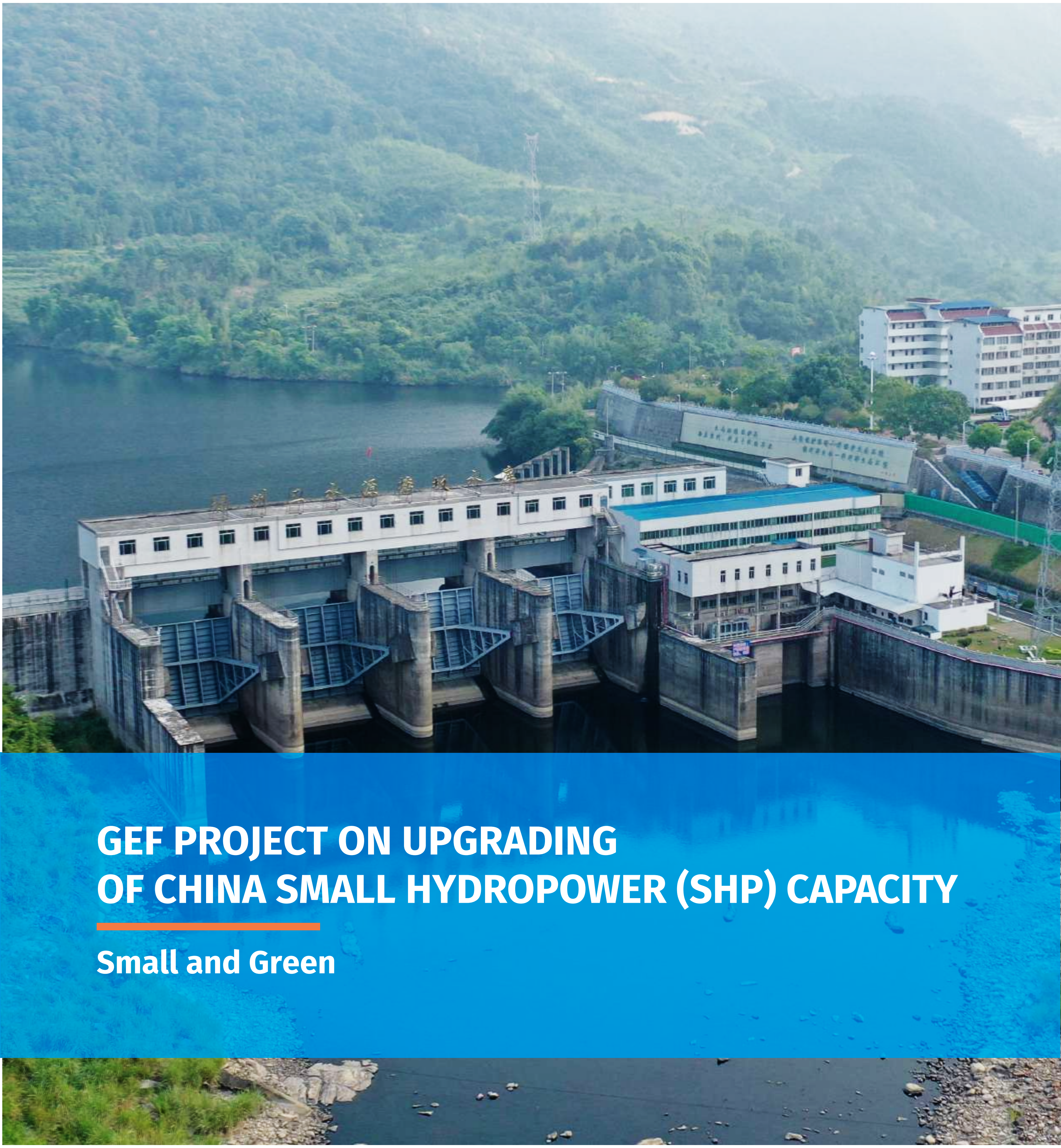
UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

SUSTAINABLE DEVELOPMENT GOALS



GEF PROJECT ON UPGRADING OF CHINA SMALL HYDROPOWER (SHP) CAPACITY

Small and Green

global environment facility
INVESTING IN OUR PLANET

MINISTRY OF WATER RESOURCES
OF THE PEOPLE'S REPUBLIC OF CHINA

INTERNATIONAL CENTER
ON SMALL HYDROPOWER

Disclaimer

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Cover photo: Tangban SHP Plant in Fujian, China

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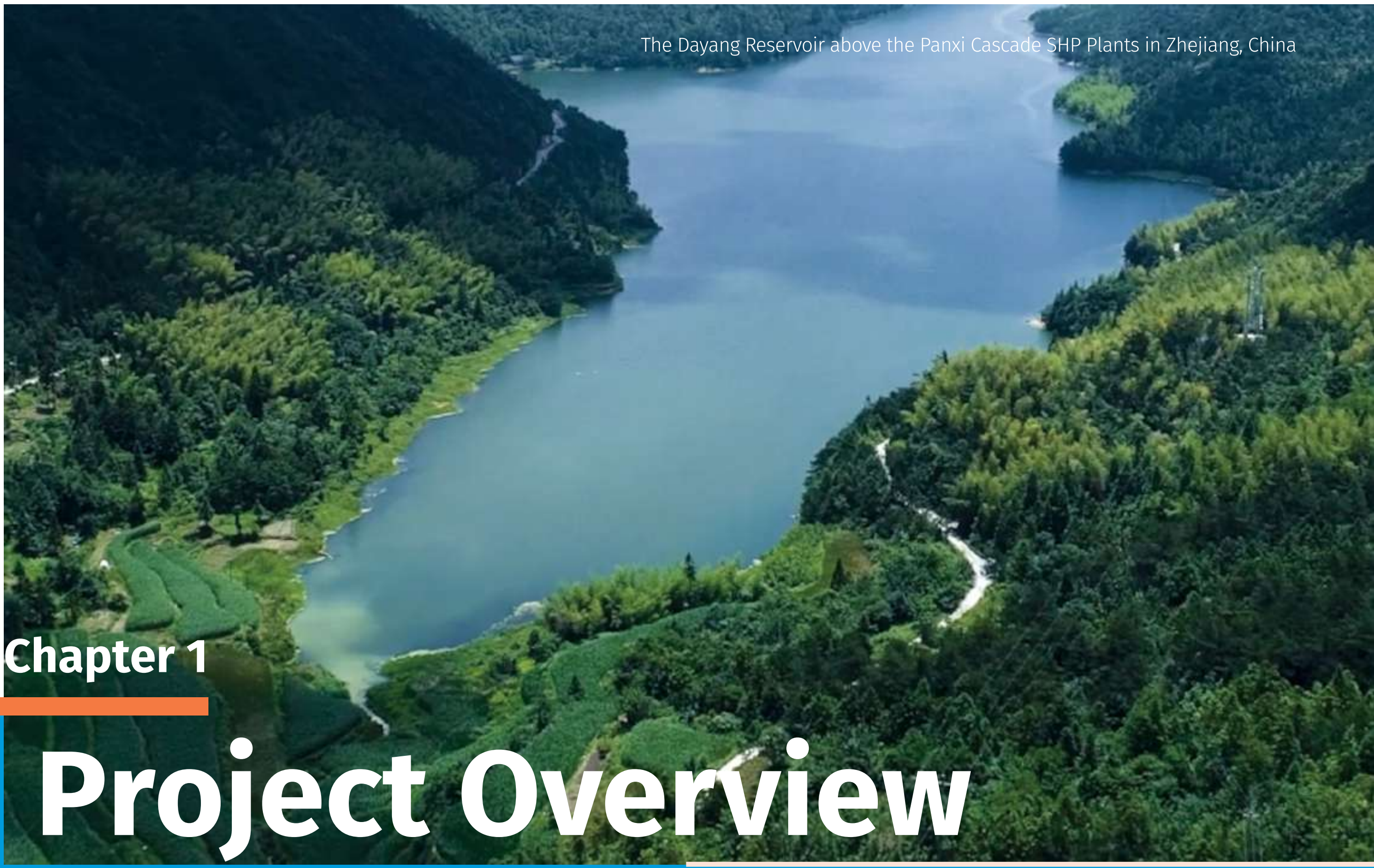
SMALL AND GREEN



The Dayang Reservoir above the Panxi Cascade SHP Plants in Zhejiang, China

Chapter 1

Project Overview

Background

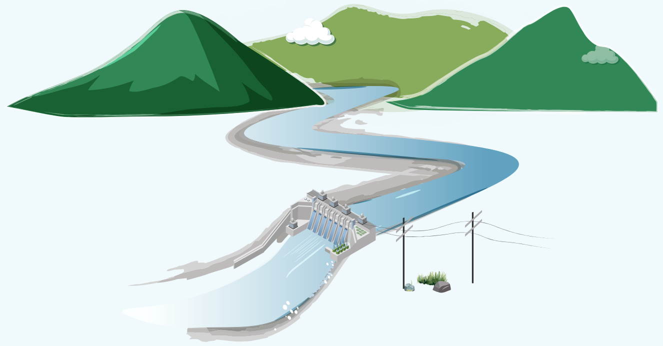
Small Hydropower (SHP) refers to hydropower projects with a small installed capacity. Most countries define SHP as those with installed capacities under 10 MW. In China, the bar is raised to 50 MW, and SHP in China is also known as rural hydropower because most SHP projects are located in rural and mountainous areas. Distributed widely in more than 30 of its provinces, China has a total exploitable potential of SHP around 128 GW.

