Hydropower Solutions

HYPOSO

Hydropower solutions for developing and emerging countries

D4.2
Activity schedules including venues and schedule for training workshops

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 857851.

Project no.	857851
Project acronym:	HYPOSO
Project title:	Hydropower solutions for developing and emerging countries
Call:	H2020-LC-SC3-2018-2019-2020/H2020-LC-SC3-2019-RES-IA-CSA
Start date of project:	01.09.2019
Duration:	36 months
Deliverable title:	D4.2 Activity schedules including venues and schedule for training workshops
Due date of deliverable:	July 2020

Organisation name of lead contractor for this deliverable: *IHE Delft (04)*

Name	Organization
Miroslav Marence[1], Angeles Mendoza-Samet[1], Alessandro Cattapan[1], Shreedhar Maskey[1], Mario Franca[1], Daniel Valero Huerta[1], Anish Pradhan[1], Ingo Ball[2], Dominik Rutz[2], Bernhard Pelikan[3], Nino Frosio[3], Luigi Lorenzo Papetti[3], Beatrice Baratti[3], Janusz Steller[4], Ewa Domke[4], Ewa Malicka[5], Petras Punys[6], Antanas Dumbrauskas[6], Marc Buiting[7], Dan Marlone Nabutsabi[8], Joseph Kenfack[9], Veronica Minaya[10], Andres Gonzales[11], Mauricio Villazón[11], Carlos Velasquez[12]	[1]IHE Delft, [2]WIP, [3]SF, [4]IMP PAN, [5]TRMEW, [6]VDU, [7]1to3, [8]HPAU, [9]SHW, [10]EPN, [11]UMSS, [12]CELAPEH

Dissemination level		
PU	Public	X

History			
Version	Date	Reason	Revised by
01	28/08/2020	Draft version	IHE Delft
02	29/07/2020	Final version	IHE Delft, WIP

Table of Contents

1 Introduction 4
2 Information about the Deliverable 4
3 Summary of Scoping Results 4
4 Workshop Organisation 5
4.1 General 5
4.2 Study Plan 7
4.3 Teaching plan 8
4.3.1 Workshop content and objectives 8
4.3.2 Short course organisation 25
4.3.3 Participants selection 25
5 Proposed workshop schedule 26

List of Figures

Figure 1: Bankability Matrix and Bankability Building Blocks 21

List of Tables

Table 1: A study plan for the capacity building in small hydropower 7
Table 2: Types of the hydropower scheme based on the head and the concept 18
Table 3: Bankability - Levels of analysis........ 21

1 Introduction

HYPOSO is a multi-approach project to tackle several objectives; identification and mapping of the European hydropower industry, hydropower stakeholders in the HYPOSO target countries, education of new hydropower experts through capacity building activities and bringing together relevant actors from the EU hydropower sector with stakeholders in the target countries. Interaction with stakeholders is, therefore, an integral part of the activities, like workshops, capacity building activities and interviews with national/local stakeholders are envisaged in all target countries which are outside the European Union, namely workshops in Bolivia, Colombia and Ecuador in Latin America, and Cameroon and Uganda in Africa. Additionally, capacity building courses will be carried out in Bolivia and Ecuador, and in Cameroon and Uganda.

2 Information about the Deliverable

This deliverable D4.2 is an outcome of Task 4.2 "Training method and curriculum for four training workshops" of the WP4 "Capacity building" (Task leader: IHE Delft, Partners: Studio Frosio, VDU, IMP PAN, TRMEW, 1to3, CELAPEH, HPAU, SHW, EPN, UMSS).

WP4 focusses on capacity building intending to strengthen key stakeholders in target countries in strategic development, design, implementation, operation and maintenance of sustainable hydropower and research needs in the field of hydropower.

Based on the results of the scoping process in the target countries, the needs in education and research in the field of small hydropower have been identified. The recognized prerequisites have been integrated into the short course plan. The short course includes all phases of the small hydropower life cycle; planning, design, construction, operation, maintenance, but also environmental and social impact and financing.

The capacity building will be organized as a week course in each of the target countries, except Colombia, together for the participants from the same continent. The teaching efficiency and intensity will be increased by pre- and post-course activities. These additional activities will allow a stronger and deeper understanding of the topics and will additionally improve the quality of the capacity building. All of the activities during the course will be recorded and will be a part of the Knowledge and Capacity Development (KCD) systems. The KCD system could be used by the participants, but also by additional persons interested in hydropower also after finishing of the project.

3 Summary of Scoping Results

The framework analysis about the hydropower situation in the target countries has been performed in WP3 and quantified in the report HYPOSO_D3.2. In the report HYPOSO_D4.1 the results concerning existing education in the field of hydropower, research and needs have been discussed. For all target countries, it could be summarized that:

- There are some educational and research institutes in the targeted countries where R&D projects associated with hydropower are conducted. Although there are few educational organizations which produces skilled manpower in the market, there is still a need for hydropower experts.
- As hydropower personnel is normally educated and trained during the work, the gaps in the education system should be fulfilled with the KCD (Knowledge and Capacity Development).
- There is a huge hydropower potential in the targeted countries with several existing hydropower power plants. Also, there is the need for optimization, maintenance and refurbishment of the existing power plants.
- Most of the targeted countries have identified the hydropower potential, but in some of them, detailed studies still have to be carried out.
- This KCD will allow participants to learn deeply about the hydropower topic giving them an overview of the life cycle process.
- In the short course, all steps of the hydropower life cycle will be addressed. Data collection, hydraulic and structural design, construction, operation, maintenance and refurbishment. Also, important topics such as environmental and social impacts and financial possibilities are parts of the short course.

4 Workshop Organisation

4.1 General

The training will be tailor-made, matched on the needs detected and defined during the survey phase described in the framework analysis. The training has to take into account the specific tasks and roles, as well as the fact that all technical staff to be involved will have basic training in their respective field of activity (engineering, environmental and social sciences, etc.) and at least some practical experience. The final content and amount of training, i.e. the definition of the specific courses to be delivered, their exact content, main focal points, as well as duration is defined based on needs assessment performed in framework analysis and discussion with the colleagues from the target countries. Their experience had special value in this project phase. Some basic principles that have been applied in the course preparation and will be followed during all training activities are listed here:

- to the maximal extent possible, teaching will not remain purely theoretical, but will always be illustrated with practical examples (i.e. real projects), drawing on the vast experience of the experts providing the teaching;
- experience of the trainees shall be included. This means that the participants will be given the occasion, and will be asked, to contribute with examples from their own professional experience. Direct involvement of the participants, also in the formal classroom teaching will be encouraged;

- the group size will have to be defined. For classroom teaching, a number of 20 to 25 (not less than 10, not more than 30) is adequate. Discussions and direct involvement of participants get very difficult in the case of larger groups;
- in classroom teaching, presentations (PowerPoint) will usually be used. The participants will be provided with copies of this material (as hard copy and/or electronically), and they will be encouraged to complete this material with personal notes;
- other teaching material may be used when required; as e.g. case studies, parts of reports ("good" or "bad" examples), technical or scientific articles to be read and discussed in class, available freeware software and tools, etc.

