IEA Hydropower Task 16 - Hidden and Untapped Hydropower Opportunities at Existing Infrastructure

White Paper No. 1 "Overview and major needs for identifying and acting on Hidden and Untapped Hydropower Opportunities at Existing Infrastructure".

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Summary

To meet rapidly approaching targets for renewable electricity generation goals, hydropower must play an important role. Development of "hidden" or "untapped" hydropower involves exploiting existing infrastructures that either do not already produce electricity or those with resources and operations that can be upgraded or modified to increase capacity or generation.

There are challenges to identifying, assessing feasibility, and tracking hidden and untapped hydropower opportunities (HUHO). However, emerging data and analytical techniques such as geospatial inventories of infrastructure and water resources as well as machine learning approaches can produce robust catalogues and powerful communication tools, supporting site selection for detailed analysis and development while helping to place HUHO in the context of broader energy development opportunities.

Successful refurbishment or expansion projects at existing hydropower facilities can include upgrades of equipment or better utilization of available water resources through design or operation modifications. Additionally, generation capabilities can be implemented within diverse infrastructures, from irrigation canals to municipal water systems, non-powered dams, and former mines. While facing constraints from the existing infrastructure, other water demands or availability, these projects offer many benefits through reduced civil works, capital costs, and environmental impacts compared to greenfield development.

Research and innovation are needed to support further identification of HUHO and to realize the full energy potential that exists within hydropower and water management infrastructure. Development of environmentally sustainable and economically competitive hydropower technologies and demonstrations are essential to ensure the growth of HUHO projects.

Understanding the range of HUHO, best practices, challenges, and research needs is critical to assessing the role of these opportunities in the broader context of energy development and water management.

Introduction

Renewable energy is the foundation of our future electricity mix and enables a sustainable energy supply with a limited carbon footprint. Hydroelectricity provided more than 4 252 TWh in 2022 and must increase its production to reach a goal of 5 700 TWh by 2030 (IEA, 2022). To develop the potential of hydropower, in addition to new greenfield projects, Hidden and Untapped Hydropower Opportunities (HUHO) at Existing Infrastructure must be considered. The term "hidden hydro opportunities" (HHO) addresses the portion of hydropower potential that exists within infrastructures that do not already produce electricity, whereas "untapped hydro opportunities" (UHO) refers to potential generation capabilities that come from exploiting resources and operations at existing hydropower infrastructures.

Type of hydropower opportunity	Description
Hidden	New plants equipping non-powered dams, water conveyance structures, or other existing irrigation/municipal/industrial water systems.
Untapped	Refurbishment of existing plants by improving or enhancing the performance/production of existing hydropower facilities or utilizing novel or improved electrical or mechanical components or new materials.
Greenfield development	Not included in Task 16 activities.

This white paper is the first publication produced by Task 16 of the IEA Technology Collaboration Programme on Hydropower, whose goal is to increase the hydroelectric potential from HUHO at existing infrastructures in a sustainable way. Task 16 activities focus on:

- Identifying and understanding sustainable HUHO that have not been addressed through traditional approaches to hydropower development planning.
- Describing techniques used to identify and quantify the potential for sustainable HUHO including the development of inventories.
- Finding where HUHO opportunities can be encouraged through improvements in data gathering, technology innovations, changes in regulation policies, or deployment measures.
- Formulating needs for further technology development to maximize the future use of the potential of sustainable HUHO and develop a research and innovation agenda.
- Identifying the overall benefits of HUHO and best practices in its implementation.

The aim of this white paper is to enable the reader to understand the concept of HUHO, how to identify opportunities and best practices in its implementation and to encourage the development of such sustainable projects. It presents an overview of different opportunities for developing the hidden or untapped generation potential of existing infrastructures through concrete examples. The summary highlights the variety of project types, techniques used to increase power or develop projects, and challenges associated with HUHOs. Additionally, the paper summarizes needs related to identifying and tracking opportunities as well as research and innovation.