SHP is a valuable source of clean and renewable energy. Compared to fossil fuels such as coal, the average greenhouse gas emission from SHP development is much lower. The use of SHP is advantageous for forming decentralized generation and distribution systems, supplying local communities and lowering costs. It could be a useful supplement to centralized grids since most SHP plants are built in remote areas. However, in the historical development, some SHP projects, due to insufficiencies in planning, technology and management, have caused adverse impact on aquatic ecology and environment, and such impact accumulates. This might include depleting flows in the river section between in-take and powerhouse, modifying connectivity of rivers, and loss of biodiversity, etc.

Safety has also been a key concern for the SHP industry in recent years. A large number of SHP plants in China were constructed long time ago (mostly in the 1970s and 1980s). Some prominent issues include ageing facilities, low generation efficiency, poor management and so on. Some plants, due to a lack of awareness, might even prioritize economic gains over safety. Therefore, it is particularly important to strengthen safety regulations and promote standardized measures for safety improvements in SHP operation.

Diversion scheme

Riverbed scheme



Typical layout schemes of SHP projects[1,8]. The diversion type is the most widely used one in SHP development, accounting for more than 80% of the total [2] .

SHP development in China is highly market-driven, with its main funding source from the private sector. In some areas such as Zhejiang, private finance could account for more than 80% of the total. However, SHP development has evident externalities that make the market incomplete in regulating the industry. These externalities might include greenhouse gas emission cuts and improvements in local livelihood (positive), as well as impacts on aquatic ecology and environment of the rivers (negative), which calls for additional regulations through governmental institutions.

The green and sustainable development of SHP requires an integrated approach that takes into consideration multiple aspects including ecology and environment, safety, economy, and societies. This approach should maximize the social-economic benefits from SHP development and take control of its adverse impacts to a certain extent so that river systems and services could be preserved in good status. Only in this way could SHP development fit into the sustainable socio-economic and environmental development.

A modified and improved weir of Panxi SHP Plants, Zhejiang

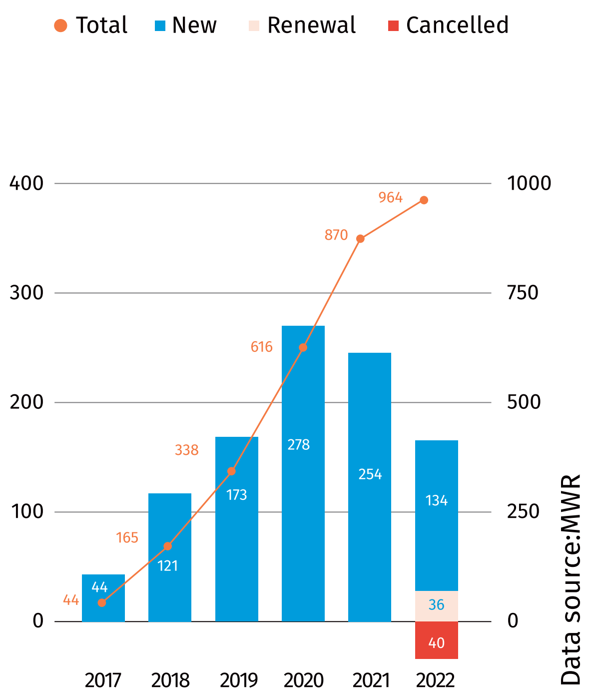
Green SHP development is intricately linked to China's rural revitalization and goals for carbon neutrality. In 2016, China's No. 1 Central Document, which is usually the blueprint of its annual rural policy, articulated that green SHP is a key part of the rural infrastructure. In September 2020, Chinese President Xi Jinping pledged on behalf of the Chinese government at the 75th UN General Assembly that "China will scale up its intended nationally determined contributions [under the Paris climate agreement] by adopting more vigorous policies and measures and aim to achieve peak emissions before 2030 and carbon neutrality by 2060." SHP's wide application in rural and mountainous areas, and its low carbon emission make it a valuable tool for bolstering local economies and decarbonizing energy portfolios in China. This also aligns well with the UN Sustainable Development Goals (SDGs), including Goal 7, "Affordable and Clean Energy", Goal 9, "Industry, Innovation and Infrastructure", and Goal 13, "Climate Action".

The United Nations Sustainable Development Goals (SDGs) are a set of goals adopted by the United Nations for implementing sustainable development around the globe. The SDGs build upon the Millennium Development Goals (MDGs) to create a future global development framework that is to be achieved by 2030. The set of 17 Goals provides a shared blueprint for peace and prosperity for people and the planet, now and into the future, and addresses global challenges including poverty, inequality, climate, environmental degradation, prosperity, peace and justice. These goals are interlinked and aim to leave no one behind.

To support green and sustainable SHP development in China, in particular ecological restoration of rivers, operational safety management, and automation improvements, the United Nations Industrial Development Organization (UNIDO), in cooperation with the Chinese Ministry of Water Resources (MWR) and Ministry of Finance (MOF), proposed the project, "Upgrading of China SHP Capacity" (hereinafter referred to as "the Project"), which was officially approved by the GEF Council in June 2016. Implementation of the Project was kicked off formally in November 2017.

Through the GEF fund, the Project leverages the Rural Hydropower Capacity Expansion Program under China's 13th Five-Year Plan. It puts additional value to the program by facilitating the formulation of policies to support green SHP development, setting up demonstration plants for green SHP certification, and standardizing safety measures, introducing modern equipment and technology, and improving industrial capacity. The Project is also meant for accumulating experiences in green SHP development around the globe.

How many certified Green SHP plants are there in China?

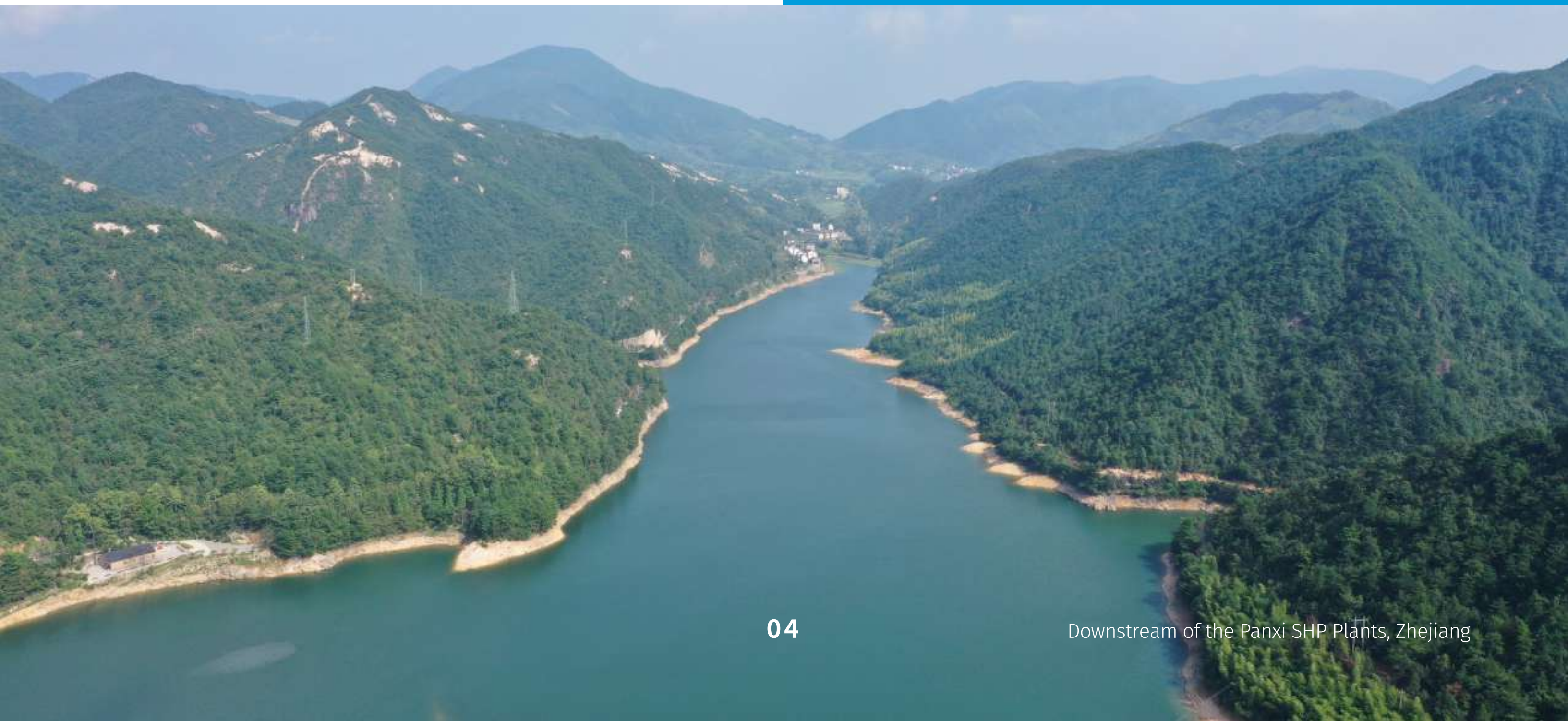


Green SHP Certification in China

Green SHP Certification of China was officially kicked off by MWR in 2017, after which the certification has been continuously conducted on an annual basis. By the end of 2022, there are a total of 964 certified plants across 25 provinces of the country.

Standardizing Measures to Improve Operational Safety of SHP in China

Standardizing measures are crucial for improving operational safety of SHP plants as it provides low-cost and standardized solutions for owners and managers of SHP projects. In 2013, MWR introduced a tiered system of SHP operational safety, which consists of three tiers of standardized measures that could be adopted by SHP owners to improve their projects' safety. By the end of 2021, the system has been adopted by a total of 3,963 SHP plants in China, among which 99 Tier 1, 1,498 Tier 2, and 2,176 Tier 3.