Monitoring can/will be done basically in two ways: asking participants for feedback and evaluation of the course, and carrying out knowledge tests and assignments. An outline of courses is provided, keeping in mind that modifications are possible and may be required. The expected content of the courses and lectures is itemised:

- hydropower data acquisition: topography, geology, meteorology and hydrology,
- hydropower potential and site selection
- basics of hydropower (concepts, schemes and layouts, design and function of the system and their parts, operational principles)
- dams and weirs (function, types and layouts, design and operation, dam foundation, dam safety and monitoring),
- small hydropower schemes and specifics of the small hydropower
- environmental and social impact of hydropower projects, sustainable hydropower development including water-energy-food-ecosystem nexus
- operation and maintenance issues
- financial analysis and the way to the bankable projects

All lecture documents, recorded lectures and used freeware software related to the capacity building will be prepared as open access documents and will be part of the Knowledge and Capacity Development (KCD) systems.

4.2 Study Plan

The study plan for the short course is defined based on the needs defined by the target countries and considering the experience of the consortium in teaching hydropower topics. The study plan is specified in Table 1.

Table 1: A study plan for the capacity building in small hydropower

	Topic	Responsibility	Days		
			Online	Face-to-face	Online
			Preparation before course	Short course	Assignments after course
Week 1	Basics of hydropower exploitation	IHE	0.5	0,5	-
	Hydrology	IHE	0.5	1	1
	GIS&HP potential	VDU	1	0.75	1
	Hydraulic design	IHE	1	1	1
	Computer based tools for hydropower resources	VDU	1	0.75	1
	Dams and storage basin	IHE	1	1	1
	Weirs and water intakes	SF	0.5	0.5	0.5
	Power waterways	IHE	1	0.5	1
	Total week 1		**6.5**	**6.0**	**6.5**
Week 2	Hydraulic Units	IMP	0.5	1	1.0
	Electrical equipment & lines	IMP	-	0,5	0.5
	Hydropower systems	SF IHE	1	1 0.5	1.5 0.5
	Operation and maintenance	IMP/TRMEW/SF	-	1	1
	Financial analysis	1to3	-	-	1
	Design training	SF	-	1	3
	Total week 2		**2.5**	**6**	**9.5**
Total study load (week 1 + week 2)			**9**	**12**	**16**

During each week of the course, a two-day study trip to the hydropower sites will be organized. The plan is made based on the original course schedule (Uganda M13, Cameroon M18, Bolivia M27 and Ecuador M28). The first week is planned in country 1 (Uganda, Bolivia) and the second week in country 2 (Cameroon, Ecuador). In case of restrictions in Uganda in September 2020, the course in Uganda will be re-scheduled for April 2021 (see also Chapter 5).

4.3 Teaching plan

4.3.1 Workshop content and objectives

In this chapter, the topics and syllabus of the teaching modules and their objectives will be discussed. The teaching modules have been defined and selected based on the scoping performed in the targeting countries and experiences of the partners in the lecturing and capacity building. Special care is made on the balance between theoretical and practical matters, considering that participants have to understand and apply the theoretical knowledge in the practical subjects that they will need to solve on their projects. The implementation of accepted knowledge will be trained on the various practical assignments, but also implemented in the bigger and complex tasks simulating real feasibility studies and real practical problems.

4.3.1.1 Basics of Hydropower Exploitation

The module will be organised by IHE Delft during the first week and consists of half-day preparation work and a half-day face-to-face lecturing.

The module is an introduction to hydropower and especially small hydropower development. In the first part, it will be performed in the form of an online video lecture with an overview of energy, power and energy sources. This online lecture will discuss the main and most important definitions that will follow the participants during the whole course as electrical power system, production, producers and demand of electrical energy but also energy, power, capacity, load, load factor and load shape. Daily, weekly, monthly and seasonal energy demands will be discussed and the need for grid regulation explained.

The sources of electrical energy, from fossil and nuclear to the whole renewable energy family and the different types of hydropower will be discussed and evaluated. The advantages and disadvantages of hydropower and influence of hydropower on the economy of energy, water resources and the environment will be elucidated.

The types of hydropower plants based on the different criteria and functions in the grid will be shown and their characteristics clarified. The main components needed for the safe and successful operation of the hydropower system together with the definition of the hydropower capacity and potential will be presented.

The difference between large and small hydropower with the special significance of the small hydropower and their benefits in rural areas will be reflected. The concept of greening small hydropower by mitigating the negative influences will be discussed and evaluated with the participants.

4.3.1.2 Hydrology

This module will be organized by IHE Delft during the first week of the short course and consists of a half-day preparation work before the course, one day of face-to-face lecturing during the course and one day of course activity after the face-to-face lecture.
The module covers aspects of hydrology that are essential for hydropower development, and is divided into four subtopics:

1. Hydrological cycle and precipitation–runoff processes
2. Flow duration curves: definition, construction and interpretation
3. Approaches to flow duration curves for ungauged basins
4. Climate change impacts on the hydrological cycle and flow duration curves

Subtopic 1 provides a general overview of the hydrological cycle and hydrological processes leading to runoff from precipitation. Components of runoff (surface flow, interflow and baseflow) will be discussed in relation to how they play a role in runoff-of-river and storage hydropower designs. Subtopic 2, which is the key element of the module, deals with the development and interpretation of flow duration curves and relating them to power duration estimation and analysis. In this topic also traditional data collection, like discharge measurements, gaging stations will be addressed. In Subtopic 3, various approaches to deriving flow duration curves for (partially) ungauged basins will be discussed. Globally available hydrology related data products, such as remote sensing-based precipitation and evaporation products, will be explored and their potential for hydrological assessment will be discussed. In recent years, there have been increasing concerns about climate change impacts on water resources, intensification of hydrological extremes (e.g. floods and droughts) and non-stationarity of hydrological regimes. In response to this concern, Subtopic 4 introduces intrinsic links between climate change and hydrological cycle, relating it to likely impacts on flow duration curves. This topic also discusses approaches to handle hydrological non-stationarity in design.
This is a compact one-day course with supplemental assignments before and after the delivery of the lectures. The course will be delivered in an active learning environment. Teaching/learning activities consist of lectures, hands-on exercises, problem-based assignments and group discussions.