Benefits of hidden and untapped hydro

While hidden and untapped hydro projects are often individually small in terms of power generation, development of many sites can provide significant benefits with cumulative low impacts (Nielsen, 2019) and thus provide a sustainable solution to produce electricity. HUHO are also unique because there is often an opportunity for cooperative development, where generation can be added at the same time as other retrofits or refurbishments. In some cases, the revenue from generation can help support needed infrastructure improvements. HUHO sometimes allow using generated power locally on site, hence providing significant economic benefits.

HUHO have a variety of potential advantages and factors that enable development, especially compared to greenfield or other small hydro development. In general, HUHO:

- have lower costs for overall development than alternative greenfield sites
- use existing infrastructure to maximize the energy benefits from underutilized facilities
- require fewer new environmental/social studies due to the low additional impacts
- emit few or no additional carbon emissions due to use of existing structures and limited changes in reservoir operation
- are often the most feasible option for increasing hydropower production that is considered and approved in many jurisdictions

In addition, many hidden hydro plants can be developed in rural and off-grid communities, which addresses the issues of rural electrification while providing communities with non-fossil options to achieve greater energy resilience. In broad terms, increasing hydropower capacity through HUHO strengthens the water-energy nexus and helps increase flexibility and reliability of the electricity grid.

How can the potential be identified?

Hundreds of examples worldwide have shown that hidden and untapped hydropower at existing infrastructures can produce affordable and sustainable electricity; however, it is a real challenge to identify and assess the potential at large or even small scales. Several reasons why it is so difficult to identify and quantify this potential are:

- The large number of different infrastructure types that could be used to produce electricity besides their primary function: drinking water networks, irrigation systems, wastewater systems, water supply and flood control dams, ship locks, desalination plants, cooling systems, etc. require different technologies.
- The large number of actors involved in the planning, construction, and operation of these infrastructures: Municipalities, utilities, private companies, private-public partnerships, etc.
- The range of outputs to be considered in the inventory: The lower the considered unit output the more potential, but also the more difficulties to identify the possible resources. For instance, pressure reducing valves (PRV) are widely used in most water distribution networks, each one representing a hidden hydro potential of some W or kW. Identifying the corresponding potential would need huge workforce that will be disproportionate to the result that can be expected.
- The fact that it is hidden! It is then impossible to use the same methods as those applied in the assessment of river potentials based on hydrologic models and topographic data, etc.
- There may be multiple owners, for example between the infrastructure, the hydropower plant, and the adjacent land.
- Different technological paths of exploring the hidden hydropower potential in existing infrastructures, involving complex decision making including complicated economic assessments and different schools of thought.

In addition, inventories of potential often provide snapshots that are limited by conditions that exist when they are created. For instance, a potential site could be non-profitable today because of the actual electricity price or absence of financial support, but fully profitable in some years if new conditions appear (for instance feed-in tariffs). In other cases, current lack of suitable materials may be addressed by future advances in materials or manufacturing.

For all these reasons, it is necessary to:

- have a precise target when planning an inventory. Is it only to have a picture of the current situation, or will this picture identify the problems that burden the development of hidden hydro projects in order to define development strategy, supporting tools, roadmap, adapted administrative procedures, etc.?
- clearly define the type of hidden hydro potential to be assessed. Different data and methodologies will be needed to assess various types of HUHO. For instance, the potential of dams and ship locks can be evaluated through existing inventories or

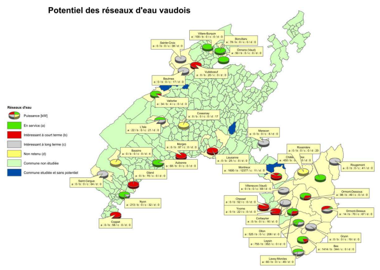
remote sensing, and they are generally geographically limited (i.e., along rivers and coastal regions). On the other hand, the location, and characteristics of drinking water networks with pressure reducing valves or mines are generally only known by the operators of the systems. The region of interest may help prioritize which types of potential should be assessed.