Downstream of the Panxi SHP Plants, Zhejiang

Project Activities

Component 1.
Policy and institutional framework

· Formulate or revise and issue technical standards and supporting policies for green SHP certification;

· Propose and introduce preferential policies for green SHP development at national and local levels;

· Promote the adoption of standardized measures for SHP operational safety nationwide.

Component 2.
Technical demonstration

· Provide technical support for pilot plants;

· Complete feasibility studies;

· Refurbish 19 demonstration projects (including 26 pilot plants) to complete green SHP certification and adopt standardized safety measures (with additional 20.21MW installed capacity and 133,585MWh annual electricity output);

· Monitor and analyze the energy efficiency of pilot plants;

· Conduct case studies;

· Assess socio-economic and environmental impacts of the demonstration.

Component 3.
Capacity building and knowledge sharing

· Provide training program for capacity-building to 1,200 SHP owners, developers and technicians;

· Provide training program for capacity-building to 200 SHP officials on the regulation of green SHP certification and safety measures;

· Organize overseas studies to learn green small hydropower related experience;

· Organize awareness raising campaigns for green SHP, including workshops, seminars, project film and brochure, etc.

· Train 350 SHP practitioners in the Green SHP Certification; provide technical support for 24* SHP plants to pass green SHP certification;

· Provide training programme to 200 SHP technicians on the standardized measures safe operation; provide technical support for 24* SHP plants to adopt standardized measures for operational safety.

* Apart from the pilot plants under Component 2

Partnerships

Project partners

UNIDO	GEF Implementing Agency
MOF	GEF National Focal Point
MWR	National Executing Entity
ICSHP	Delegated Executing Entity

Project management

Project Steering Committee

Composition: UNIDO, MWR, MOF, ICSHP, and provincial water departments from the provinces where technical demonstration is conducted.

The PSC, also known as NPCC, is responsible for designing project policies, setting project targets and milestones, managing project budget, and making decisions over project implementation. It oversees the progress, quality and budgets throughout the implementation of the Project.

Project Management Office

PMO

Hosted by ICSHP

The PMO implements and executes the policies and decisions of the PSC, and is the entity that is responsible for the day-to-day implementation of the project including the organization, coordination, support and management of various activities under the Project.

Provincial PMOs

Hosted by provincial water departments in 8 provinces, Zhejiang, Fujian, Hubei, Guangdong, Guangxi, Chongqing, Yunnan, and Shaanxi

Provincial PMOs are responsible for the organization, implementation, coordination, management, supervision and evaluation of demonstration projects within their jurisdiction.

E-flow releasing and monitoring facilities at Guanxi SHP plant, Guangdong Province

Chapter 2

Project Implementation and Outputs

The Project consists of four main components, including (1) improving policies and institutional frameworks for China's SHP industry, (2) selecting SHP plants to carry out technical demonstration, (3) offering programs for capacity building and knowledge sharing among the industry and general public, and (4) conducting monitoring and evaluation throughout the implementation of the Project.

Policy and Institutional Framework

Technical Demonstration

Capacity Building & Knowledge Sharing

Monitoring and Evaluation

Policy and Institutional Framework

The Project has promoted the formulation and revision of industrial standards related to green SHP and ecological flows, and contributed to MWR's macro policies on future SHP development and regulation. To support day-to-day operations of green SHP certification, it supported the compilation of a technical manual based on extensive practical experience and knowledge. The Project has also proposed a long-term development plan based on trend studies of the industry. These have together formed an integrated framework of policies in the SHP industry of China.

To streamline the management of information and newly emerged circumstances, the Project supported MWR to set up managerial rules and develop an online Management Information System.

In terms of supportive policies for green SHP, the Project has proposed to 8 provinces where demonstration is in implementation of a policy package consisting of an array of measures including awareness raising, public participation, investment and financing, feed-in tariffs, payment for ecosystem services, and e-flow incentives. Among the 8 provinces, Zhejiang and Guangdong have already incorporated some of the proposed measures into their policies. A policy study on national level is currently undergoing in attempts to materialize incentives from the central government.

China's present green SHP certification standard takes into consideration four aspects of SHP development, eco-environmental friendliness, social impacts, project management and economic efficiency. A further study funded through the Project recommends that future revisions to the present standard could consider breaking down the eco-environmental benchmarks, so that targeted incentives could be provided to those better performing ones in this regard.

A best practice manual has been developed under the Project to support a wider roll-out and adoption of standardized safety measures. The manual was based on analysis of 12 SHP plants sampled from a total of 90 (by end of 2020) from the country that have adopted Tier 1 safety measures. Feedbacks were very positive from its use in 8 provinces where demonstration activities were carried out.

Policy Outputs

Standard for Evaluation of Green Small Hydropower Stations (SL/T 752-2020)

Technical Guidelines for Control of Flow Reduction Downstream of Small Hydropower Stations (SL/T 796-2020)

Technical Guideline for Green SHP Certification

Recommendations on development strategy of China's green SHP

Best Practice Manual based on case studies of operational safety of SHP plants

Management Information System for green SHP certification

Recommendations for green SHP labelling system

Recommendations for incentive policies at national and local levels

Technical Demonstration

Technical demonstration has been completed at 19 SHP projects to upgrade equipment and facilities, release ecological flows, improve environments, complete green SHP certification, and adopt standardized safety measures. These measures help increase efficiency of power generation, minimize their environmental impacts, and improve operational safety. The demonstration includes:

1 Upgrading equipment and facilities

Updating and renovating hydraulic structures (barrage dams, diversion channels, pressure forebay), electric and mechanical facilities (turbines, generators and auxiliary equipment, electrical equipment, booster station equipment), metal structures (sluice gates and other valve) to expand installed capacity and improve power generation efficiency.

Building integrated control center and monitoring system.

Upgrading automation and safety control systems.

2 Releasing ecological flows

Installing facilities to release ecological flows (by adding or modifying plant schemes, or leaving certain generators continuously on to release flows).

Installing equipment for monitoring and data collection.

3 Improving Environments

Restoring habitats (river channel, vegetation, wetlands, etc.) and ecosystem services with key parameters (hydrology, water quality, etc.) monitored;

Managing waste (trash, debris, wastewater, oil leakage, sanitation, etc.);

Improving workplace conditions (interior and outdoor) of the plants.

4 Green SHP Certification

Improving management and operation schemes;

Installing systems for hydrological monitoring and flood forecasting;

Sharing benefits by contributing to local infrastructure (water supply, irrigation, roads, lamps, recreation, etc.);

Completing Green SHP certification of MWR.

