UNITED NATIONS
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Convening global partnerships for standards setting:

Boosting renewable energy access from small hydropower

Small Hydropower Technical Guidelines Brochure

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1. Foreword

Despite being a pillar for the achievement of the Sustainable Development Goals (SDGs), clean, renewable energy is only accessible to a small number of countries around the world. Available renewable energy must become a tool to catalyze development and meet basic human needs. What is more, UNIDO's mandate of Inclusive and Sustainable Industrial Development (ISID) relies on renewable energy.

In this respect, small hydropower (SHP) has become an important renewable energy solution to face the challenge of green electrification. Yet, the design and implementation of SHP remains underdeveloped, particularly in developing countries—typically constrained by the absence of technical guidelines.

Responding to the growing demand from our Member States to provide guidance on sustainable SHP development, UNIDO has partnered with the Ministry of Commerce (MOFCOM) of the Government of China, Ministry of Water Resources of the People's Republic of China (MWR), Standardization Administration of the People's Republic of China (SAC) and International Network on Small Hydropower (INSHP) to produce this toolkit. We aim to help Member States and interested parties to address the scarcity of technical guidelines, by providing tools with which to support the development of their own hydropower systems.

The Technical Guidelines (TGs) for the Development of Small Hydropower Plants were created to be used as a baseline to support a country's current policy, technology and ecosystems. Countries with limited institutional and technical capacities will benefit from the development of SHP plants by attracting investment, encouraging favourable policies and assisting economic development at the national level.

UNIDO is confident that this invaluable tool will facilitate the technology's access to our Members States and partners. We, hence, encourage its use for training and knowledge building purposes.

We thank our partners for their collaboration in the creation of a future with sustainable hydropower.

LI Yong
Director General, UNIDO

2. In Brief

The United Nations Industrial Development Organization (UNIDO)

UNIDO is a specialized agency under the United Nations system aiming to promote globally inclusive and sustainable industrial development (ISID). The relevance of ISID as an integrated approach to all three pillars of sustainable development (social, environmental and economic) is recognized by the 2030 Agenda for Sustainable Development and the related Sustainable Development Goals (SDGs), which will frame United Nations and country efforts towards sustainable development in the next 15 years. UNIDO's mandate for ISID covers the need to support the creation of sustainable energy systems as energy is essential to economic and social development and to improving quality of life. International concern and debate over energy have grown increasingly over the past two decades, with the issues of poverty alleviation, environmental risks and climate change now taking centre stage.

International Network on Small Hydro Power (INSHP)

INSHP is an international coordinating and promoting organization for the global development of small hydropower (SHP), which is based on voluntary participation of regional, subregional and national focal points, relevant institutions, utilities and companies, and has social benefit as its major objective. INSHP aims at the promotion of global SHP development through triangle technical and economic cooperation among developing countries, developed countries and international organizations, in order to supply rural areas in developing countries with an environmentally sound, affordable and adequate energy solution. This allows rural communities to increase employment opportunities, improve environmental conditions, reduce greenhouse gas emissions associated with electricity generation, alleviate poverty, raise local living and cultural standards and ensure economic development.

3. SHP/TGs – What are they?

Through global expert cooperation based on successful experiences, UNIDO jointly with INSHP decided to develop Small Hydropower Technical Guidelines (SHP/TGs) to meet the demand existing in Member States. The TGs address the current limitations of the regulations applied to the technical guidelines for small hydropower (SHP) plants drawing on the expertise and best practices from across the globe. The TGs are intended to provide countries with guidance on improving their current SHP-related policies, technologies and environmental conditions. Countries that have limited institutional and technical capacities will be able to enhance their knowledge in developing SHP plants, thereby attracting more investments, while at the same time encouraging favourable policies and therefore subsequently assisting in accelerating economic development at a national level. The TGs are a valuable asset for all countries, especially as they allow for sharing the technical know-how and best practices among countries with limited technical capacities.

The TGs are the result of a collaborative effort between the United Nations Industrial Development Organization (UNIDO) and INSHP. About 80 international experts and 40 international agencies were involved in the preparation and peer review of the document; they provided concrete comments and suggestions to make the TGs professional and applicable.

4. SHP/TGs – Why are they important?

SHP is increasingly seen as an important renewable energy solution to adequately respond to the challenge of electrification in remote rural areas. However, while most countries in Europe, Northern and South America, as well as China have high levels of installed capacity, the potential of SHP in many developing countries remains untapped and SHP development is often hindered by the lack of good practices as well as SHP development standards on a global level.