4.3.1.3 GIS Tools and Hydropower Projects

The module will be organized by VDU during the first week of the short course and consists of one-day preparation work before the course, 0.75 days of face-to-face lecturing during the course and one day of after course activities.
Nowadays, European attractive policies are encouraging the construction of small hydro-power plants. The most common options for the assessment of small hydropower (SHP) sites of rivers are based on traditional methods and include field inspections. Usually, high potential locations for hydroelectric power stations are in difficult accessible mountain areas with no roads, so evaluation of these locations through traditional methods is costly. However, the application of

Geographic Information Systems (GIS) and Remote Sensing (RS) may provide a more convenient way to evaluate hydropower potentials and feasibility studies. Advanced technologies of remote sensing for spatial data acquisition and GIS software may be utilized to find these areas, which can greatly overcome the limitations of the traditional methods.
This module intends to provide participants with the background knowledge and practical skills on applying open source GIS software for the planning and design of small hydropower plants. This is a very short introductory course (only 1 day) covering a small part of the theory and application of geographic information systems. The course includes an overview of the general principles of GIS and practical experience in its use. The practical component involves the hands-on use of the open source desktop GIS software package (QGIS) through which attendees will get introductory knowledge of the practical application. Any hydropower plant needs:

1. Hydrological data (catchment area and flow discharge at the intake point, reach lengths, etc.)
2. Surface elevation data (estimated gross head etc.),
3. Data on existing infrastructure and constraints (roads, grid network, protected areas, etc.).

Therefore, the practical application of GIS will include processing of digital terrain data, river network development, catchment delineation, and theoretical HP potential calculation.

4.3.1.4 Hydraulic Design

The module will be organized by IHE Delft during the first week of the short course and consists of one-day preparation work before the course, one day of face-to-face lecturing during the course and one day of online activities after the course.
This module aims at providing participants the technical skills that will enable them to perform the hydraulic design of a hydropower plant. Given the variability in participants' background, this module will start with a refresh on fundamentals of hydraulics, which will cover conservation laws: mass, momentum and energy. The teaching approach will be based on their application to cases relevant to hydropower design (e.g. forces acting on a sluice gate, forces acting on a penstock bend, etc.). This will allow participants to immediately appreciate their importance from a practical point of view.
The module will then proceed with a description of head-works and the hydraulic design of water intakes. This will include the computation of head losses and the analysis of trade-offs in design between intake efficiency, construction costs and operational costs. This part will involve the hydraulic analysis of a series of existing water intake designs, pointing out the benefits and disadvantages of alternative solutions.
Next, the module will cover the desilting basins design. This topic will involve the practical application of a design exercise to allow participants to face the practical issues they might encounter later in their profession.

To conclude the part on head-works, participants will learn how to select a trashrack and how to account for its associated head losses. Different cleaning systems will also be introduced, together with the discussion on where these structures could be placed within the intake system.
The module will then tackle the practical problem of defining the optimal sizing of the headrace channel. This problem will be shown through an example, which will lead to some hydrological and hydraulic considerations on the location of the forebay.
Participants will be taught how to perform the hydraulic design of a pressurised pipe systems like penstocks, how to compute the required submergence, and how to take into account continuous and localized head-losses into the hydraulic design and their impact on the plants' performances. Participants will learn also the effects of dynamic pressure waves in pipe systems and, in particular, how to compute the maximum pressure due to water-hammer.

4.3.1.5 Computer-Based Tools for Hydropower Resources and Project

The module will be organized by VDU during the first week of the short course and consists of one-day preparation work before the course, 0.75 days of face-to-face lecturing during the course and one day of the after course activities.
The assessment of small hydropower (SHP) sites for development represents a relatively high proportion of overall project costs. A high level of experience and expertise is required to accurately conduct this assessment. To model and analyse any SHP project, to complete its pre- or feasibility analysis commonly a five-step standard analysis has to be conducted, including energy analysis, cost analysis, emission analysis, financial analysis, and sensitivity/risk analysis.
Over the last several decades, a variety of computer-based assessment tools have been developed to facilitate this engineering work and enable a prospective developer to make an initial assessment of the economic feasibility of a project before spending substantial amounts of money. These tools range from simple first estimates to quite sophisticated programs. As many hydro tools exist to support this exercise, the selection of the proper software by hydropower engineers and consultants with limited experience in these tools can be daunting and confusing.
This course is intending to provide participants with background knowledge and practical skills in applying software tools for the planning and design of small hydropower plants. The main emphasis is given on small scale hydropower resource assessment computer tools and methodologies for the development of SHP plants corresponding to a preliminary or feasibility study level.
These tools vary from simple initial estimates to quite sophisticated software. First of all, the turbine selection software is analysed, further on assessment tools for site-specific hydropower energy and economic evaluation are discussed. Web-based interactive maps intended for hydropower resource assessment are presented. This is especially useful for regions or areas where access is restraint and data are scarce, and limited financial resources to proceed with the feasibility study. They might be only a kind of discovery, identifying automatically sites worthy of further investigation (pre-feasibility or feasibility study). Software designated for real-time hydropower system operation is briefly pointed out. A particular field of application of

multi-criteria analysis tools is the evaluation and analysis of the conflicting aspects of hydropower exploitation, affecting the three pillars of sustainability (i.e. economic development, environmental protection, and social justice and local community).
These tools or desktop studies can be of great help for SHP designers and practitioners, however, a reliable assessment of real economically feasible potential implies some further refinements onsite.
The computer software to be considered was developed in various countries, but here the attention is paid to the products of the European Union, highlighting their advantages.