Once the target is fixed, the type of potential defined and the area identified, the following practices are recommended:

- Identification of the promising places through geographic information systems (GIS). This initial analysis can provide foundational information on key resources, including catchment areas, reservoirs, irrigation channels, ship locks, place of wastewater treatment plants, existing dams, and weirs. Places, water resources (available discharge), levels and slopes (available head) can be identified roughly to make a first ranking of sites in function of the potential output and power production.
- Contact with the authorities in charge of drinking water, water sewage, river navigation, etc. These types of contacts are important to assess the legal aspects that can influence the potential, but also to identify the right persons to meet or ask for more detailed information about project characteristics or operations.
- Questionnaire and interview of owner/operators of the infrastructures. This is a very important step to get relevant information and to make local decision makers aware of the possible potential.
- Site visits of the most promising identified sites. The number of visits will of course depend on the available budget and the area to be covered.
- As far as possible, incentives could be proposed to enhance the willingness to answer and to provide reliable information. For instance, one can imagine making a preliminary rough analysis of the potential of a municipality freely available, the cost of this service being borne by governmental program.

An inventory can take a variety of forms and be accompanied by products to effectively communicate hidden hydro development opportunities. Examples of products include:

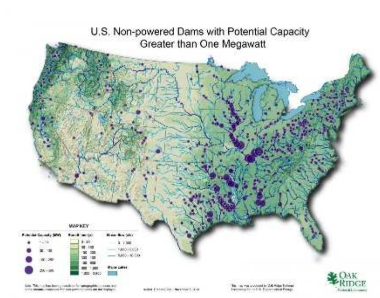
- a synthesis report showing potential along with completed projects,
- maps or lists of sites showing potential (i.e., capacity, generation, etc.) and characteristics relevant to development,
- fact sheets with success stories,
- roadmaps guiding how to valorise the potential,
- check lists on how to develop a site,
- presentations to decision makers.



Conduit inventory in Canton de Vaud, Switzerland

The energy law of this state member of the Swiss Confederation binds the energy department to identify the hydropower potential of the Canton (3,212 km^2). An inventory was performed in 2008. It identified 26 hydro sites in operation on existing infrastructures (5.5 MW, 24 GWh) and 101 potential sites for 20 MW and 76 GWh. The study was limited to drinking water, irrigation water, wastewater, and drainage water. Following this inventory, at least 14 projects have been implemented and some others are under study.

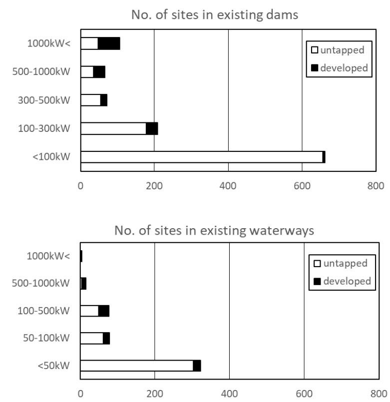
This project was based on cartographic analysis, information received from the authorities, questionnaires sent to municipalities, sites visits, and prefeasibility studies supported by the local government.



NPD Resource Assessment, Oak Ridge National Laboratory, 2012

USA Non-Powered Dam Resource Assessment

A 2012 analysis of more than 54,000 non-powered dams estimate generation potential and power capacity. The resulting inventory describes potential generation and potential power capacity at nearly 600 dams - including major diversion structures and dams with locks – with at least 1 MW of capacity. To identify these locations, the study used georeferenced dam locations, adjustments to the dam height to obtain representative hydraulic head, national hydrography data such as river locations and average streamflow and assumed capacity factors based on those of nearby powered dams. The estimates did not account for any site-specific limitations such as operational constraints or factors that might reduce feasibility (e.g., site access or dam condition). Of the projects identified, nine have become operational since 2012, adding a total of over 80 MW of capacity. An additional 47 projects are in the development pipeline.



The New Energy Foundation (NEF), Japan, 2009.

The New Energy Foundation (NEF)'s Survey, Japan

NEF conducted a survey on untapped hydropower potential in existing dams and waterways during 1999-2008 commissioned by the Ministry of Economy, Trade and Industry, Japan. The survey is an update to the previous assessment of national hydropower potential, which was completed in 1986. The survey identified 1389 potential sites for 330 MW and 1.66 TWh as of March 2009.