SHP development is a systematic engineering practice and requires technical support of multiple disciplines in the stages of site selection planning, pre-feasibility study, feasibility study, construction, installation, operation and management.

Automatic control facilities

5. SHP/TGs – What will they do?

The TGs can be taken as a principle and basis for planning, designing, constructing and managing SHP plants up to 30 MW. The TGs are divided into the following five key topics that address the multi-faceted nature of SHP development:

- The **Terms and Definitions** specify the professional technical terms and definitions commonly used for SHP plants.

- The **Design** Guidelines provide guidelines for basic requirements, methodology and procedure in terms of site selection, hydrology, geology, project layout, configurations, energy calculations, hydraulics, electromechanical equipment selection, construction, project cost estimates, economic appraisal, financing, social and environmental assessments—with the ultimate goal of achieving the best design solutions.

- The **Units** Guidelines specify the technical requirements for SHP turbines, generators, hydropower turbine governing systems, excitation systems, main valves as well as monitoring, control, protection and DC power supply systems.

- The **Construction** Guidelines can be used as the technical guidance document for the construction of SHP projects.

- The **Management** Guidelines provide technical guidance for the management, operation, maintenance, technical renovation and project acceptance of SHP projects.

6. SHP/TGs – Content

6.1 VOLUME 1: TERMS AND DEFINITIONS

This document defines the professional technical terms and definitions commonly used for SHP plants.

ADDRESSED SUBJECTS	
Hydrology	Hydraulic machinery
Engineering geology	Hydro mechanical structure
Hydraulic engineering and energy	Electrical system
Hydraulic structure	Social and environmental impact assessment
Engineering construction	Economic evaluation and project investment

6.2 VOLUME 2: DESIGN

The Design Guidelines provide strategies for basic requirements, methodology and procedure, in terms of site selection, hydrology, geology, project layout, energy calculations, hydraulics, electromechanical equipment selection, construction, project cost estimates, economic appraisal, financing, social and environmental assessments—with the ultimate goal of achieving the best design solutions.

DESIGN PART 1: SITE SELECTION PLANNING

This Part of the Design Guidelines specifies the general principles of site selection planning for SHP projects, and the methodologies, procedures and outcome requirements of SHP plant site selection.

ADDRESSED SUBJECTS	
Planning principles	Preparation of site construction plan
Planning scope	Preliminary assessment of social and environmental impacts
Planning methods and steps	Assessment of power demand
Basic data collection and analysis	Cost estimation ad benefits assessment
Computation of river basin or sub-basin hydropower potential	Evaluation of planning site and development sequence
Site surveys and investigations	Preparation of site selection planning report

DESIGN PART 2: HYDROLOGY

This Part of the Design Guidelines covers the basic hydrological data as well as the computation methods for the required rational analysis of the main hydrological parameters such as rainfall, runoff, flood and sediment applicable during the planning, design, construction and operation of an SHP plant.

ADDRESSED SUBJECTS	
Basic data	Design flood
Design runoff	Stage-discharge relation curve
Flow duration curve	Sediment, evaporation, ice regime and others
Low water analysis	Rationality check of outcomes

DESIGN PART 3: ENGINEERING GEOLOGY

This Part of the Design Guidelines clarifies the basic provisions on engineering geological investigation of an SHP station, specifies the technical requirements for investigation in terms of aspects of areal geology and reservoir engineering geology and defines specific requirements for investigation technologies and methods to be applied in various stages in relation to aspects of engineering geology of the dam area, water delivery way, power plant area and natural construction materials.

ADDRESSED SUBJECTS	
Basic provisions	Engineering geological investigation of water delivery route
Areal geology	Engineering geological investigation of power plant area
Engineering geological investigation of reservoir area	Geological investigation of natural construction materials
Engineering geological investigation of dam area	

DESIGN PART 4: HYDRAULIC ENGINEERING AND ENERGY CALCULATION

This Part of the Design Guidelines specifies the methods and steps of hydraulic engineering and energy calculations for SHP development, and covers the aspects that might be involved in hydropower station design, such as the load assessment and the electric power load balance.