4.3.1.6 Dams and Storage Basins

The module will be organized by IHE Delft during the first week of the short course and consists of one-day preparation work before the course, one day of face-to-face lecturing during the course and one day of the after course activities.
In general, water can be diverted by constructing a barrier across a river. The barrier can be a dam (concrete, earthen, rock-fill), barrage or weir. The selection of the most feasible type of diversion structure for a given site is governed by various factors such as topography, geological conditions, depth of bedrock, availability of suitable construction materials, spillway size and location, the height of the diversion structure, and the need to be able to cope with conditions of extreme flood or earthquake.
The dam can store water in a reservoir and can raise the level of water. The barrier formed in the river enables the diversion of the river water in the power waterway.
The lectures will give an overview of the dam types, criteria for dam type selection and also an overview of the dam design and construction. The big dams are normally not a part of the small hydropower system and these lectures have informative character and also give participants knowledge needed in case of involvement in bigger hydropower schemes. Failures of dams in the last years in the developed and developing world show importance of the dam safety during operation. A lecture on dam safety will be prepared. The lecture will deal with dam observation, monitoring, measured data interpretation and detection of the problems that are crucial for dam safety. Also, risk mitigation measures and alarming and evacuation plans will be discussed.
During the course, the participants will become familiar with the dam stability design calculation for earthfill and gravity dams. The stability calculations will be performed with freeware software.

4.3.1.7 Weirs and Water Intakes

The module will be organized by Studio Frosio (SF) during the first week of the short course and consists of a half day preparation work before the course, 0.5 days of face-to-face lecturing during the course and 0.5 days of the after course activities.
Hydropower harnessing needs necessarily water diversion from a natural creek or river. Such natural flowing water is usually transporting much more than only water. Depending on the characteristic of the catchment, the slope, the recent flow condition and some other influencing parameters there is a significant transport of bedload, of suspended load and debris.

The hydropower operator is essentially interested in clear water conditions, thus making sure that several components of a hydropower plant remain in good shape and condition, providing high efficiencies and high production values. The separation of water from all the other material transported by the water is a challenging task and requires expertise as well as experience because there is no general formula available but several tools to be applied.
Consequently, the location where the artificial water conveyance structure begins is of crucial importance for the satisfying function of the entire hydropower plant. Any mistake or incorrect planning will induce a variety of problems, cost and malfunction during the whole lifetime of the plant.
This course will describe in detail the toolbox on how to manage the targets mentioned above and can be divided into three chapters in a logical sequence:

- Weirs
- Intake structure
- Sand traps

Naturally, there is a big difference between the components to be applied in high head plants and those applicable in low head plants. This differentiation is recommended due to the diverse requirements in terms of flow and material transport. Even with these distinctions, the individuality of the sites forces the designer into individual and sometimes sophisticated solutions.
The description of the different solutions will include the technical function, the dependencies with other components and the range of application. Necessarily, the presentations will include pictures of all components, videos if available. Companies providing these components will be mentioned.

4.3.1.8 Power Waterways

The module will be organized by IHE Delft during the first week of the short course and consists of one-day preparation work before the course, a half of a day of face-to-face lecturing during the course and one day of the after course activities.
Power waterways transfer water from the reservoir to the powerhouse and back to the river. The power waterways are expensive structures, with cost reaching 30-40 % of the total plant costs. Therefore proper and optimal layout and hydraulic and structural design are crucial. The power waterways could be designed as systems under free flow, pressurized flow or combined conditions. Based on the flow conditions one can distinguish between channels and pipe systems. Both of the systems will be discussed with their characteristics and also specific features necessary for operation. For the appropriate and safe operation of the power waterways structures as forbays, surge tanks, valves and manifolds will be presented. In the case of small hydropower systems, the power waterways are often designed as pipes of relatively small diameter made of different construction materials. These materials, their characteristics and possible implementation will be discussed.

Hydraulic and structural loads acting on the pipe systems will be defined and calculation methods for such systems will be defined. Influence of dynamic, transient, hydraulic pressure in the pipes will be specially discussed and problems caused by transient loading in the pipes especially mentioned.

4.3.1.9 Hydraulic Units

The module will be organized by IMP PAN in the second week of courses and will include 0.5 days preparation before the course and one day for face-to-face lecturing and one day of after course activities.

Hydraulic electricity generating sets (hydraulic units) are the core components of each hydro-power installation. The units applied in small hydro show even higher diversity than those to be encountered in the large hydropower plants. Therefore, the purpose of this block will be to provide an overview of various machinery and equipment types together with basic knowledge enabling their selection and avoiding major errors at the plant planning and design stages. Fundamentals of the hydraulic turbine theory will be presented to assist the proper interpretation of performance characteristics. Basic knowledge of some unwanted phenomena – including cavitation – and structural material properties may appear helpful at various plant development and operation stages.

The lecture block will start with explaining basic terminology and classifications, including division between gravitational engines and hydraulic turbines. Attention will be driven to Archimedes screws as a highly successful European low head gravitational engine technology, having found numerous implementations throughout the latest 3 decades. Turbines will be discussed in division into 3 major groups: impulse, reactive and hydrokinetic ones. Most attention will be addressed to the reactive turbines which are also the most widely represented ones. In addition to presenting the classic hydraulic turbine runner types (Pelton, Francis, propeller/Kaplan, Deriaz) as applied in various configurations, several designs typical for small hydropower will be presented, including Turgo and Cross-flow, VLH (very low head) and some hydrokinetic units (e.g. Stromboje or Gorlov turbines). The use of pumps as turbines (PATs) will be considered as a cost-effective option in case of rather steady operation conditions (e.g. energy recovery systems in municipal and industrial water cycles). Last, but not least, attention will be paid to some fish-friendly designs which - in addition to VLH turbines and Archimedes screws (in single- and bi-directional configuration) - include also the Alden turbines.

Generators will be discussed only in as much as it is necessary for this block – mainly from hydraulic unit configuration as well as generator impact on the hydraulic part design and its parameters. The issue is always of significance - both in the classic and integrated configurations, such as Straflo, VLH or small bulb and hydrokinetic turbines. The electrical aspects of generator design and operation will be considered in the Electrical Equipment and Lines block.

The abovementioned survey will be followed by a discussion of some significant components of the most typical hydraulic turbine designs. Firstly, various kinds of reactive turbine distributors – including stay and guide vane cascades, guide vane adjustment mechanisms, relevant safeguards and sealings – will be reviewed. Afterward, the runner blade adjustment mechanisms, guide and thrust bearings, and shaft sealings will be taken under consideration. Attention will be brought to the use of ecologically friendly design concepts, including self-lubricating or water lubricated guide bearings. This mechanical machinery group of topics will be concluded by discussing the chain of power transmission from the turbine to the generator shaft. The design and operational features of couplings and speed increasers will be reviewed on this occasion.

The hydraulic turbine governor will be the last major hydraulic unit component to be discussed within this thematic block. Mainly functional aspects, including some parts of the regulation mechanism (actuators and main regulating rods), will be considered. A simplified mechanical-hydraulic scheme will be used to demonstrate the main governor functions - nowadays often taken over by the digital automation systems to be discussed in the Operation & Maintenance block.