A broad range of facilities were assessed for the entire country via review of literature and questionnaires sent to facility managers: hydropower dams (compensation flow), non-powered dams (multi-purpose, drinking water, industrial water, irrigation and sediment control) and waterway networks (drinking water, industrial water, sewage water treatment and irrigation). The survey described untapped potential capacity, optimized facility layout, outline for a development plan, and an estimation of construction cost for selected sites.

Untapped Hydro Opportunities: existing power plant projects

By 2030, more than 20% of the global hydropower generation units will be more than 55 years old and require refurbishment (IEA Hydropower Special Market Report, 2021). This provides an ideal opportunity to upgrade, uprate or generally modernize the plant. In the past decade alone, refurbishments and upgrades have received significant investments: more than 13 billion (2019 US dollars) in North and South America, 5.5 billion in Europe, and 11.5 billion in Asia (Uría-Martínez et al, 2021). Renewal and additions to existing hydropower facilities accounted for nearly three-quarters of capacity additions between 2010-2019 in the United States.

IEA Hydro Task XI on Renewal & Upgrading of Hydropower Plants (2010-2016) conducted a study on global renewal and upgrades of hydropower plants with a collection of 70 case histories from 10 countries (Akiyama, 2016). More than two-thirds of cases involved recovery of degraded performance, increase of output and power, or improvement of flexibility. Since completing the IEA Hydro Task XI survey, more than one hundred case histories have been collected globally (Miyanaga et al, 2023).

Based on these studies, methods to harness untapped hydropower potential can be generally categorized into three types of projects: refurbishment, expansion, and operational improvement. For refurbishment projects, the renewal of the electromechanical parts can increase power output by as much as 20%, increase the capacity factor, offer improved durability, and enable greater flexibility. For refurbishment of civil works such as intake facilities or dam heightening, power can be increased by as much as 50%. Expansion projects such as adding turbines to use environmental flow releases can increase production by up to 4%. Construction of new power plants adjacent to existing hydropower facilities that use untapped potential in rivers or water channels can lead to an increase from 22% to 483% of the production. Expansion or new construction can also improve the flexibility of conventional hydropower or pumped storage power plant and increase peak supply capacity from 60% to 102%. Optimizing reservoir operations has also increased annual power production by 1 to 3%.

Successful examples of UH projects, , based on the study of case histories (Miyanaga et al, 2023) are summarized as follows:

Renewal/refurbishment projects

- Reduction of maintenance by improving durability of turbine/generator (see Example 1)
- Reduction of construction cost by reuse of existing parts and downsizing of renewed facilities
- Improvement of pumped storage function from fixed speed system to variable speed system
- Reduction of water intake interruption period by refurbishment of aged dam

Expansion/re-development projects

- Use of environmental/minimum flow from dam, spilled water at dam, unused water head in existing water channels, fish ways, etc. (see Example 2)
- Addition of pumped storage function at existing power plant

Operational improvement projects

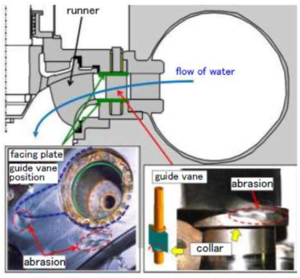
- Extension of flow range for power generation (see Example 3)
- Optimization of intake discharge management
- Water diversion from other catchments
- Refinement of reservoir inflow prediction

Recently, the energy potential of modernizing the European hydropower fleet was assessed, including dam heightening, head loss reduction in waterways, increase of weighted efficiency of electro-mechanical equipment, digitalization and using inflow forecasts, and floating photovoltaic (evaporation reduction). The overall energy generation increase was estimated to be 8.4% for European Union and 9.4% for all of Europe (Quaranta et al., 2021). Similarly, the potential increase in conventional hydropower from refurbishment and upgrades in the United States was estimated to be roughly 8.8% (US DOE, 2016).

The most common challenges in the development of UHOs are technical issues. Economic efficiency is also a major concern in most of the projects. Most of environmental challenges are not significant barriers to the development because renewal, expansion and operational improvement projects have less additional environmental impact as compared to new construction projects.