ADDRESSED SUBJECTS	
General principles	Selection of the installed capacity and unit size
Runoff calculation	Selection of the head race dimension and the daily regulating pond volume
Hydraulic energy calculation	Analysis of the reservoir sediment accumulation and calculation of the backwater
Load prediction and electric power load balance	Reservoir operating modes and operational characteristics over the years
Selection of the characteristic water level for flood regulation and flood control	Figures
Selection of the normal and dead reservoir levels	

The tailwater of Suoxi small hydropower plant in Hunan, China

DESIGN PART 5: ENGINEERING LAYOUT AND HYDRAULIC STRUCTURE

This part of the Design Guidelines clarifies the flood control design standards for the hydraulic structures of an SHP station, defines specific requirements for the general engineering layout as well as the type selection and the design of the water retaining structure, water releasing structure, diversion structure, powerhouse and switchyard, and specifies the technical requirements for engineering safety monitoring, and concrete and steel performance. The applicable height of a reservoir dam in this document is: 30 m for a rolled earth-rock dam, 50 m for a concrete faced rockfill dam and 70 m for a concrete (masonry) gravity dam. When the above-mentioned height is exceeded, the building design standard and safety margin shall be determined by referring to other technical standards.

ADDRESSED SUBJECTS	
Flood control standard	Diversion structure
General engineering layout	Powerhouse
Water retaining structure	Engineering safety monitoring
Release structure	Concrete strength, durability and steel performance

Small hydropower plant of Dongjiao River in Shanxi, China

DESIGN PART 6-1: HYDRAULIC MACHINERY AND TURBINE GENERATOR

This Part of the Design Guidelines specifies the type selection design and arrangement of the main and auxiliary hydraulic machinery, the type selection design and arrangement of the turbine as well as the design of the heating, ventilation and fire control systems of an SHP station. It includes the basic principles of type selection for different machines, the selection and calculation of the basic parameters, scheme comparison as well as the examples of typical diagrams of different powerhouse layouts.

ADDRESSED SUBJECTS	
Turbine	Auxiliary system
Generator	Fire extinguishing system
Turbine governing system	Layout of the powerhouse
Main value of the turbine	

DESIGN PART 6-2: ELECTRICAL SYSTEM

This Part of the Design Guidelines sets forth the general requirements for the design of the electrical system of an SHP station, and defines specific technical requirements for the selection and arrangement of connections to the power system, main electrical connection, grounding, lighting, relay protection, control system and other electrical equipment.

ADDRESSED SUBJECTS	
Connection of the hydropower station to the power system	Excitation system
Main electrical connection wiring	Automatic monitoring system

ADDRESSED SUBJECTS	
Selection of the main transformer	Plant service power supply and dam region power supply
Selection of high-voltage electrical equipment	DC operational power source
Lighting overvoltage protection and grounding system	Video monitoring system
Lighting system	Communication
Arrangement of the main electrical equipment inside and outside the power station	Electrical repair and electrical testing
Automatic devices for relay protection and system safety	

DESIGN PART 6-3: HYDRO MECHANICAL WORKS

This part of the Design Guidelines sets out the contents and requirements for design of hydro mechanical works in an SHP station and provides specific requirements for the selection and arrangement of hydro mechanical equipment, hydraulic design calculations and anti-corrosion measures.

ADDRESSED SUBJECTS	
Contents and requirements of design	Anticorrosion of hydro mechanical structures
Selection and layout of equipment	Workload of hydro mechanical structures
Hydraulic design and calculation	

DESIGN PART 7: CONSTRUCTION PLANNING

This Part of the Design Guidelines sets out the principles for construction planning for an SHP station and the specific requirements for river diversion, construction of the main engineering works, construction and planning of roads and transportation, construction of the plant facilities, the general construction layout, the overall construction progress and safety measures. Most of the given guidance will need to be simplified accordingly when dealing with smaller capacity stations (below 10 MW).

ADDRESSED SUBJECTS	
Construction of a river diversion	General construction layout
Construction of the main works	Overall construction programme
Construction planning of roads and transportation	Construction safety
Construction of plant facilities	

DESIGN PART 8: SOCIAL AND ENVIRONMENTAL IMPACT ASSESSMENT

This part of the Design Guidelines sets out the general principles, contents and requirements for an environmental impact assessment of an SHP construction project. As countries typically have robust policies in place for social impact assessment, resettlement and soil and water conservation impact assessment, special studies are usually carried out by the departments designated by the country; this document only provides general technical guidance.

ADDRESSED SUBJECTS	
Environmental impact assessment	Social impact assessment
Resettlement	Conclusion of assessment and advice
Soil and water conservation	

DESIGN PART 9: PROJECT COST ESTIMATES

This part of the Design Guidelines specifies how to formulate cost estimations for SHP projects and details how to prepare cost estimation documents.