The practical interpretation of hydraulic turbine performance characteristics should be one of the key skills acquired by the students. The topic will be introduced on a step-by-step basis from the constant head characteristics, through similarity laws and parameters, specific speed and its link with runner geometry, efficiency hills in dimensionless or factorised (doubly-reduced) co-ordinates, ending with the four-quadrant characteristics and their significance for planning the start-up and shutdown processes. The direct link between the characteristics shape and hydraulic turbine design will be illustrated by numerous examples. The technique of optimizing the double-regulated cam curves will be mentioned as well.

The topic of performance characteristics will be immediately followed by that of cavitation. A brief introduction on the physical fundamentals will be conducted by showing the main consequences in hydraulic machinery, including the most vulnerable erosion sites. The terms of Net Positive Suction Head and Thoma number (sigma value) will be explained. Finally, cavitation characteristics - including allowable and installation sigma values - as well as cavitation guarantees will be introduced. The block will be concluded with discussing the problems of cavitation and hydro-abrasive erosion as well as some basic material strength and erosion resistance problems.

4.3.1.10 Electrical Equipment and Lines

The module will be organized by IMP PAN in the second week of courses and will include 0.5 days preparation before the course and 0.5 days for face-to-face lecturing.

Discussing electrical equipment of a small hydropower plant requires a wider perspective than the restriction to the main devices. The necessary approach should enable a global overview and understanding of the process of electricity generation and conversion in hydroelectric installations. Therefore, the training will be preceded by a brief introduction showing the role of hydropower plants in the electrical power system structure and explaining the basic electricity-related terms. Next, the essential components of the power plant electrical equipment, control systems and transmission lines will be discussed.

In the introductory part, the operation in parallel to the stiff grid and the isle grid operation will be presented when discussing the hydropower plant role in the electrical power system. Furthermore, the terms necessary to understand the electricity-related problems will be discussed, including direct and alternative current, current/voltage effective values, and electrical power notion as referred to the single and three-phase alternative current systems (active, reactive and apparent power as well as active power coefficient).

When discussing the basic electrical equipment, the types of generators employed in the hydropower plants (synchronous, asynchronous, with permanent magnets) will be presented together with a discussion of their applicability, characteristic features, basic parameters and the necessary auxiliary components (e.g. exciting and reactive power compensating systems).

The purpose of using transformers will be explained together with their main parameters and structural options - including division according to winding structure (transformers and autotransformers), insulation type (dry and oil ones), voltage regulation capabilities (constant ratio transformers, non-load and on-load changing of taps).

An indispensable component of each power plant are on the one hand devices enabling proper operation of equipment inside the powerhouse and on the other one – those enabling proper operation in parallel to the grid. The relevant connection, safety and measurement devices will be discussed in the course of the training.

The main goals and practically employed power plant control system configurations will be briefly described.

The last topic under discussion will concern transmission lines, including their division according to the structural features (overhead and underground) and the voltage value.

4.3.1.11 Environmental and Social Impact

The module will be organized by IHE Delft in the second week of courses and will include a one-day preparation before the course and one day for face-to-face lecturing and one day for the assignments and discussions after the course.

The objective of this module on the Environmental and Social Impact Assessment (ESIA) for hydropower projects is to apply the principles and basic steps of the impact assessment process to identify the impacts and benefits of a hydropower project. The training includes the integration of ESIA with other management tools and the complementarity of ESIA and Strategic Environmental Assessment (SEA) to support sustainable hydropower.

During the first phase, the participants will compete in individual activities to understand the foundations of the ESIA process. This part will include:

1. Videos produced by IHE. These will cover two topics: one video will explain the legal principles that guide the practice of environmental assessment, for example, the precautionary principle, the participation principle and the polluter pays principle. Then, a series of videos will cover the basic steps of the environmental assessment process.
    - Screening: determining the need to conduct an ESIA,
    - Scoping: determining the content of the ESIA, including needs for public participation, alternatives, and baseline.
    - Impact Analysis: an overview of different types of impacts of concern around hydropower project and impacts on environmental, social and economic

components. Analytical tools to integrate information from different disciplines and methods to determine the significance of impacts.
- Impact Management: identification of mitigations, determination of residual effects and formulation of an environmental and social management plan.
- Reporting, Revision and Decision making: the administrative part of the assessment process.
- Follow up: implementation of the environmental and social management plan and evaluation of mitigations and project environmental and social performance. International Finance Corporation guidelines, hydropower sustainability guidelines.

2. Discussion of required reading. Based on their knowledge and experience, each participant will write a reflection on the article about spatial design principles for sustainable hydropower development in river basins.

3. Reviewing national requirements for ESIA. Each participant will review the environmental act, law or regulation in their country to identify the legal requirement for the assessment of hydropower projects.

During the face-to-face phase, the participants will attend the morning lectures and discussion on the use of ESIA and SEA and their advantages and limitations to integrate into the assessment of hydropower development, climate change, human rights, ecosystem services and cumulative effects. In the afternoon, the participants will be organized in groups to work on a group exercise to identify different types of impacts of a proposed development project. This can be the project they have selected for the feasibility study or another project proposed by the instructor. The local environmental and social legislative framework will be addressed and discussed.

During the last phase, the participants will submit their assessments of the impacts and benefits of the project for which they are conducting a feasibility study. This can be in the form of a written report or a presentation. A virtual group discussion will be organized to discuss the results of the assessments and give feedback. Previously, during the face-to-face meeting the participants will receive the instructions for submitting the assessments.

4.3.1.12 Hydropower Systems

Laymen may think that hydropower is a quite simple and old-fashioned technology mainly consisting of a turbine and a generator. The story is much more complicated. Even after several decades of very close relation to hydropower, it is still most likely to become acquainted with a new individual solution. Therefore, hydropower systems have a special position in the whole course and represent the integration of the knowledge collected in the system component lectures. The module will be organized by Studio Frosio (SF) in cooperation with IHE Delft in the second week of courses and will include one-day preparation before the course and one and half-day for face-to-face lecturing and two day for the assignments and discussions after the course.

A hydropower system can be described as a 3-dimensional system, in which the head, the concept and the mode of operation define the individual plant. The number of options is unlimited and consequently there exist not even two identical plants in our world. That makes hydropower a unique and challenging technology. Hydropower design should be tailor-made to achieve the highest possible efficiencies and best possible quality in terms of equipment and operational needs.