A variety of innovations have provided solutions to technical and economic concerns of UHOs. Particularly for operational improvements, projects have used rapidly advancing technologies such as machine learning and modelling to extend the range of power plant operation (see Ex.3), to integrate meteorological observation, reservoir inflow prediction and dam operation, etc. Reduction of project costs have been achieved through innovations in design, construction, and operation and maintenance. Policy support is expected to enhance such technological innovations. For example, the US Department of Energy's Innovations for Low-Impact Hydropower Growth program led to industry development of an artificial-intelligence-driven forecasting software package which supports more informed operation and better system performance (USDOE, 2021). Additionally, the Horizon Europe-funded H-HOPE project1 will develop a hydro energy solution that uses a novel technology to collect hidden hydro oscillating power from otherwise ignored open streams, piping systems and open channels.

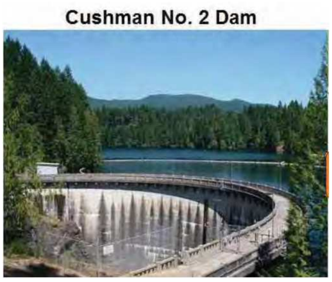
[1] H-Hope; Hidden Hydro Oscillating Power for Europe | H-HOPE Project | Fact Sheet | HORIZON | CORDIS | European Commission (europa.eu)



Source: Annex XI

Reduction of sand abrasion of turbine

At the Himekawa No.2 Power Station in Nagano Prefecture of Japan, run-of-river type with a capacity of 14.4MW, parts of turbine were frequently damaged due to sand abrasion. During 2005-2010 an improved design of guide vane shape reducing sand abrasion was developed and verified using solid-liquid two phase flow CFD analysis with field tests. The new design has successfully extended repair intervals of turbine about twice before the improvement saving average repair cost and loss of power generation due to shutdown for maintenance.



Source: Annex XI

Use of minimum instream flow from hydropower dam

The North Fork power station in Washington, USA, reservoir type with a capacity of 3.6MW, was constructed in 2013 using the minimum instream flow released from the intake dam of the Cushman No.2 power station with a capacity of 81MW. The new power station has increased annual power production about 13% of the Cushman No.2. An innovative upstream fish passage system was constructed as a part of this project using water discharge from the new power station and a fish trap to collect and transport fish from the bottom to the top of the dam. The system is intended to restore fish access to historical habitat upstream the dam.

https://portugal.edp.com.

Extension of flow range for power generation

Energias de Portugal (EDP) and GE have been working together on range extension program of hydropower plants. The methodology is using historical operation data and site testing data of the machines with digital technologies to reduce lower thresholds of operation range based on risk assessment. It has been successfully applied to the Valeira Power Station in the Douro River in Portugal, run-of-river type with a capacity of 264MW since 2019. The range extension is expected to increase flexibility of EDP's power supply to the Iberian Electricity Market.

Hidden Hydro Opportunities: new projects using existing infrastructure

A broad range of infrastructure exists to support water storage, treatment, or conveyance, including:

- Dams and weirs
- drinking and wastewater networks
- ship locks
- irrigation canals
- environmental flow outlets
- old water mills
- tailrace channels or river training structures downstream of large hydropower plants
- desalination stations
- cooling and other industrial systems associated with new power plants

Existing civil works and controls on water flow can sometimes provide opportunities for adding power without additional effects on the environment or existing water systems. In many cases, the infrastructure creates conditions where sufficient hydraulic head is created (e.g., an existing dam that has increased elevation of the impounded water) or the setting of the existing infrastructure already has topographic variation (e.g., gravity-fed drinking water networks or drops in irrigation canals). Some industrial processes as desalination station or cooling systems need medium to high pressures to operate. At the end of the process, the remaining pressure is still high and could be used to generate electricity. Each of these projects are typically constrained by existing hydraulic head (pressure) and flow (i.e., no additional major civil works to increase head or further alteration of the releases or flows through the infrastructure are possible).