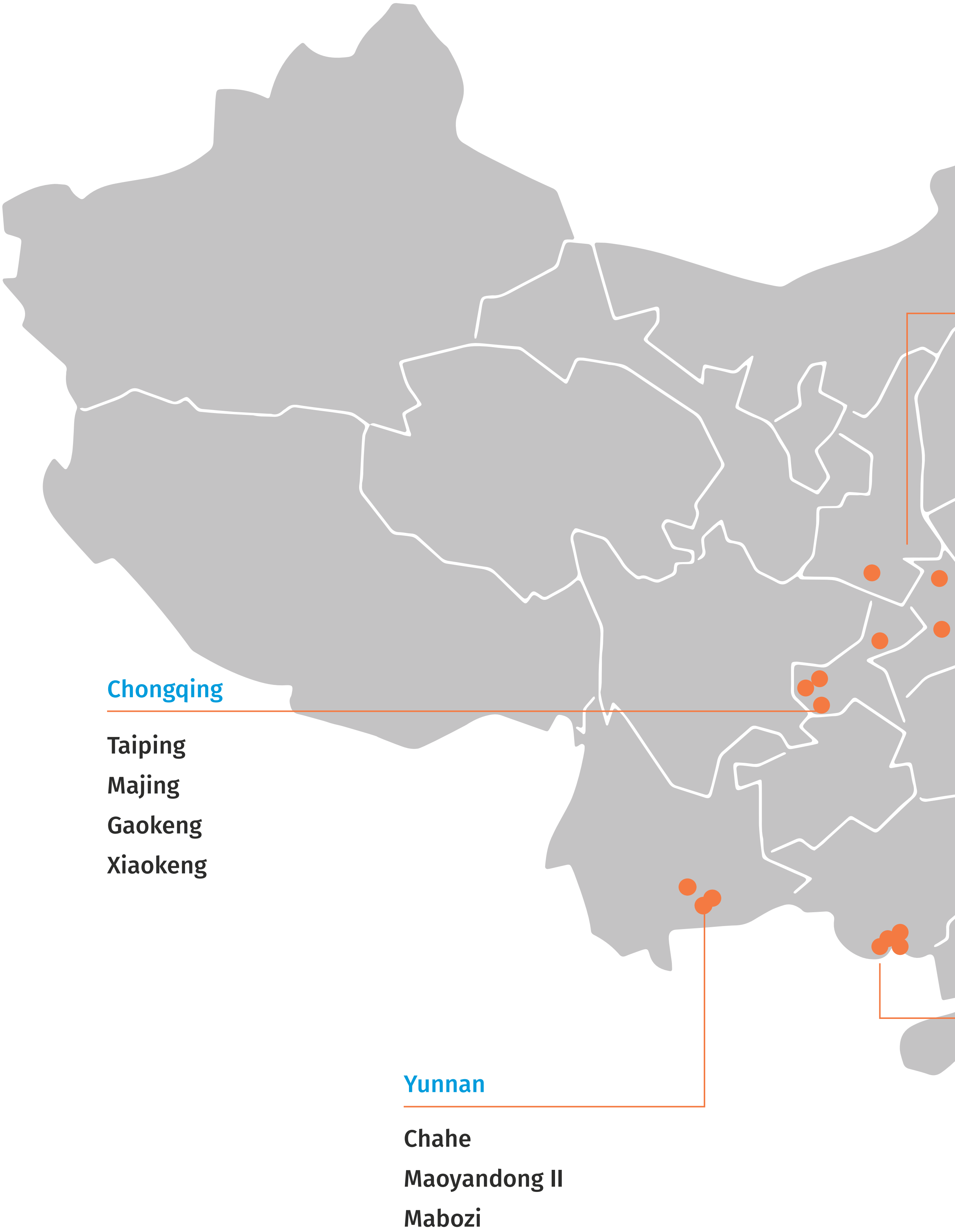
5 Adopting standardized safety measures

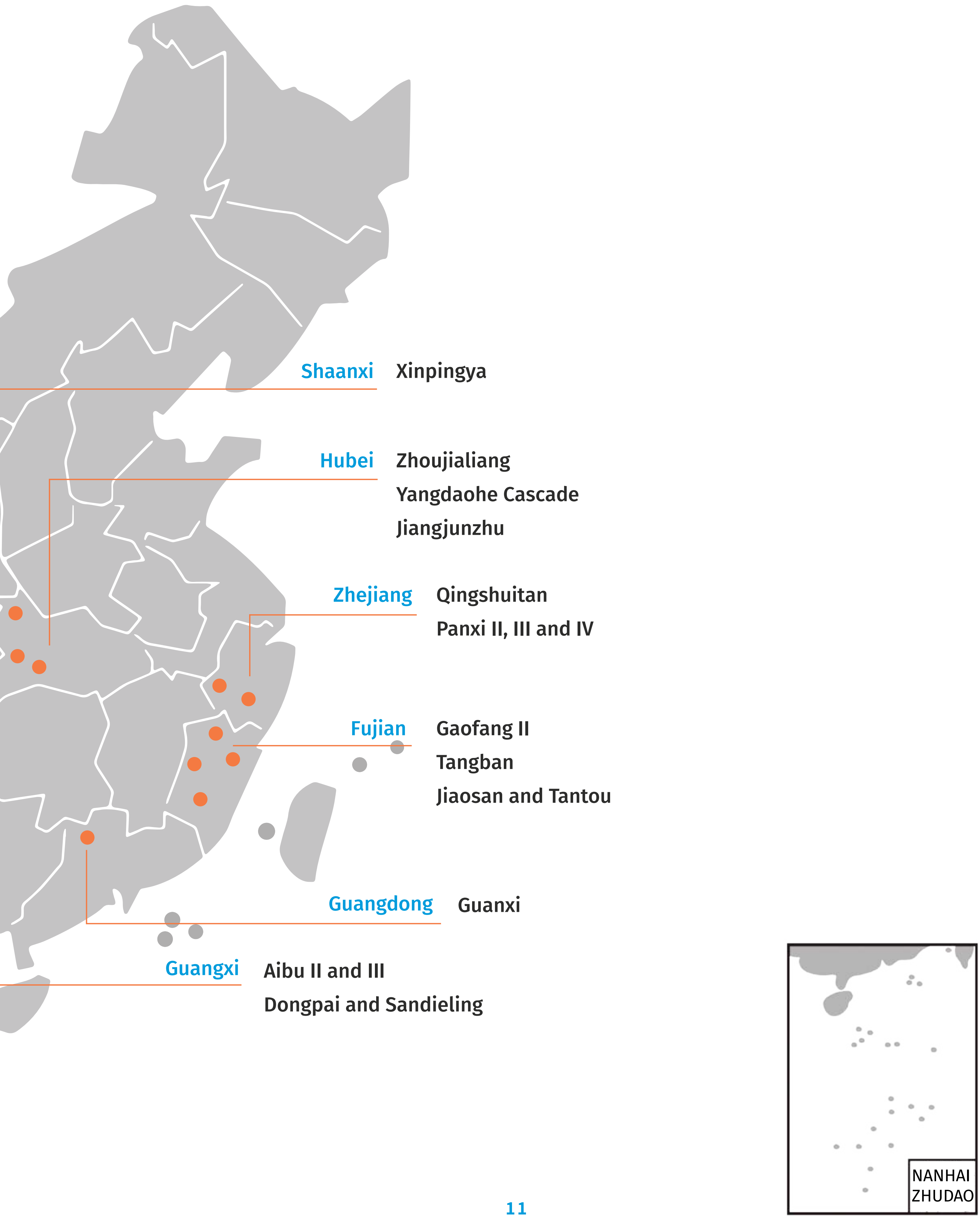
Identifying risks and setting up warning and forecasting schemes and systems;

Improving equipment, plans and rules for daily operation and management, occupational health, data collection and information sharing, and reporting and investigation of emergencies;

Improving emergency preparedness through response plans, regular training and drills, and extensive involvement and participation;

Passing accreditation of safety measures (Tier 1/2/3).


Chongqing
Taiping
Majing
Gaokeng
Xiaokeng
Yunnan
Chahe
Maoyandong II
Mabozi


Shaanxi
Xinpingya
Hubei
Zhoujialiang
Yangdaohe Cascade
Jiangjunzhu
Zhejiang
Qingshuitan
Panxi II, III and IV
Fujian
Gaofang II
Tangban
Jiaosan and Tantou
Guangdong
Guanxi
Guangxi
Aibu II and III
Dongpai and Sandieling
NANHAI
ZHUDAO

CASES

Dongpai and Sandieling SHP Plants

Releasing and monitoring of e-flow

Dongpai and Sandieling SHP plants are located in Huren Township, Jingxi City, Guangxi Province, and are the first and second SHP plants on the Luoshui River. Luoshui, a tributary of Heishui River, has a catchment area of around 1,199.89km². Both plants were commissioned in the 1990s, with installed capacity of 15,00kW and 13,500kW, and average annual power output of 3.4 GWh and 27.68 GWh respectively. The two plants underwent capacity upgrades between November 2017 and May 2019, after which the installed capacity remained the same but annual output was significantly raised. The Dongpai plant now sees a designed annual output of 4.2 GWh and Sandieling, 32 GWh, which increased respectively by 23.5% and 15.6%.

After the refurbishment, a steel pipe has been installed in the dam of Sandieling, and Dongpai modified its diversion channel 10 meters downstream its dam to release flow through an opening. Additional facilities have also been installed to collect real-time data of the e-flow and record that to a designated repository.


E-flow releasing and monitoring facilities of Sandieling SHP Plant

Ecological flow

Ecological flow, also known as the minimum flow, or simply e-flow, is commonly understood as the amount and time of quality water that is needed to sustain the integrity and services of aquatic ecosystems of rivers and lakes.

CASES

Jiangjunzhu SHP Plant

Restoring vegetation

The Jiangjunzhu SHP plant is located on the Wangjia River in Xingshan of Hubei Province, which is a county adjacent to the Shennongjia Forestry District. The plant is approximately 150km away from the city of Yichang. Built in a diversion scheme, it was first commissioned in the 1980s. The plant has a 285.5km² catchment area upstream its dam, and a 3,000kW installed capacity. The average annual output was around 12.89 GWh. Its facilities have aged severely after 30 years' operation. Its turbine unit and electrical facilities were replaced in the refurbishment, but the installed capacity remained unchanged, after which the design annual output has been raised to 15.73 GWh. A pipe was installed in its dam body for e-flow release at $0.52m^3/s$ under real-time monitoring.

Refurbishment of Jiangjunzhu plant paid special attention to vegetation restoration for its approximation to the forestry reserve, with considerable amounts of trees and grasses planted in and around the plant.

Special attention was paid to vegetation restoration when Jiangjunzhu SHP Plant was refurbished due to its approximation to the forestry reserve.

CASES

Panxi Cascade Plants

Protecting aquatic species

The Panxi Plants re-stock the stream with fish to supplement existing populations.

The Panxi II, III and IV plants are located in Jinyun County, Lishui, Zhejiang Province. They are developed on the Panxi stream, a tributary of the Ou River to its south. All the three plants were built in penstock schemes and first commissioned in the 1970s. The cascade plants were designed to maximize the use of hydropower with the tailwater of the upstream plant going directly into the canal of the downstream one. Therefore, some of the river sections were depleted. After refurbishment, the free plants now release enough e-flow to support ecological services of the river. Also improved were plant facilities and management. These plants have all passed the green SHP certification of MWR and now form a model cascade SHP development.

Three weirs of the plants were modified to fit local morphology and distribution of aquatic species so that in flood season fish could migrate upstream freely. During the dry season, these weirs help raise water depth in the river sections between them. The owners of the plants are in cooperation with the local water department on a fishing ban on the river section for conservation of aquatic species, and re-stock it with fish on an annual basis to supplement existing populations.

CASES

Guanxi SHP Plant

Improving automation

The Guanxi SHP plant is located in the middle reaches of the Nanshui River, about 800m upstream of Ganxi, a village in Hougongdu Township, Yuyuan Yao Autonomous County, Guangdong Province, with a catchment area of 838km². Built in a barrage scheme, the plant has a 12-meter-high dam, and a reservoir with a capacity of 560,000m³ at a normal water level of 69.50m. The plant was commissioned in 1986 with 3×1,600kW installed capacity, and its average annual output was around 15 GWh. Its ageing equipment raised safety risks and lowered generation efficiency. Moreover, as a renovated upstream SHP plant is releasing more tail water, Guanxi had to curtail more that it could not cope with. After refurbishment of the plant, its installed capacity has been raised to 3×2,000kW (+25%), and the efficiency of the generator increased by 10%. The design annual output has also been raised to 17.99 GWh.