The following table explains the space, spanned by the criteria:

Table 2: Types of the hydropower scheme based on the head and the concept

	Low head (<10m)	Mean Head (10-50 m)	High head (>50 m)
In river	run off	run off / storage	storage
Diversion	run off	run off	run off / storage

The boundaries between powerplant types specified in Table 2 are fuzzy and it is not possible to define sharp threshold values. The lectures envisaged will describe and demonstrate the complex typology, the procedure on how to select the suitable system and type of operation and which criteria can be applied.

A special chapter will be dedicated to pump-storage plants, which – in a formal view – should not be defined as a hydropower based production unit but as a battery. Another special chapter will focus on the recent development of ocean energy, the technical solutions applied and the problems ocean energy is faced with.

The entire course will enable the participants to evaluate unexploited hydropower potential, to select a suitable way of exploitation and to finally decide upon all components necessary to build a reliable and sustainable hydropower plant, meeting the needs of the society. Finally, the Lugarawa SHP will be presented, as it is a typical application of the theoretical approach to a real case in Africa. Studio Frosio has the chance to describe the hydroelectric scheme and also how Studio Frosio came about it, from the preliminary survey on-site to the construction design, based on a detailed topographic survey and the hydrological analysis, confirmed by direct measures of the available flow rate on site. Moreover, the geological report and the environmental assessment, carried out by professionals, gave further inputs for the final design.

The hydraulic works undoubtedly are a very significant part of a SHP, so it will be illustrated how a theoretical hydraulic scheme can be implemented in actual schemes with weir, channels, pond and penstock, giving also some detail on the design process and on the final choices. Presenting the powerhouse, participants will face a typical civil works design, from the layout to the structural works dimensioning.

This includes the electromechanical equipment, gates, valves, protection device of the penstock, cranes, generating unit, control panel and electric cubicles, that represent all the

typical equipment installed in any hydroelectric plant. Also, the commission tests will be quoted, as they are a significant step of the project.
Finally, the rural grid (33 and 0.4 kV lines) will be illustrated and also the connection line to the national grid, which allows the plant to work in parallel with the national utility grid, as well as in stand-alone mode.
In the end, the daily accumulation basin and the penstock of an African real case will be the subject of specific training, to show practically the hydraulic and structural criteria to design these important works of a SHP.

4.3.1.13 Operation and Maintenance

The module will be organized jointly by TRMEW, IMP PAN and Studio Frosio in the second week of courses and will include one day face-to-face lecturing and one day of post-course activities. The operation and maintenance rules of each hydropower installation are highly dependent on several local constraints. Usually, they are described in detail in such documents as:

- technical design documentation including inventory drawings and electrical diagrams;
- SHP operation manual to be issued by the installation developer or supplier;
- water use permit and water management guidelines issued by relevant local authorities;
- stipulations following from the grid connection contract and other related documents.

Therefore the purpose of this thematic block is to provide participants with the framework knowledge of the O&M basics and to present them with some practical procedures applied to a real case. Only typical O&M procedures will be discussed - based mainly on European experience, adapted in as much as possible to local conditions in the target countries. Use will be made of relevant guidelines, standards and regulations as issued by various institutions and technical bodies. The HYPOSO team believes the knowledge passed may be useful in any case, but it will be not able to replace the detailed technical documentation.
The lecture block will start with such strategic issues as:

- operation strategy as dependent on the installation type, performance characteristics, plant role in the local grid (electricity supply regime), hydrology, water management function and environmental constraints;
- maintenance strategy as dependent on the kind of equipment and available condition monitoring practices.

Next, the main threats to civil works and electromechanical equipment will be presented. Possible consequences as well as basic countermeasures and safeguards will be mentioned also. Immediately afterward, the control and supervisory systems will be discussed based on some good practice examples. Reference will be made to the Hydraulic Units and Electrical Equipment and Lines lecture blocks. However, the operator perspective will be represented this time rather than that of the power plant designer or planner.

The subsequent topic will consider technical and legal prerequisites for operating a small hydropower installation. This will include the already mentioned documentation and necessary qualifications. Both, good European practice and the legal status in the target countries will be taken into account.

The two key topic groups will be operation and maintenance procedures. Commissioning, start-up, normal operation and shut down (normal and emergency ones) procedures will be discussed. In addition to good practices, use will be made also of recommendations to be found in international standards and guidelines. Presentation of normal operational procedures will end up with discussing procedures in exceptional circumstances as illustrated by some technical failure scenarios.

European practices will be also used when presenting typical maintenance procedures. While not replacing a regular SHP operation manual, the lecturers will point out some key issues in daily maintenance (including key components, checklists and frequency of activities) and present some recommendations on the overhaul planning.

The performance and diagnostic test scope and procedures will conclude this lecture block. Although some simple tests can be conducted by a skilled operator himself, the main purpose will be to pass the knowledge necessary to assess when they are needed, what are the main conditions of their success and how to interpret the results.

Also, a typical maintenance procedure applied to a real case in Africa will be presented. The experience in Africa will lead to a comprehensive and site-specific treatment of this topic: an example of a manual for a SHP in Lugarawa will be the starting point for a fruitful discussion among the participants and the HYPOSO team.

4.3.1.14 Financial Analysis

The module will be organised by 1to3 after the second week of course as a one-day online lecture.

The course on the financial structuring of hydropower assets aims at increasing bankable propositions by teaching all elements that are making a credit proposal (for raising debt finance) and/or investment memorandum (for raising equity or quasi-equity). The approach differs in that the course provider is a partner at an ‘open source’ crowdfunding platform and can teach from a position with access to finance platform(s), produces sharable information (‘syndicated funding’) and therefore can include points of views on risk and mitigation which otherwise stay in the domain ‘to be found from due diligence’. Hence, drafting proposals are taught that will fly with the majority of financial institutions from a content point of view. Then it is still possible that financing is not available as per some specific reasons like war, creditworthiness, etc.

The lectures aim to prepare at least 3 proposals for small-scale hydropower in each of the 5 target countries. Proposals that can be submitted and reviewed at financial institutions at a stage where ‘in-principal’ approval-decision making is possible, apart from KYC (Know Your Customer) processes.

The lectures will be delivered in two ways: 1) through recordings that can be assessed through 1to3’s website and/or HYPOSO’s website, and 2) interactive webinars/skype calls/team meetings prior, during or after the face-to-face meetings take place of the other consortium members in the target countries.

The recorded lectures will ensure that participants have the opportunity to get informed about all aspects that makes a SHP financeable. The webinars are meant to assist the applicants of the SHP-finance proposal per respective country to finalise such proposals.