Nearly two-thirds of dams in the Global Reservoir and Dam database (GRanD) do not currently generate hydroelectricity (Lehner et al, 2011). Large dams or lock structures can often use traditional turbine technologies that are fitted in relatively standard schemes (e.g., inside of existing penstocks or outlet structures, nested within lock gates, etc.). The water wheels in old mills can be modernized and electrified as well as gated weirs of diversion run-off-river schemes equipped with turbines (Quaranta et al, 2022). Generation capacity at these types of facilities is typically characterized as “mini” and “small hydro” (greater than 100 kW but less than 1 MW and greater 1 MW but less than 10 MW respectively). Development of generation capabilities within other water infrastructure is typically characterized as “micro hydro,” (less than 100kW capacity). Such small generation can support local facilities or systems rather than being sold or used to supply other needs of the grid.

Both challenges and opportunities for hydropower development within existing infrastructure can be largely characterized under three themes: uncertainty in water availability, condition or constraints of the existing – often aging - infrastructure, and policy/support. Addressing these development challenges on large scales (i.e., beyond individual facilities) is complicated by limited public data related to water availability, infrastructure layout, and detailed environmental and socio-economic characteristics (Hansen, et al, 2021).

Uncertainty in Water Availability

Existing infrastructure has typically been designed for historical flows; however, future hydroclimate conditions and inflows may not be stationary, resulting in modifications to operations of dams, reservoirs, and other water regulation infrastructure (Ehsani et al, 2017, Watts et al, 2011). For example, streamflow may increase due to increasing impervious area or changing precipitation patterns or flows in municipal or industrial water systems may increase with greater demands (for water supply or cooling). Conversely, climate change could result in decreases in water availability or shifts in seasonal patterns as rainfall/snowmelt-runoff-streamflow processes change. Uncertainties and variability in flows should be accounted for when evaluating the potential for development to avoid over- or underestimating capacity and generation capabilities.

Aging infrastructure

Aging infrastructure also presents several challenges and opportunities for hydropower development. For example, existing infrastructure may have limited space for siting for large construction equipment. While steps to correct or avoid causing issues to the structural integrity of a dam can lead to increased costs, the addition of generation may be able to occur in tandem with planned refurbishment of existing structures. Additionally, existing infrastructure may have been built prior to policies or practices that promote environmental or functional outcomes. For example, through hydropower retrofit of older dams without fish passage, developers may be able to implement fish-friendly solutions during the construction while other modifications are made to add generation equipment.

Policy/Support

Development and retrofit of existing infrastructure can lead to significant reductions in required investment compared to traditional hydropower. Many capital costs have been incurred when the infrastructure was built and there may be opportunities for coordinated development where coincident environmental or structural improvements to the infrastructure can be made or revenue from generation can offset costs of necessary structural or site improvements.

The feasibility and success of projects involving existing non-powered infrastructure depends on coordination and support from governments, utilities, energy authorities, and the public. Development may require negotiations between multiple parties who own or manage the infrastructure, surrounding land, and water rights. Where regulatory and permitting processes can be represent a significant cost for developers, some countries have streamlined these processes (e.g., through expedited licensing processes) which reduces this burden. Alternatively, policies such as feed-in-tariffs which provide a guaranteed, above-market price for producers of renewable energy can provide significant incentives to developers.


Photo credit: Commune de Savièse

La Zour, Switzerland municipal water conveyance system

The Savièse Community project in La Zour, Switzerland is an example adding generation capabilities to a municipal water conveyance system. The project was completed in 2004.

This installation was part of the general improvement project of the municipal water supply system made necessary by problems of quantity and quality, due to changes in consumption (population growth, increase in individual consumption, changes in the type of housing), the retreat of the glacier and the disappearance of the permafrost (turbidity due to melting snow and heavy rainfall). With a maximum capacity of 300 l/s and a gross head of 217 m, it has an output of 465 kW, generating 1,800 MWh annually (roughly equal to energy demands of 400 households) and avoiding the emission of more than 860 t of CO_2 per year. The municipality has three other installations (250 kW, 350 kW and 80 kW) in its drinking water network, commissioned in 2001 and 2009.