ADDRESSED SUBJECTS	
Project division	Composition of cost estimation documents
Composition of expenses and unit costs	Preparation of investment estimation for the construction part
Formulation of cost estimation in construction	

DESIGN PART 10: ECONOMIC APPRAISAL

This part of the Design Guidelines sets forth the principles, contents, methods and parameters of the economic appraisal of SHP projects. This document is applicable to the economic appraisal at the pre-feasibility study and feasibility study stages of SHP projects

ADDRESSED SUBJECTS	
Cost calculation	Financial appraisal
Benefits calculation	Uncertainty analysis
Economic analysis	Proposal comparative method

DESIGN PART 11: REPORT PREPARATION

This part of the Design Guidelines stipulates the principles, contents, requirements and outlines of different reports required for an SHP project at the pre-feasibility study and feasibility study stages.

ADDRESSED SUBJECTS
Report compilation principles
Guidelines for the pre-feasibility study report
Guidelines for the feasibility study report

6.3 VOLUME 3: UNITS

The Units Guidelines specify the technical requirements for SHP turbines, generators, hydropower turbine governing systems, excitation systems, main valves as well as monitoring, control, protection and DC power supply systems.

UNITS PART 1: HYDRAULIC TURBINES

This Part of the Units Guidelines specifies the technical requirements, main component structure and material requirements, the supply scope, spare parts, technical documents as well as the basic requirements for inspection and acceptance, packing, transportation, storage, installation, testing, commissioning, contractual performance testing, operation and maintenance for SHP hydraulic turbines. This document is applicable to SHP hydraulic turbines with unit capacity less than 10 MW; for Francis and Pelton turbines, the nominal runner diameter is less than 1.0 m; for axial-flow, diagonal and tubular turbines, the nominal runner diameter is less than 3.3 m.

ADDRESSED SUBJECTS	
Service environment conditions	Inspection and acceptance
Technical requirements	Nameplate, packing, transportation and storage
Supply scope and spare parts	Installation, operation and maintenance
Technical documents	Quality guarantee period

Downstream of Zhongxia small hydropower, Guizhou, China

UNITS PART 2: TURBINE GENERATOR

This Part of the Units Guidelines specifies the technical requirements as well as the basic requirements for the supply scope, spare parts, technical documents, inspection and acceptance, packing, transportation, storage, installation, operation and maintenance for the three-phase 50 Hz or 60 Hz salient pole synchronous turbine generator with rated capacity up to 12.5 MWA connected to a turbine.

ADDRESSED SUBJECTS	
Service conditions	Inspection and acceptance
Technical requirements	Nameplate, packing, transportation and storage
Supply scope and spare parts	Installation, use and maintenance
Technical documents	Quality guarantee period

Equipment of Shiwang'andu small hydropower station, Zambia

UNITS PART 3: TURBINE GOVERNING SYSTEM

This Part of the Units Guidelines specifies the technical requirements as well as the basic requirements for the supply scope, spare parts, technical documents, inspection and acceptance, packing, transportation, storage, installation, operation and maintenance for the SHP turbine governing system. This document applies to the electro-hydraulic governor (hereinafter referred to as the governor) with a working capacity of 350 N•m or above as well as an oil pressure device. It is recommended to use the electric governor or operator for the governor with a working capacity less than 350 N•m.

ADDRESSED SUBJECTS	
Service conditions	Inspection and acceptance
Technical requirements	Nameplate, packing, transportation and storage
Supply scope and spare parts	Installation, operation and maintenance
Technical documents	Quality guarantee period

UNITS PART 4: EXCITATION SYSTEM

This Part of the Units Guidelines specifies the technical requirements as well as the basic requirements for the supply scope, spare parts, technical documents, inspection & acceptance, packing, transportation, storage, installation, operation and maintenance for the SHP excitation system. This Document applies to the synchronous machine excitation system.

ADDRESSED SUBJECTS	
Service conditions	Test
Technical requirements	Nameplate, packing, transportation and storage
Supply scope and spare parts	Installation, operation and maintenance
Technical documents	Quality guarantee period

UNITS PART 5: MAIN VALUES

This Part of the Units Guidelines specifies the technical requirements as well as the basic requirements for the supply scope, spare parts, technical documents, inspection, testing, packing, transportation, storage, installation, commissioning and operation & maintenance for the SHP turbine main valves. This document is applicable to butterfly, spherical and gate types of SHP turbine main valves.