Credit applications, investment propositions, etc. follow a structure that is similar to most financial institutions, funds, etc. The main reasons for this are the sharing of risks that are associated with loans, bonds, shares, etc. with other lenders, bonds investors, share investors, etc. The building blocks are used from an approach to derive standardized credit applications, much similar to how credit agencies for example ‘rate’ credits like Standard & Poor’s or Moody’s.

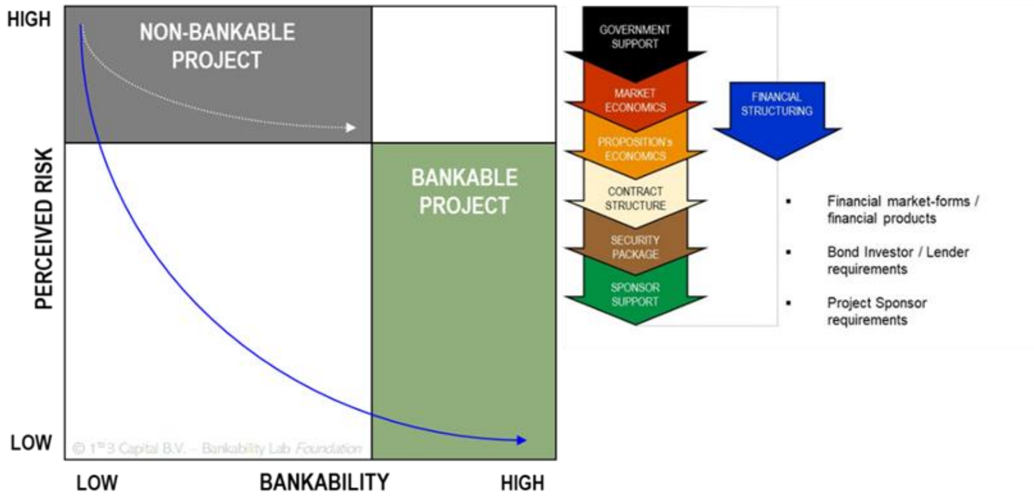

Figure 1: Bankability Matrix and Bankability Building Blocks

The blocks represent major risk or risk mitigation categories and answer high-level the following questions:

Table 3: Bankability - Levels of analysis

Analysis-level	Credit Application Lead-Questions
Macro-economic - Country level, Global level	Why lending to opportunities in this country, region, continent, etc.? Is the country eligible or is it below investment grade?
Sectoral level	Why lending to this RE – EE sector and not to other sectors in the area defined at 1.?
Individual – Propositions’ level	Why this proposition of this technology type in this sector of 2. in this area 1.?
Contractual level – business model	Why this proposition of 3. with business model A (PPA for example) and not model B or C, in this sector of 2. in this area 1.?
Security level	If this proposition is the one to lend to or invest in what would be minimum requirements for the security of the loan

Equity / owner level	If this proposition at a certain set of securities seems okay, then what requirements are associated with the owners/equity providers?
Financial structuring elements	Finally, the proposition will need a balanced risk-return allocation and which structure at what terms and conditions are optimal with what financial products, which markets and what roles?

Taking this approach into mind the content of the lectures is the following:

1. Basic concepts and elements of finance (a.o. Capital Asset Pricing Model)
2. The role of a financial model in financial analysis and structuring of finance (participants will receive a copy of 1to3's financial model)
3. Financial modelling: cases per country
    i. Building Blocks financial model: input requirements
    ii. Financial statements
    iii. Bankability analysis and financial ratio analysis
4. The finance paragraph in a credit application
5. Overall structure credit application
    i. Background, macro-economic impact, enabling environment, RE sector, legal and tax support mechanisms, LCOE, main parties involved
    ii. Risk matrices and risk allocations
    iii. Borrower and borrower types
    iv. Business models
    v. Contractual structures, both construction and operational period
    vi. Security structures including insurance, both construction and operational periods
    vii. Financial structures, the interests of debt, sub-debt and equity providers
        a) Financial markets, forms, underwriting, syndication and club deals, including the role of development banks
        b) Financial products including blended finance, smart grants and result-based finance
    viii. Other requirements such as social and environmental requirements, KYC, permits and licenses, etc.

The material that has been prepared before at the country level will by then have been transferred in drafts documents by 1to3 and will be shared upfront with participants. The videos will be accessible through the website of 1to3 which is being set-up to accommodate external access to these videos with a code or upon the use of a password. In the week commencing 5 July 2020, the further design of the website is in the planning. All participants will also have access as from early September 2020 to an independent financial model that will have information pre-entered on the specific SHP cases per country. If participants wish, they can work with Retscreen which aims at the same output (1to3 works with its own material from risk perspective which is a material part of the arrangements with regulated crowdfunding in the Netherlands but with EU-reach).

4.3.1.15 Design Training

The module of design training will be organised by Studio Frosio (SF) at the end of the short course as the implementation and application of all subjects discussed and learned during the whole short course. The module will be organised as a one day face-to-face lecture and three days of the work on the project online after finishing of all lectures.

Designing a hydropower plant successfully requires a series of steps in a certain order. Mistakes in an early phase of this procedure will necessarily lead to wrong decisions in later stages. The knowledge of the many different components of a plant is the basics and minimum qualification for starting the design process.

The designer has to precisely know about the important input facts like hydrology, topography, geology, legal framework conditions, land property, accessibility, electricity consumption and -transport and some others. In many cases, all this information is not available to a sufficient extent or quality and the designer has to evaluate the reliability of data and – in many cases – has to trust in estimations and - last but not least – in his own experience.

As said above, the quality and completeness of input data have a direct impact the quality of the design. Governmental organisations and their data are, of course, on top of a list of sources but a designer must not forget about the local experience and – what is most important – a site visit to complete a picture gained from maps with personal contact with nature. An experienced design engineer said: “Design has to be made on-site” and was right because only under the direct impression of the location the engineer will find a suitable solution.

The only way to gather design experience or at least to do the first step along this way is to practice on real cases and under realistic conditions. The design training will perform these stepwise procedures directly including the course participants. The target level is a pre-feasibility study.

Because the design training will mainly consist of practical work of the participants it is necessary to perform the course in face-to-face format. The lecturer will continuously be available to individually supervise the work of the participants, to guide them through the design process and to discuss solutions and decisions.

Individual questions will be answered individually – Questions of general interest for all groups will be answered and discussed in the plenary group with all participants.

The practical work to be done by the participants will include:

- Writing a short technical report.
- Sketches made by hand or AutoCAD.
- Hydraulic calculations.

