system and the head pond side is connected by a fish return pipeline (Figure 2). Two entrances in the tailwater and conventional vertical slot passes ensure that the fish can find the pass. A total of 1,393 fish were transported by the lift fish pass in 2016 and 719 in 2017. All in all, four different

fish species were transported: brown trout, rainbow trout, grayling and bullhead.

Similarly, the construction of the fish pass (Figure 3) at the Opponitz power plant established access for fish from the downstream side of the Göstling dam to the upstream side. A vertical slot pass was built on the left bank of the Ybbs River. The downstream entrance of the fish pass is located directly below the outlet of the residual water turbine, a constant attraction flow is ensured, securing the findability of the fish pass. The overall length of the fish pass is around 150 metres and the maximum altitude difference to be bridged is 6.2 metres. Moreover, ecological flow was increased from 0.25 m³/s to 1.2 m³/s.

Incentives for ecological restoration of SHP

In Upper Austria, an Energy Agency is responsible for awareness-raising and management of an advisory programme, which oversees consultations of plant owners, trainings and awareness campaigns. Overall 790 of the Upper Austrian hydropower plants are smaller than 0.5 MW, so the advisory service has a strong focus on SHPs. SHP owners can ask for preliminary advice about the optimization potential, technical and ecological requirements (best available technique including river continuity) and funding and incentive schemes. Since 2007, a total of 338 one- or two-day consultations have been undertaken by independent experts. Costs are met entirely by the programme.

Moreover, scientific research activities are supported by many stakeholders to deepen the scientific basis of specific fields. For instance, a HyTEC (Hydromorphological and Temperature Experiment Channel) test facility (Figure 4) was established to develop causal relationships with regard to

the reaction of aquatic organisms to surging and sinking phenomena by means of experimental approaches under controlled conditions. The project and the pilot plant are financed by the Austrian Ministry of Economy as well as by hydropower plant companies.

Lessons for future SHP development

Lesson 1: There is a need for a common understanding of ecological flow

A unified common understanding of ecological flow is essential for the proper implementation of Eflows policy. The understanding of Eflows should not only refer to the minimum flow but also specific requirements on dynamic flow, water depth and flow velocity, which are critical to river habitats.

Lesson 2: An orderly approach is needed to promote the sustainable development of SHPs

To restore the ecological impacts of existing SHPs, an orderly prioritization approach is needed. The ecological and economic effects should be balanced to promote the sustainable development of SHPs and the conservation of river ecosystems. Mitigation measures should be taken on a site-specific basis.

Lesson 3: Green SHP development requires incentives

Incentives are needed to guide the development of green SHP. Scientific findings and cost-effective technologies play an important role in accelerating the restoration of riverine reaches impacted by SHP development.



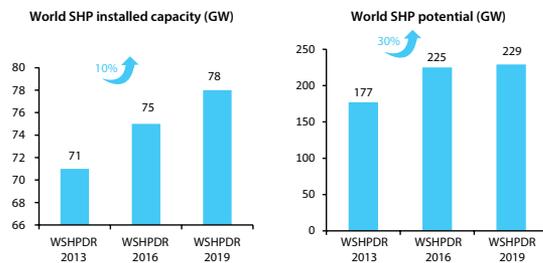
Figure 4. Research facility hydromorphological and temperature experiment channel



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World Small Hydropower Development Report

The *World Small Hydropower Development Report (WSHPDR) 2019* is an update of the Report's first two editions in 2013 and 2016. The *WSHPDR 2019* contains **166** national reports and **20** regional reports, with 21 new countries added since its first edition.



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- SHP for productive use
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 - a. Electricity sector;
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