After refurbishment, the plant now operates with a significantly higher level of automation and energy efficiency. Equipment upgrades have substantially reduced the manpower required for operation and management of the plant, which helps cut costs and raise efficiency.

The central control room of Guanxi before (L) and after (R) refurbishment.

CASES

Majing SHP Plant

Serving local communities


An EV charging station was built by Majing SHP Plant fo public use.

Majing SHP plant is located on the Qingxi River in Qijiang District, Chongqing. The plant has a catchment area of 303.3km² upstream its dam. The plant is in a penstock scheme, and was first commissioned in 1986 with an installed capacity of 2×2,500kW. Its average annual output was around 25.06 GWh. The plant is meant for integrated purposes including flood control, water supply and irrigation. However, its outdated facilities were causing higher risks of failure and declining efficiency. After refurbishment, the capacity of the plant was increased to 2×3,200kW, and its efficiency significantly improved.

The plant subsidizes the local communities for their electricity bill. Moreover, to contribute to local transport, it has provided funds for renovation of a local bus stop, installation of a charging station for electric vehicles, and retrofitting of road lamps.

CASES

Tangban SHP Plant

Improving safety

First commissioned in 2000, Tangban SHP plant is located in Tangban Village, Pandu Township, Lianjiang County, Fujian Province, on the middle reaches of Aojiang River. Its original installed capacity was 2×5,500 kW and average annual output was 35.45 GWh. The ageing of its infrastructure was bringing growing safety risks but declining efficiency, which prevented the plant from effectively developing the energy. After the refurbishment, the installed capacity of the plant was raised to 2×6,000kW, and the design output was increased to 43.51 GWh.

The plant significantly improved its safety measures and passed the Tier 1 accreditation of MWR. Standardized measures were adopted by the plant to manage safety risks, improve preparedness and emergency response. Training and drills have been organized on a regular basis, and plant employees are extensively involved and participating in these.

Regular drills are organized in Tangban plant to improve preparedness for emergencies such as flooding.

CASES

Xinpingya SHP Plant

Improving income of females

Xinpingya is the 5th SHP plant on the Badao River. It is located in Ziyang County, Shaanxi Province in the middle reaches of the river. The plant is in a penstock scheme with a gravity overflow dam 4.8m high and 22.5m long 4.8km upstream. No storage capacity exists in the scheme and water is diverted to the powerhouse through a 2.5km channel at a waterhead between 115.7 to 122 meters. Construction of the plant started in 1996 and it was first commissioned in 1992 with 2×1,250kW installed capacity, 118m design water head, and 9.7 GWh design output per year. However, the plan became limited after decade-long operation due to insufficient installed capacity and increasing curtailment. Therefore, the refurbishment increased its installed capacity to 2×1,600kW and its design output to 11.87 GWh (+22.3%). The plant was re-commissioned in April 2019 and is now performing with eveidently improved efficiency.

The refurbished plant sees a significant improvement in incomes of the employees, in particular female employees. Monitoring data between July 2020 and June 2021 shows that the average incomes of employees increased by around 40% after refurbishment, while that of female employees around 59%.

Female employees of Xinpingya SHP Plant working in their posts

CASES

Maoyandong II SHP Plant

Upgrading equipment

The newly refurbished powerhouse of Maoyandong II SHP Plant

Maoyandong II is the 8th SHP plant on the Xiaojiang River, a tributary to the Nanpanjiang River. Located in Luxi County of Honghe Prefecture of Yunnan Province, on the lower reaches of the Xiaojiang River, the plant is approximately 34km away from the town center of Luxi, and 210km away from Kunming, capital of Yunnan Province. The plant was first commissioned in 1988 with 2×6,300kW installed capacity. Its annual output was designed as 52.7 GWh, and the long-term average was 65 GWh. Its ageing facilities and declining safety after decade-long operation had become a major setback for the plant's efficiency. After refurbishment, the plant improved its efficiency as well as environmental friendliness.

The refurbishment included upgrades of its generators, auxiliary equipment, and all electrical facilities. The installed capacity was increased to 2×7,500kW (+19%) and design output to 68.49 GWh (+29.9%).

Capacity Building & Knowledge Sharing

The "green turn" of the SHP industry and improving safety depends on industrial capacity. Through various knowledge sharing events including training programs, seminars and so on, the Project has offered valuable opportunities to build professional capacities among SHP owners, industrial associations, government officials and technical experts. These events have also served in raising awareness among the general public and winning more support for green SHP and other renewable energy.


December 2020, the second session for SHP practitioners held in Haikou

Training Programs

The project has offered capacity-building training programs to 1,780 SHP owners, technical experts, and industrial association personnel, and 211 government officials on technologies, equipment and facilities, management, and incentive policies related to green SHP development. Through participatory learning and analysis of green SHP development in China and abroad, trainees gain knowledge through real-world cases. Special attention has also been given to the sustainability of these activities. Training of 50 trainers was first completed under this component with active involvement of universities and other educational institutions, so that knowledge and experience sharing could be continued even after end of the Project. Gender mainstreaming has also been emphasized in these programs to make sure that female participants are over 25% of the total, and women are offered additional support to further develop their professional skills for their careers.


A study tour was organized under the Project to LIHI in the United States in June 2019 to learn their experiences in low-impact hydropower certification.

"The U.S. attaches considerable importance to river ecology and fish conservation, and also promotes this philosophy to the public to increase environmental awareness and educate citizens about the importance of environmental protection and fish conservation in a fun and participatory way...... LIHI certified SHP plans get additional subsidies from the state government and market, and people could choose to purchase electricity from low-impact sources. This is critical for promotion of green SHP development."

—— Mission report to LIHI, United States

"The Austrian and Swiss federal governments and state governments at all levels offer incentives and subsidies for hydropower development. Power stations that undergo renovations to meet environmental standards are offered financial subsidies based on their sizes and scales, and electricity prices from green power stations are also additionally subsidized. Policies such as these incentivize power stations to undergo eco-friendly transformations, and should be studied for China's green hydropower strategy.

——Mission Report for the technical tour to Austria and Switzerland

November 2019, SHP officials from China discussing with local experts during a technical tour to Austria and Switzerland

Knowledge-Sharing Seminars

In order to further share the knowledge and experience gained through the Project, three domestic and one international seminars have been organized in Xi'an, Nanchang, Kunming and Beijing (online) respectively. Participants of the seminars include officials from government agencies from central to local levels overseeing environment, water management and macro-policies, industrial associations, owners, investors, technical experts, media, NGOs, and the general public. Apart from knowledge and experience sharing, these seminars have provided arenas for communication and exchange between stakeholders, awareness-raising, and creation of business opportunities.

Expert team communicating with SHP owners during site visits to assess operational safety and offer technical support

Technical Support for Green SHP Certification and Safety Improvements

Technical support and consultancy have been provided under the Project to 24 SHP plants (apart from the pilot ones) on the certification of green SHP and improvements in operational safety through standardization. The support was provided through training, policy interpretation, document review and on-site visits, and covered both infrastructural and managerial aspects, which has received very positive feedback from the plants.

By the end of this sub-component, the Project have trained a total of 554 SHP plant employees, and 148 (26.7%) of them were female. All the supported plants have passed MWR's green SHP certification, and obtained its safety accreditations (Tier 1, 2 or 3).

Monitoring and Evaluation

Monitoring and evaluation (M&E) of the Project have been conducted in accordance with established UNIDO and GEF procedures. As defined by Project Component 4, the M&E of the Project has taken a two-pronged approach that measures against respectively (1) GEF's strategic indicators, and (2) technical indicators for outputs under Project Component 1 to 3.

- **GEF's strategic indicators:** Based on the Results Framework of the GEF-6 Programming Directions, the Project is expected to contribute to GEF's target in cutting GHG emissions to support transformational shifts towards a low-emission and resilient development path. Moreover, by the Proces Framework of GEF-6, stakeholder involvement and gender equality are also required to be incorporated into the implementation of the Project.
- **Project outputs:** Project Component 1 to 3 produce an array of outputs ranging from refurbished SHP plants, improved policies and institutions, and enhanced capacity and awareness. These outputs are monitored and measured against specific technical indicators set at project preparation and inception phases. For all demonstration activities, an ESMP has been developed, implemented and monitored at each of the SHP plants.

Mid-term Review

In 2019, due to restrictions out of the Covid-19 pandemic, a mid-term performance evaluation was conducted in place of the mid-term review by national experts in compliance with MOF requirements. The experts concluded that the Project has been in 'smooth implementation'. The Project was included in the "*2019 Case Study of Performance Evaluation of IFI and Foreign Governmental Loan Projects in China*", and was the only project implemented by central government agencies of China included in the report.

Terminal Evaluation

The terminal evaluation is under preparation in compliance with GEF and UNIDO policies and will take place between July and December 2023. It is to provide a comprehensive and systematic account of the performance of the Project by assessing its design, implementation, and achievement of objectives.

28 April 2021, Fourth PSC Meeting in Hangzhou

"The project objectives and content are directly aligned with China's small hydropower development strategy and policy priorities, and the project outputs are highly relevant to the sustainable SHP development in China. The Project has a clear target beneficiary group in addressing their most pressing concerns."

—— Mid-Term Performance Evaluation Report of the GEF Project on Upgrading of China SHP Capacity

The refurbished control room of Tangban SHP Plant

Chapter 3

Outcomes of the Project

Economic Benefits

The direct economic benefits come from the refurbishment of the demonstration plants. After refurbishment and upgrades, the plants have expanded their installed capacity for power generation. Additionally, these activities have significantly promoted their adoption of automated operations and management, which helps lower operational costs and labor demands for the plants. The Internal Rate of Return (IRR) of the demonstration activities was 10.73%.