ADDRESSED SUBJECTS	
Technical requirements	Acceptance and guarantee
Supply scope and spare parts	Nameplate, packing, transportation and storage
Technical documents	Installation and welding
Tests	Operation and maintenance

UNITS PART 6: MONITORING, CONTROL, PROTECTION AND DC POWER SUPPLY SYSTEM

This Part of Units Guidelines specifies the technical requirements as well as the basic requirements for the supply scope, spare parts, technical documents, testing, inspection and acceptance, packing, transportation, storage, installation, training, operation and maintenance for SHP station monitoring, control and protection and the DC power supply system.

ADDRESSED SUBJECTS	
Service conditions	Site acceptance
Technical requirements	Nameplate, packing, transportation and storage
Supply scope and spare parts	Installation and training
Technical documents	Quality guarantee period
Factory inspection	

6.4 VOLUME 4: CONSTRUCTION

The Construction Guidelines can be used as the guidance technical document for the construction of SHP projects.

CONSTRUCTION PART 1: CIVIL WORKS AND HYDRO MECHANICALSTRUCTURES

This Part of the Construction Guidelines stipulates the general principles, construction conditions, operating methods, working procedures, technological requirements, and quality standards for civil works and hydro mechanical structures according to construction characteristics of SHP stations. This document includes only technical guidance on engineering construction and excludes construction organization management.

ADDRESSED SUBJECTS	
Construction survey	Construction of hydraulic structures
Construction diversion	Installation of hydro mechanical structures
Basic regulations for civil works construction	Environmental protection

Equipment of small hydropower in Micronesia

CONSTRUCTION PART 2: INSTALLATION OF ELECTROMECHANICAL EQUIPMENT

According to the construction characteristics of SHP projects, this part of the Construction Guidelines stipulates the basic regulations and technical requirements for the installation of electromechanical equipment. This document includes only technical guidance on engineering construction and excludes construction organization management.

ADDRESSED SUBJECTS	
Installation of turbine generator units and hydraulic machinery auxiliary equipment	Installation of the automatic hydrological forecasting and reporting system
Electrical equipment installation	Installation of safety monitoring Equipment

Hydro turbine manufacture

6.5 VOLUME 5: MANAGEMENT

The Management Guidelines provide technical guidance for the management, operation, maintenance, technical renovation and project acceptance of SHP projects.

MANAGEMENT PART 1: PROJECT CONSTRUCTION MANAGEMENT

This Part of Management Guidelines sets forth the basic contents, management method and general requirements for construction management for SHP projects.

ADDRESSED SUBJECTS	
Project management organization	Procurement management for the project
Project integration management	Project contract management
Early stage planning of the project	Project environmental protection and water and soil conservation management
Project scope management	Engineer management
Project technical management	Project communication management
Project quality management	Project information management
Project progress management	Occupational health and safety management for the project
Project cost management	Project risk management

MANAGEMENT PART 2: OPERATION AND MAINTENANCE

This Part of the Management Guidelines specifies the basic management requirements for the operation and maintenance of an SHP station as well as the specific requirements for the operation and maintenance of a hydraulic structure, hydro mechanical works and electrical and mechanical equipment.

ADDRESSED SUBJECTS	
Basic requirements	Electro-mechanical equipment
Hydraulic structures	Optimized operation
Hydro mechanical works	

MANAGEMENT PART 3: TECHNICAL RENOVATION

This Part of the Management Guidelines specifies the basic principles, contents, methods and requirements for the technical renovation of an SHP station.

ADDRESSED SUBJECTS	
General provisions	Renovation contents and requirements
Status analysis and evaluation	Technical performance index
Detection and evaluation	

MANAGEMENT PART 4: ACCEPTANCE OF PROJECTS

This part of the Management Guidelines stipulates acceptance conditions and the main content of SHP key acceptance work, including acceptance before river diversion (closure) of the project, acceptance of reservoir (barrage) impoundment, acceptance of unit start-up and acceptance of project completion. The acceptance organization, specifications, procedures and methods, as well as project handover and resolution of outstanding issues, shall be handled according to the provisions of project contract documents.