Photo credit: Japan Electric Power Information Center (JEPIC)

Tochigi, Japan irrigation canal

The Momura Power Station in the Tochigi Prefecture of Japan was completed in 2006. This project has a combined capacity of 120 kW which comes from drops within the irrigation canals which reduce the momentum of water flow. Multiple installations within the same channel were possible, resulting in a series of generating units. Revenue from power that is surplus to the land improvement district is used for management and maintenance of the agricultural canals.


Photo credit: United States Army Corps of Engineers Rock Island District

Iowa, USA non-powered dam

Red Rock dam in Iowa (USA) is a federally-owned facility that was built in the 1960s for flood control. Construction and installation took place from 2014-2020. The Red Rock project has an expected annual generation of 178,000 MWh, powering up to 18,000 homes in the surrounding area. Generation occurs in a ‘run of release’ mode, generating only from flows already being released for flood control purposes. The two installed turbines have rated capacities of 18 MW; however, they can generate as much as 55 MW under high flows. Preparation and construction was initially delayed due to higher-than normal water levels. The design involved adding penstocks adjacent to the existing spillway, penetrating the dam. This required careful excavation and retention systems to minimize damage to the foundation and existing embankment.

Addressing barriers to HUHO through research and innovation

In addition to the challenges specific to hidden or untapped projects described in previous sections, there are other general obstacles for HUHO (Nielsen, 2019). However, there are also enabling factors that can help support HUHO development.

Obstacles	Potential research and Innovation themes
Possibility of opening up previous objections to a project or existing regulatory processes	Reduce uncertainties of impacts and find ways to streamline regulatory and permitting processes.
Lack of knowledge of opportunities for improved performance	Create inventories, improve access to data, and review successful projects.
Real or perceived risks of working with aging water retaining infrastructure	Develop best practices for safety and early construction phases (e.g., cofferdam construction).
Lack of a skilled workforce of contractors, hydropower engineers and operators	Create attractive career pathways to develop hydropower workforce.
Projects are not economically feasible	Describe the value of services provided by hydropower to electricity markets. Develop low-cost solutions for design, materials, and installation.
Resistance from infrastructure owners to third party development	Minimize unit outages at existing facilities.

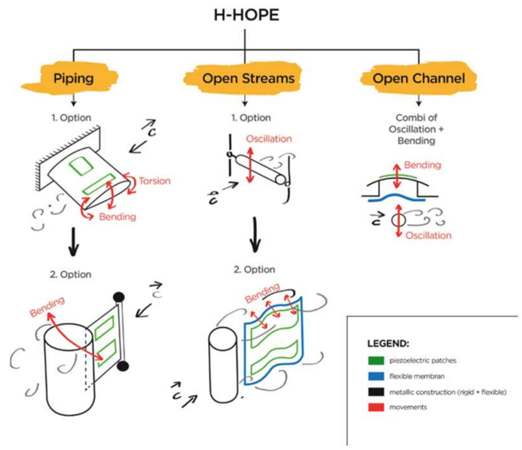
To fully realize Hidden and Untapped Hydro opportunities in the long term, a future-oriented research and innovation agenda must identify key technological solutions that can achieve sustainable and economically feasible development while meeting growing societal energy demands. This can be achieved by learning from hydropower technology developments and demonstrations based on similar types of hidden or untapped hydro projects or shared site characteristics. Additionally, the agenda must build upon best practices and success stories.

As an example, the HYDROPOWER EUROPE Forum, which was funded under the European Union's Horizon 2020 (H2020) research and innovation program and now continued as ETIP Hydropower project under Horizon Europe[2], prepared a Research and Innovation Agenda (RIA) and a Strategic Industry Roadmap (SIR) for the European hydropower sector. The RIA

[2] ETIP HYDROPOWER (etip-hydropower.eu);

and SIR are based on the synthesis of discussions among technical experts and transparent public debates through a forum that gathers all relevant stakeholders of the hydropower sector (HPE, 2021a,b). Several research themes for HUHO have been identified and supported through H2020 research programs that support pilot projects demonstrating and validating innovative solutions for hidden hydro from existing water infrastructure. These themes are geared towards achieving the following outcomes:

- Rehabilitation of old structures and better management of infrastructure in rural areas and improving rural electrification, especially for remote buildings like mills, farmhouses, mountain retreats and tourism promotion
- Valorisation of cultural heritage, historic traditions, and architecturally significant structures
- Fish-friendly energy production with exclusionary and passage features, reduced entrainment, and ecological flows
- Identifying or creating market opportunities for local companies and people (i.e., community-owned renewable energy)



Utilising unused hydro energy sources

EU-funded H-HOPE [3] project will develop a sustainable hydro energy solution that uses a novel technology to collect hydro energy from otherwise ignored open streams, piping systems and open channels. This solution will use innovations that make use of submerged oscillating bodies combined with piezoelectric materials and electromagnetic regulators to take advantage of these water flows. The result will allow to massively digitalize hydraulic systems (e.g. water district networks, irrigation channels), enhancing their resilience and sustainability.

Natel's Fish-safe turbine design

Photo Credit: Natel Energy

Reducing strike and entrapment in turbines

Natel's Restoration Hydro Turbine (RHT) runners feature uniquely thick and forward-slanted blades, which enable safe through-turbine passage of fish (Amaral et al, 2020). Safe fish passage eliminates the need for fine fish exclusion screens, reducing O&M and CAPEX costs and increasing plant efficiency. RHT runners can be designed for sites with up to 35 meters (115 feet) of head and without limit on turbine diameter and have successfully been deployed both domestically and abroad.

[3] H-HOPE - Hidden Hydro Oscillating Power for Europe. Funded by Horizon Europe, Grant agreement ID: 101084362, https://cordis.europa.eu/project/id/101084362

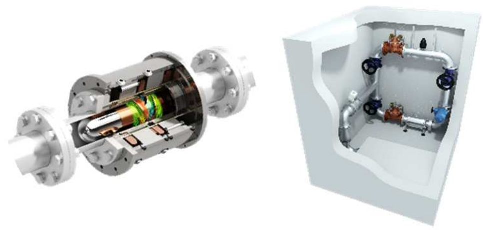


Photo Credit : HES SO Valais Wallis

Drinking water industry hides a considerable hydraulic energy potential that remains mostly unexploited for gross capacities of a few kW. **The Duo Turbo axial turbine**, (Biner et al, 2021), has been developed to harvest the energy of drinking water network. The first products of this new flexible counter-rotating turbine with variable speed can provide 5kW for a discharge of 10 l/s a head of 80m and a diameter of 100 mm.

Conclusions and Recommendations for policy makers

This white paper provides an overview on the opportunities and challenges associated with the hidden or untapped potential of existing infrastructures and provides a primer on what kind of innovations might be needed in future to fully grasp the potential of hidden hydropower.

Compared to large hydropower projects that have already been developed, hidden or untapped hydropower capacity or generation might be small for an individual project; however, its other merits are considerable, including sustainability and opportunities for coordinated and coincident infrastructure improvement. Such projects can elevate hydropower through increased contributions to global energy needs and a more rapid transition away from fossil fuels. They are also key to implementing necessary maintenance and upgrades, which ensures high performance, safety, and efficiency within the existing hydropower fleet, and they increase the overall efficiency and sustainability of necessary water infrastructures.

Hidden and untapped hydropower opportunities offer many advantages and there are a variety of demonstrated paths towards successful development and deployment. Whether refurbishments, upgrades, and operational changes at existing powered infrastructure or the addition of new generation capabilities at non-powered water control infrastructure, there are common threads required for project success. To advance in any of these opportunities, there must be coordination between various stakeholders and data owners and development of creative technical or market-based solutions to allowing for synergies with circularity and sustainability. From a policy perspective, it is critical to understand the aspects of hidden and untapped hydropower that make it a distinct category of hydropower development with unique considerations and support needs. The review of approaches used to identify and develop HUHO are a first step in this direction; additional support for research and innovation along the themes described in this white paper will be critical for connecting researchers, utilities, energy developers, asset owners, resource managers, NGOs and civil society and advancing them forward in the development process.

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