Additionally, indirect economic benefits may come from the contribution local economies through, for example, job creation, transportation, and tourism. Both direct and indirect benefits are scaled up through policy and capacity components of the Project. A study of the total economic value of the Project is undergoing for further quantification of the benefits.

The refurbished control room of Majing SHP Plant, Chongqing

Installed Capacity

After the refurbishment, the demonstration plants expanded their total installed capacity from 104.59 to 124.80 MW, representing a 19% increase.

Power Output

The long-term average output of the demonstration plants before the refurbishment was 373 GWh per year. The annual output of these plants in fiscal year 2022 (July 2021 to June 2022) increased by 28.95% to 481 GWh.

Automation

The refurbishment of the demonstration plants included replacement of hydraulic turbines, generators, and main transformers, and upgrades in control systems, speed controllers, excitation devices, and relay protection facilities, which allows the wide application of automated operation and management of the plants.

Environmental Benefits

The Project generates direct environmental benefits through the refurbishment of the demonstration plants. By modifying the original schemes of the plants to allow minimum e-flows, these activities contribute to the restoration of aquatic ecology and habitats, and therefore maintain valuable services provided by these ecosystems. Due to the low emission of hydropower use, additional power output of these plants means the demand for energy from fossil fuel could be reduced, which therefore directly contributes to cuts in greenhouse gas emission.

These environmental benefits are scaled up further in proliferation of similar practices at other SHP projects through promoting green SHP certification in China under the Project.

Releasing E-flows

All plants taking part in the demonstration have modified their original schemes to allow the release of e-flows in compliance with industrial standards. These modifications could be setting up auxiliary sluice gates, or installing additional pipes and valves, depending on the different conditions of individual plants. Additional facilities have been installed to monitor e-flows online with data collected and stored in repositories designated by local authorities.

GHG Emission Cuts

The additional power output through refurbishing plants contributes to GHG emission cuts. Compared to other energy sources from fossil fuels, the GHG emission from hydropower development is very low [4]. Supplying additional electricity from SHP development means less demand for that from fossil sources. According to monitoring data, the demonstration plants generated an additional 108 GWh of electricity (compared to the long-term average before the refurbishment), which is estimated to be equivalent to a direct emission cut of 76,100 tons. The emission cut could be even more significant as more plants follow the success stories from the demonstration.

Electrical substation of Chahe SHP Plant, Yunnan

Social Benefits

Rich social benefits arise from the Project through its activities that contribute to the SHP industry of China through improved policies and institutions, success stories created in technical demonstration, and enhanced industrial capacity.

Construction works going on at Majing SHP Plant, Chongqing

Improving Green SHP Institutions

The Project significantly improves China's institutional framework for green SHP development. These include industrial standards for assessing green SHP plants and releasing adequate e-flows. Supporting technical manuals and recommendations of development plans have also been developed under this project. These form a future-oriented framework that integrates technology and policy.

Upgrading the standardization of production safety

Improved operational safety is another benefit generated directly by the project. The best practice manual developed through case studies of the 90 Tier 1 plants (by end of 2020) across the country has been a valuable tool for improving operational safety in 8 provinces where demonstration plants are in. By end of 2022, the Project has supported 43 SHP plants (including 19 demonstration ones) to pass safety accreditations of MWR with improved capacity and safety.

Improving Practitioners' Skillsets and Managerial Capacities

The capacity building programs offered by the Project have proven to be invaluable resources in refining practitioners' skillsets and managerial proficiencies. By the end of the Project, 16 training sessions have been organized and 1,991 SHPP practitioners (owners, technicians, government officials, etc.) have been trained through these. Trainees gained in-depth understanding of green SHP and operational safety to enhance their professional skillsets and managerial capacities.

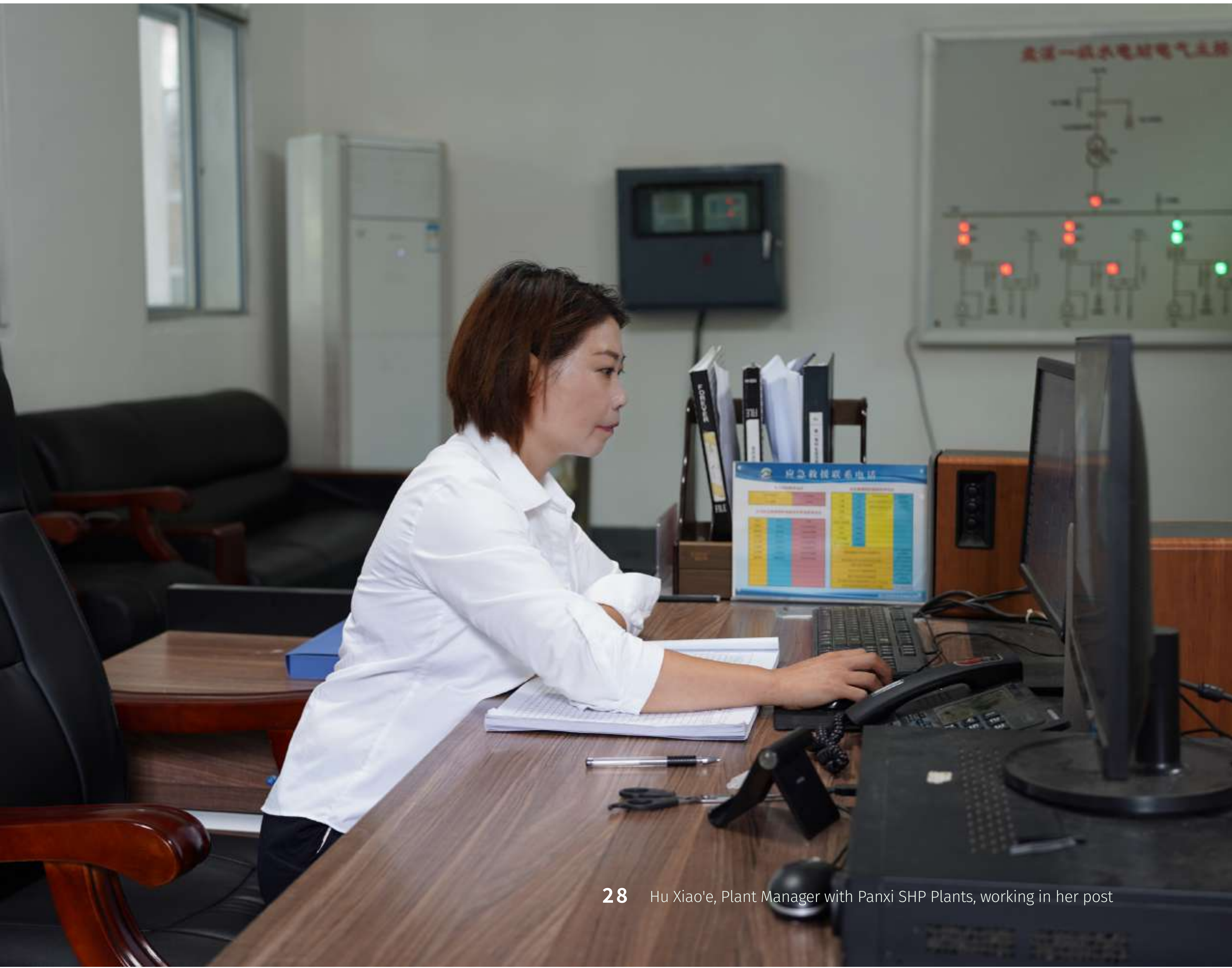
Aerial view of Gaokeng SHP Plant, Chongqing. Refurbishment of the plant included repairing a nearby road for better transport access of local communities.