To facilitate the students’ work several basic project data will be provided:

- A real topography (1:25.000), contour map.
- hydrological data (10 years time series).
- idealised cross-section of the river.

- list of content of the expected outcome.

Additionally, the students will get information guiding them through the process:

- Supporting information.
- Basic hydraulic explanations and formula (hard copy).
- Energy production calculation sheet (xls).
- Cost standard values.
- Chronological to-do-list (hard copy).
- Material from previous courses concerning weirs, intakes, pipes turbines etc.

The expected outcome per group should be a simplified pre-feasibility study.

4.3.1.16 Study Tours

During each week of the course, a study tour will be organized. The study tours aim to visit several hydropower systems. With an organized study tour to the hydropower plant, the teaching material presented during the course will be seen in the praxis and the applications will be discussed.

The site tours will be organized and guided by the local project partners. The lecturers that will participate in the site visit will use the site visit for a better understanding of the learning objectives.

In the discussion with the local partners, the one day site visit is modified into a two-day trip. The reason is that the interesting sites are situated not so near to the course venue and therefore more time will be needed. The two-day trip gives also the possibility for more effective site visits and more time for the discussions and application of the learned material.

The two days site trips will extend the duration of each short course from seven to eight days, consisting of a total of 6 days lecturing and one-two days of the site visit. This extension of the short course is included in the adopted course cost estimation.

The COVID-19 restrictions caused the rescheduling of the short courses and also restrict possibilities for detailed side trip planning. The preliminary site trip organization and schedule is shown below.

Bolivia:

The site trip is planned as a two day trip from the short course venue in Cochabamba. The first day of site trip is a drive from Cochabamba to HPP Corani Power House, the site visit and lunch on-site will be organised. After lunch, the travel to HPP San Jose II (1.5 hours) and visit of the powerhouse will be organised. Dinner and sleepover is planned in Villa Tunari. On the second day, travel back to Cochabamba and discussion and elaboration of the visit are planned.

Cameroon:

The training will be organized in Ebolowa (three hours drive from Yaoundé, capital of Cameroon). Because there is no possible accommodation on the site for approximately 30 persons, the trips will be organized as daily round trips from Ebolowa. The site visit will be to the Memve'ele power plant (211 MW), which is approximately 2 hours drive from Ebolowa, and could be organized in one day. Alternatively also the Mekin (15 MW) power plant could be visited.

Ecuador:

The course will be held in Quito in the selected hotel or on the university. Two hydropower plants that are planned for the site visit are located in the Tungurahua province, Baños de Agua Santa canton The small hydropower plant Rio Verde Chico (10 MW) is a diversion type and the main elements as diversion dam, conduction, pressure pipe, powerhouse, discharge channel and substation will be visited. The second plant is the large hydropower plant Agoyan (156 MW), the third most important hydropower plant of Ecuador. The main elements that will be visited are: dam, conduction, surge shaft, pressure pipe, machine house, discharge tunnels, control building, transmission substations and also protection of the Agoyan waterfall.

Uganda

The training venue will be in the hotel in Kampala (Hotel Africana, to be confirmed). Proposed field visits go to Nalubaale (200 MW), Uganda's oldest power dam (formerly Owen Falls dam), near the source of the Nile, and then to Isimba (183 MW) HPP, Uganda's latest addition. These two power plants are selected because of easy access from Kampala in the given time frame. Visit of the small HPPs located quite far in the mountain slopes of Rwenzori (West) or Elgon (East) are not easily reachable and the transport and logistics would be rather a challenge.

4.3.2 Short course organisation

The short course will take place in the target countries in Africa, in Cameroon and Uganda and South America, in Bolivia and Ecuador. In each country, a 6-day short course following by two days site visit is planned. The total course time is limited to 8 days in each of the training countries. The short course is planned as a face-to-face event with all lecturers actively presented in the country and lecturing venue. The participants on each course are coming from both countries of the continent.

Considering 8 participants from each country it is planned to have 16 regular participants. The course will be open for other interested persons that could take their costs. No fee will be set for the other participants. Based on the number of the other participants and their participation in the out-course activities (lunch, dinner, visits, etc.) they could be asked for the refund of the cost. These off-regular participants of additional university staff teaching hydropower topics and governmental organisations (decision-makers) are especially welcomed and will be additionally motivated to participate.

4.3.3 Participants selection

The participants should be recruited from all groups of the stakeholders involved in a small hydropower process (design, legalization, construction, operation and maintenance). Therefore the consultants, engineers, technicians, governmental and financing bodies and also the environmental staff. Based on the given study plan and existing project budget, on each continental short course approximately 8-10 participants from each country will take part. For these participants, the whole costs (travel, accommodation and meals) will be sponsored by the project. Additional participants that could sponsor their travel and stay are welcome.

Based on the discussion with the target countries the participants will be from these main stakeholders:

- National and local government (ministry of energy, water, environment or planning, a local governmental sector in administration and regulation of natural resources),
- National electricity company and private hydropower energy operators,
- Academy (staff teaching and researching in hydropower),
- NGO's working in hydropower,
- Hydropower investors.

The selection of the short course participants will be coordinated by the target countries. Potential participants will receive a letter of invitation addressed to their institutions, and will be selected based in the following requirements: work experience in the hydropower sector, background in electrical/civil/environmental/mechanical engineering, and their English skills, an intermediate level will be needed.

5 Proposed workshop schedule

The courses have been planned firstly in Africa and then in South America. The courses should start in September 2020 in Uganda following in February 2021 in Cameroon. Because of the COVID-19 restrictions, the September course in Uganda has been postponed. The alternative has been found in April 2021 in combination with AFRICA 2021 (https://www.hydropower-dams.com/africa-2021/). The conference AFRICA 2021 will be held on Lake Victoria, Uganda from 13-15 April 2021. The HYPOSO project team is planning a session on the conference presenting the project and the outcomes. Therefore the course will be combined with this conference event. Considering this modified schedule the main deadlines of the project (milestone 9 – End of activities in Africa) still could be held and no major changes in the schedule are necessary.

The courses in South America are planned in November 2021 in Bolivia and in December 2021 in Ecuador. These courses are also planned before the end of the HYPOSO activities in South America in December 2021 (milestone 11).

We are planning the courses as face-to-face events. In case that COVID-19 restriction will be still valid in 2021 the alternative to hold the short course fully online could be discussed. Such a solution has the main disadvantage in missing the personal contact between teachers and participants and is therefore considered just as the last possible option.