ADDRESSED SUBJECTS	
Acceptance before river diversion (closure) of project	Acceptance of unit start-up
Acceptance of reservoir (barrage) impoundment	Completion acceptance

Shiwang'andu small hydropower station, Zambia

7. Steps of sustainable SHP development

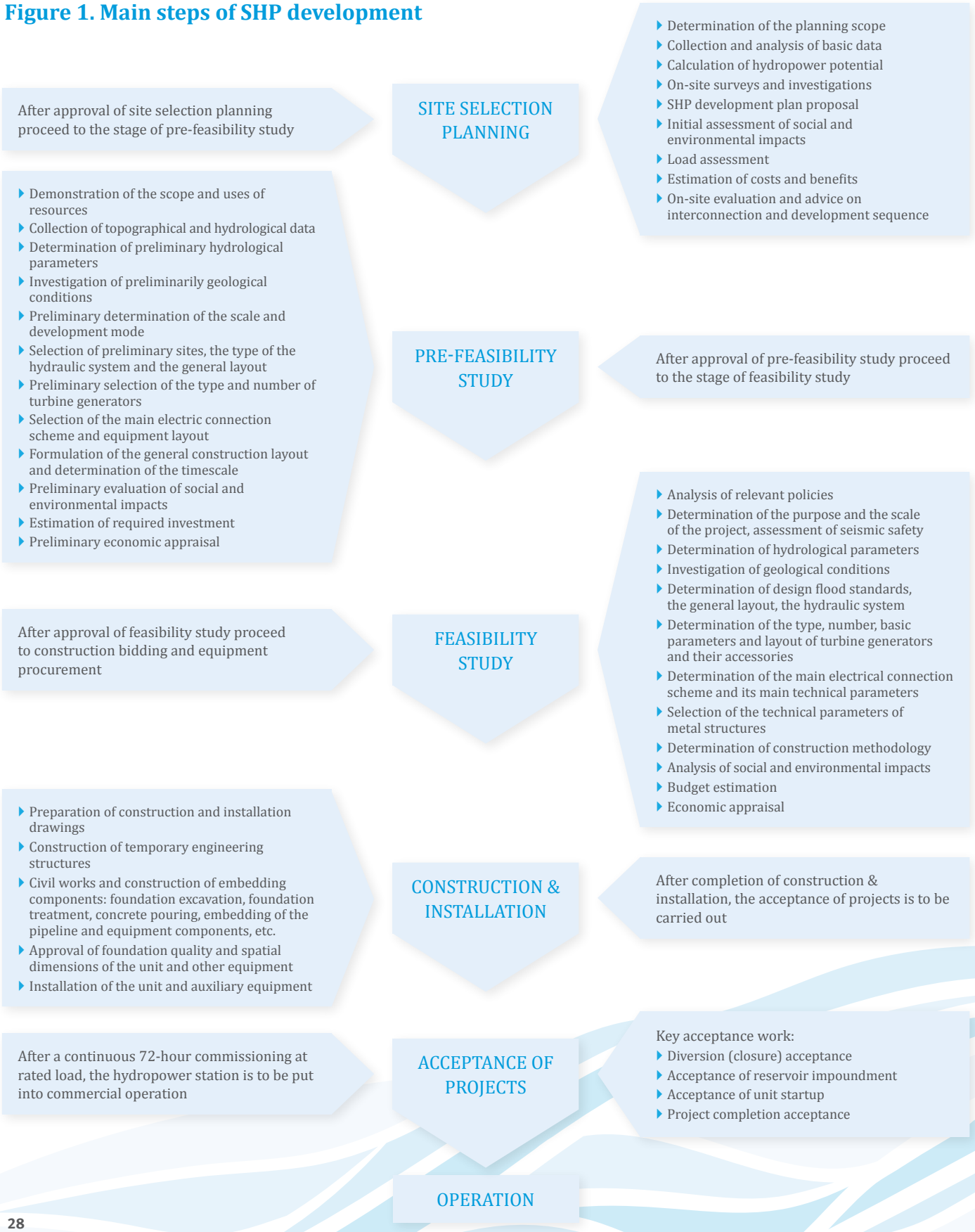
The diagram below shows a brief summary of the steps of sustainable small hydropower development. It gives a concise overview of all the key aspects to be considered and implemented. For more detailed information please refer to specific parts of the Technical Guidelines document.

8. Way forward

The small hydropower technical guidelines will be used to organize training and workshops worldwide. UNIDO and INSHP hope that the guidelines will be beneficial for countries that have limited institutional and technical capacities. Interested parties will be able to enhance their knowledge in developing SHP plants, thereby attracting more investment, while at the same time encouraging favourable policies and therefore subsequently assisting in accelerating economic development at a national level. Suggestions and recommendations for possible updates to the guidelines are very welcome.

Potential site for small hydropower

Figure 1. Main steps of SHP development



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Technical Guidelines

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