Empowering Women

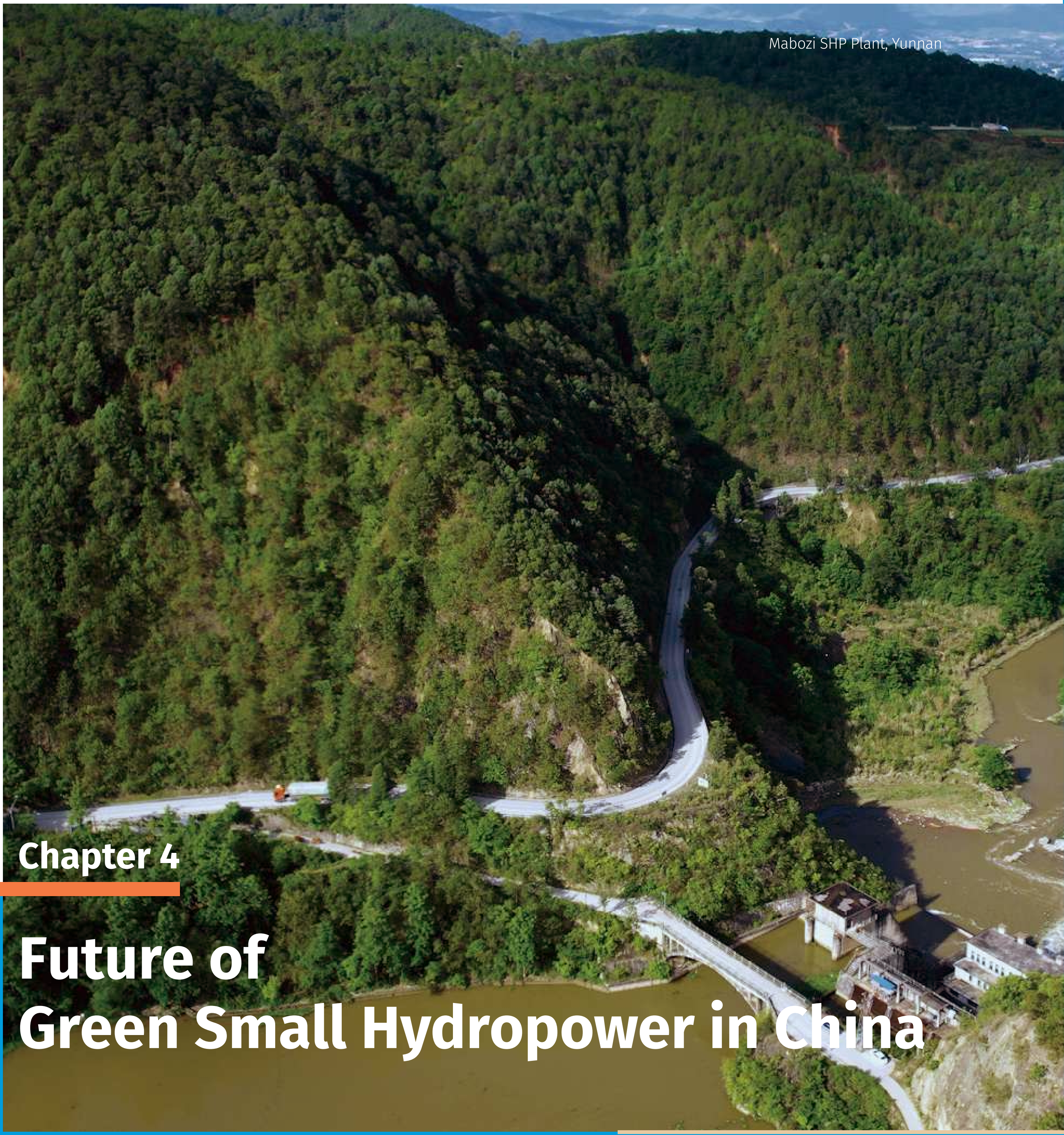
Empowering women is one of the priorities of the Project. To address gender inequalities, all components of the Project incorporate measures for women's inclusion and participation, with special attention paid to helping them improve their career skills and opportunities. Their improved capacities earn them better incomes and enable further career development. For instance, women now account for 28% of total employees of the demonstration plants, and half of the plants have female members in their leadership team.

Benefiting Local Communities

The Project's benefits are shared with local communities. Demonstration activities provide support in improving local infrastructures for power use, transport and so on. The improved aquatic ecology could now provide services that better accommodate their leisure and recreational needs. More opportunities for employment and economic development are created through other industries enabled by improved local infrastructure and ecological services, for instance, tourism, which allows the sharing of benefits further.



Hu Xiao'e, Plant Manager with Panxi SHP Plants, working in her post



Mabozi SHP Plant, Yunnan

Chapter 4

Future of Green Small Hydropower in China

Greener SHP in the Future of China

Small Hydropower and China's 'Dual Carbon' Goals

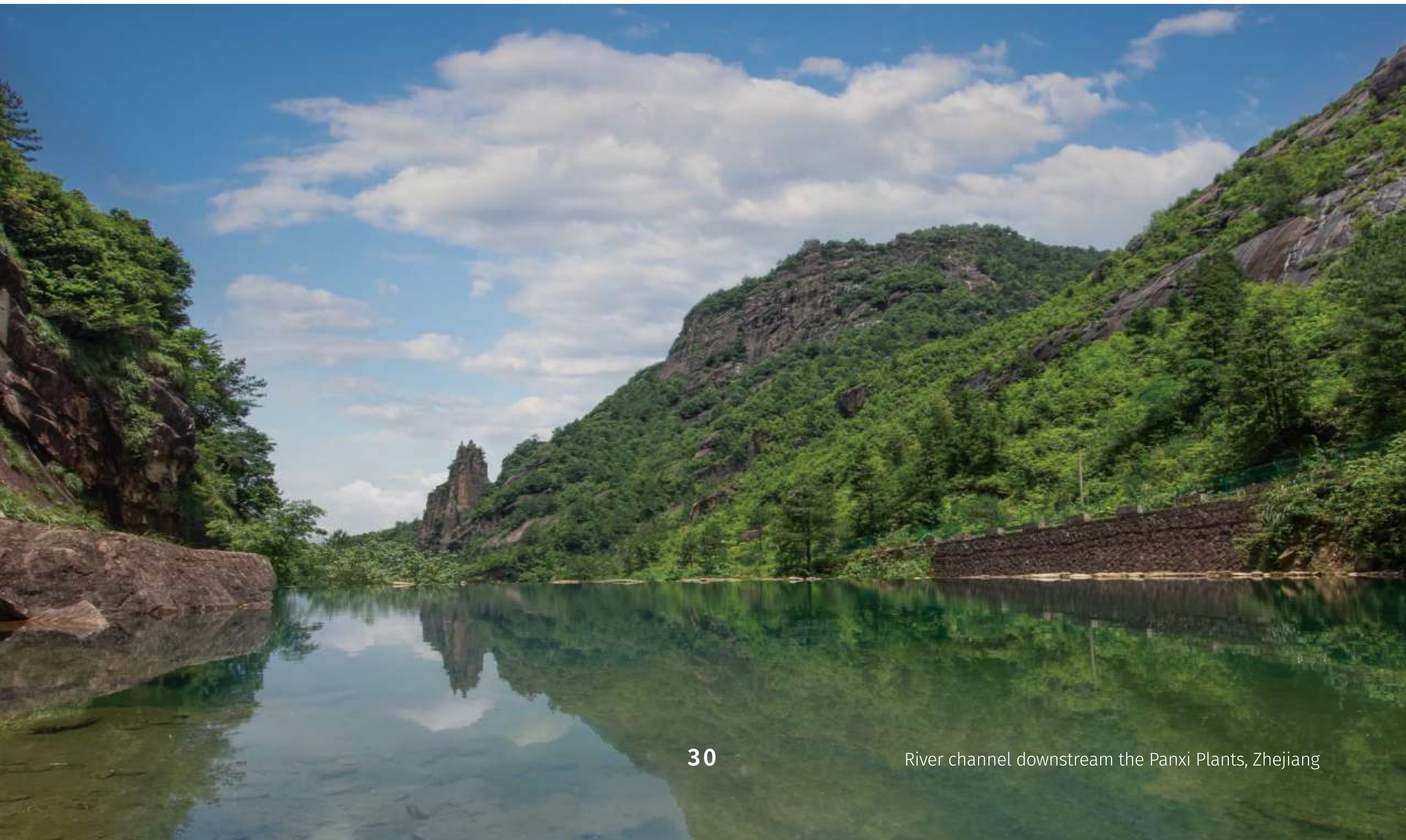
Greener SHP in the Future of China

SHP played an important historical role in rural development of China. More than 300 million rural Chinese population benefited from SHP development across half of its territory. However, with growing awareness of environmental integrity and well-being, more attention is being paid to minimizing environmental and social impacts from SHP development. This 'green turn' of the SHP industry in China has been an incremental process and is expected to continue.

The evolvement of the SHP industry in China saw a major push from the central government in combination of its efforts to reform its energy portfolio, alleviate poverty, and fight environmental degradation. In its 12th (2011-2015) and 13th (2016-2020) Five-Year Plan, a total of 13.1 billion Chinese Yuan of central government investment in renewable energy was set aside to increase its SHP capacity by 12 GW and annual average output by 4.5 TWh.

An additional 2.3 billion Yuan from the 13th FYP was put into new SHP development, from which the benefits were directly used by local governments for poverty alleviation in rural areas. This investment also catalyzed more than 7 billion local government finance, increased installed SHP capacity by 803 MW, and yielded 25.6 million Yuan annually that benefited more than 100,000 families.

In attempts to lower the environmental impacts from SHP development, MWR started its green SHP certification program in 2017, and by end of 2022, there have been 964 certified green SHP plants in the country. Apart from that, MWR in partnership with other stake-holding central government agencies, started basin-scale re-examinations of SHP projects in 2018. SHP plants are required to take measures to minimize their adverse environmental and social impacts. Those plants with impacts impossible to mitigate, or that still fail to comply with the latest requirements after taking necessary measures, are required to cease operation



River channel downstream the Panxi Plants, Zhejiang and be dismantled. The re-examination has been completed in the Yangtze River basin at the end of 2020, and more than 3,500 plants were decommissioned. Re-examination of SHP projects in other areas is still undergoing in 2023.

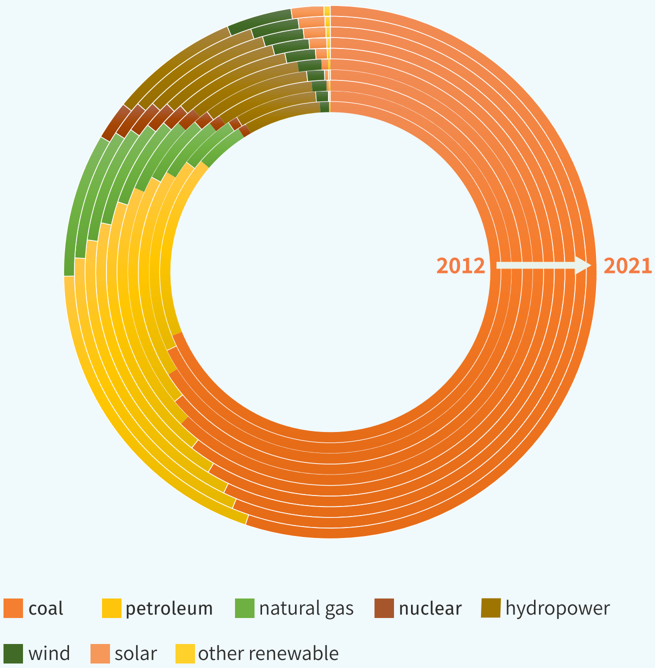
It could be seen that the incremental green turn of the SHP industry in China would continue. Such green turn would need to take into consideration not only safety, mitigating environmental impacts, safety improvements, and facility upgrades, but also balancing environmental protection and socio-economic development. This ambition would also require solid financial input. At the moment, the costs of these green measures are largely borne by SHP owners with limited options for recovering these costs through government or market institutions, which would require substantial efforts in reforming and improving SHP related institutions. Moreover, in parallel to the need to maximize the socio-economic and environmental benefits of SHP development, it is equally evident of the necessity to take into consideration social equity in the sharing of these benefits, so that the least privileged communities could benefit from it, including local residents and women.

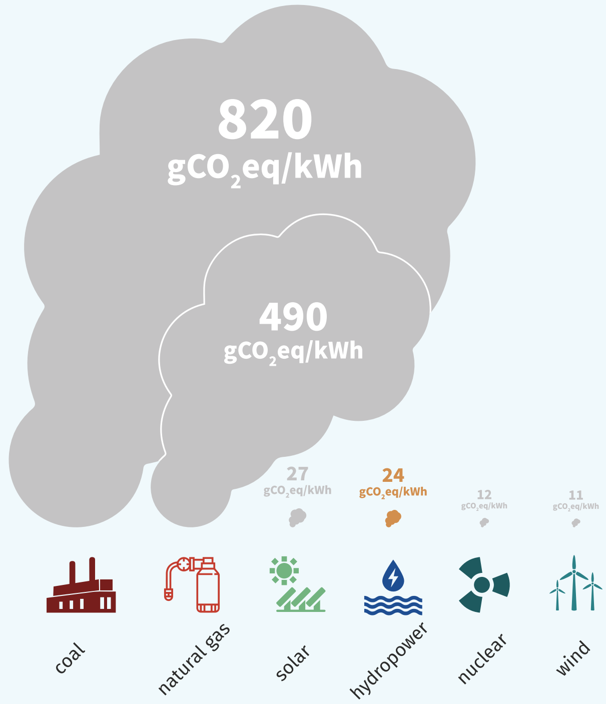
Small Hydropower and China's 'Dual Carbon' Goals

China has set up 'Dual Carbon' Goals to peak its GHG emissions by 2030 and reach neutrality before 2060. China's current roadmap sets very specific targets of raising the share of non-fossil energy in the country's total consumption to 25% by 2030 and over 80% by 2060. This would require the country to rapidly and disruptively reform its economy, cut the use of fossil energy including coal and oil, ditch its former growth model that is highly polluting and energy and resource intensive, and meet the majority of its energy demand with renewable sources.

China's 'Dual Carbon' Goals

The ‘Dual Carbon’ Goals of China are its goals of reaching peak carbon dioxide emissions by 2030 (i.e., "carbon emission peak"), and net zero emissions by 2060 (i.e., "carbon neutrality") through continuously reducing emissions after the peak. These goals were pledged by Chinese President Xi Jinping on behalf of the Chinese government at the 75th session of the United Nations General Assembly in September 2020. In a follow-up plan released in September 2021, the central government set out a roadmap of these goals through transforming its economy and society, re-structuring industries, decarbonizing its energy portfolio, facilitating low-carbon transportation, urban and rural development, promoting innovation in science and technology, improving efficiency of resource development, continuing opening up, and reforming institutions.

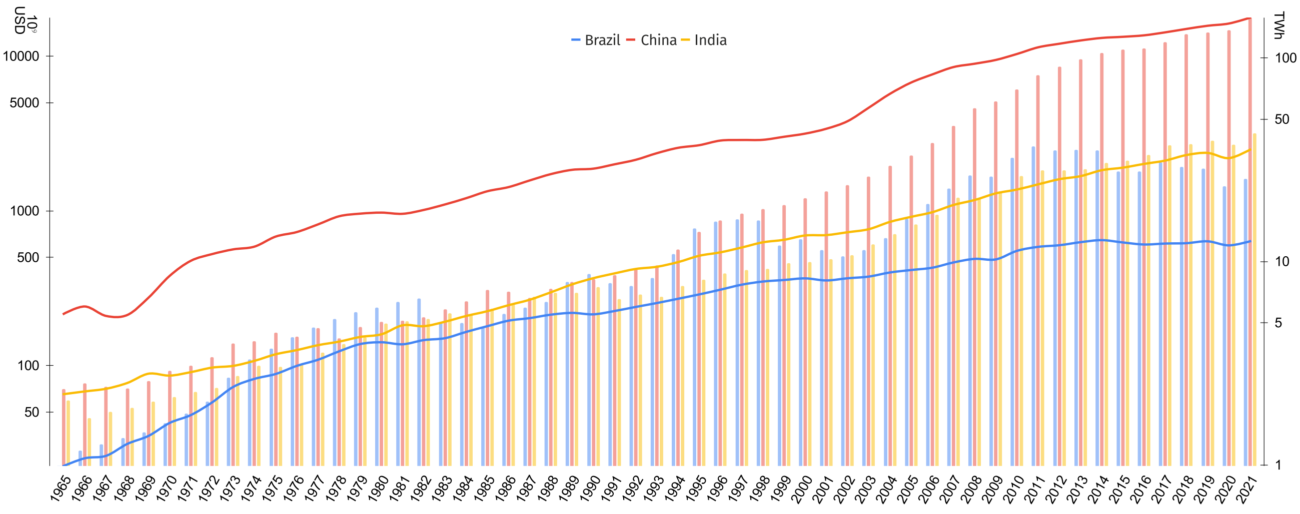




Shares of different sources in primary energy consumption of China (2012-2021). The share of non-fossil fuel consumption continues increasing to reach 16.5% in 2021 [3].

Lifetime GHG emissions of different energy sources. The median lifetime emission from hydropower development, including albedo effect, is still much lower than those of fossil fuels like coal and natural gas, and is even slightly lower than that of concentrated solar power [4] .

An overflow weir of Gaokeng SHP Plant, Chongqing



GDP (bars) and energy consumption (lines) of Brazil, China, and India (1965-2021) [2,4]. In developing countries, economic growth is one of the main drivers of energy consumption [6].

The effort to realize the 'Dual Carbon' Goals implies a significant increase of renewable energy to gradually replace the consumption of fossil fuels. For developing countries, the most important driver of energy consumption is economic development. According to China's Vision 2035 Plan, " the total economic output and the per capita income of urban and rural residents will reach new levels ", which requires the development of non-fossil energy, apart from meeting the need to replace fossil fuels, to be sufficient for new energy demands. However, non-fossil energy sources currently only account for 16.5% of China's primary energy consumption, including nuclear, hydro, wind and solar energy [3].

The technical attributes of SHP make it a very promising option for more use of renewable energy. Hydropower is a renewable energy source. While it does not emit GHG directly in generating electricity, its life-time carbon emission is in general very low compared to fossil fuels, which could be even lower than concentrated solar power [4]. The energy payback ratio of hydropower makes it the highest option among all renewable energy sources [7], which means for the same amount of energy invested for production, output from hydropower (170-280) is significantly higher than other sources like wind (18-34) or solar power (3-6). If the environmental impacts of hydropower could be effectively managed as demonstrated by the Project, SHP could have a huge role to play in China's strategy of climate adaption.

The use of renewable energy requires large-scale power storage. Renewable energy sources like solar or wind energy are subject to natural fluctuations, and often fail to align their peak potential with demand spikes in temporal regards. Excessive energy needs to be stored and released for use when demand picks up. Therefore, the proliferation of renewable energy like wind and solar must be supported by effective power storage technologies among which pumped storage is, at the moment, the most technically sophisticated option. Water is pumped from a lower reservoir to an upper one with the surplus energy and could be released later to generate electricity to feed the demand peak.

Therefore, hydropower is an important and necessary fallback for the wide use of wind and solar energy. Pumped storage is economically cost-effective and is technically feasible for large-scale application. Hydropower from pumped storage is highly responsive, which could ensure stabilized power supply from renewable sources on power grids. Such combination significantly reduces the curtailment of solar or wind energy to avoid waste and maximize usage. The distributed nature of SHP is highly valuable for the proliferation of solar and wind energy in this sense, and consequently contributes to China's efforts to realize the 'Dual Carbon' Goals.

List of Abbreviations

ESMP	Environmental and Social Management Plan
FYP	Five-Year Plan of China
GEF	Global Environmental Facility
GHG	Green-house gas
ICSHP	International Center on Small Hydro Power
LIHI	Low Impact Hydropower Institute
MOF	Ministry of Finance, P. R. China
MWR	Ministry of Water Resources, P. R. China
NPCC	National Project Coordination Committee, synonymous to the PSC under this project
PMO	Project Management Office
PSC	Project Steering Committee, synonymous to the NPCC under this project
SHP	Small hydropower
UNIDO	United Nations Industrial Development Organization

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in no particular order

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International Economic & Technical Cooperation and Exchange Center, Ministry of Water Resources

Chinese Hydraulic Engineering Society

Green Zhejiang

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Zhejiang University of Water Resources and Electric Power

China Jiliang University

New Zealand Training and Technology Transfer Limited

Low Impact Hydropower Institute of the United States

Association for Environmentally Sound Energy of Switzerland

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MINISTRY OF WATER RESOURCES
OF THE PEOPLE'S REPUBLIC OF CHINA

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