Digitizing the hydropower sector:
Trends and Barriers from D-HYDROFLEX perspective

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Funded by the European Union

D-HYDROFLEX in a glance

Starting point: September 2023

Project's budget: 4,04 M

18 Partners

3 years

7 countries

D-HYDROFLEX aims

to enhance the sustainability, flexibility, and efficiency of existing hydropower plants across Europe by leveraging digital technologies

D-HYDROFLEX will

develop a toolkit for digitally 'renovating' the existing HPPs based on sensors, digital twins, AI algorithms, hybridization modelling, cloud-edge computing and image processing.

D-HYDROFLEX outcome

- ✓ increased operational efficiency
- ✓ reduced maintenance costs
- ✓ enhanced environmental sustainability for hydropower plants

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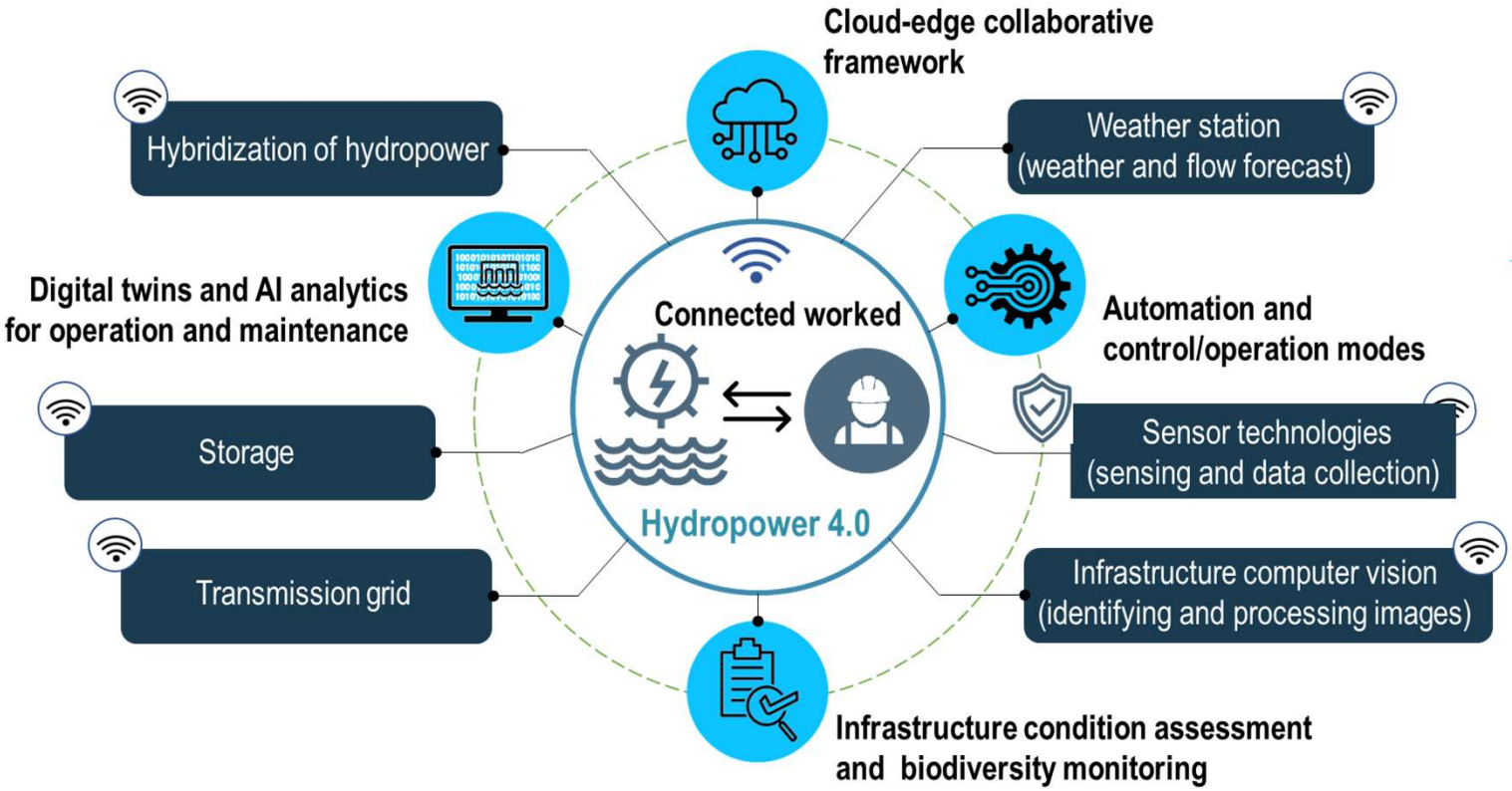
D-HYDROFLEX Vision



HOW

Design the digitalized hydropower plant of the future based on **D-HYDROFLEX Hydropower 4.0 toolkit for real-time system management and remote monitoring**

D-HYDROFLEX Demonstrators

6 hydroelectric power plants across 5 European countries

Poland, Wały Śląskie HPP

RoR, 10 MW

France, Mauzac HPP

RoR, 13.2 MW

Spain, Salto de Touro HPP

RoR, 12 MW

Romania, Bratia HPP

RoR, 1.56 MW

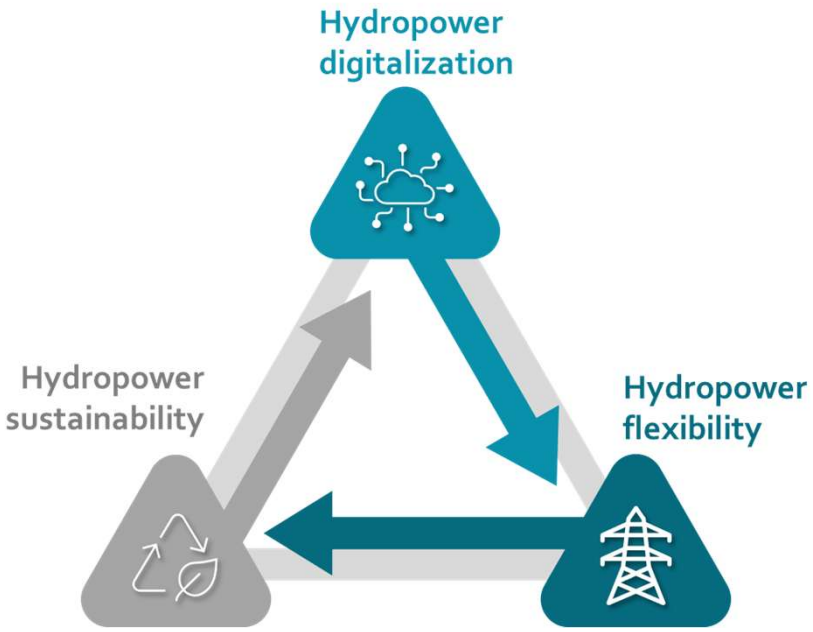
Greece, Ilarion & Platanovrisi HPPs

Impoundment, 165 & 108 MW

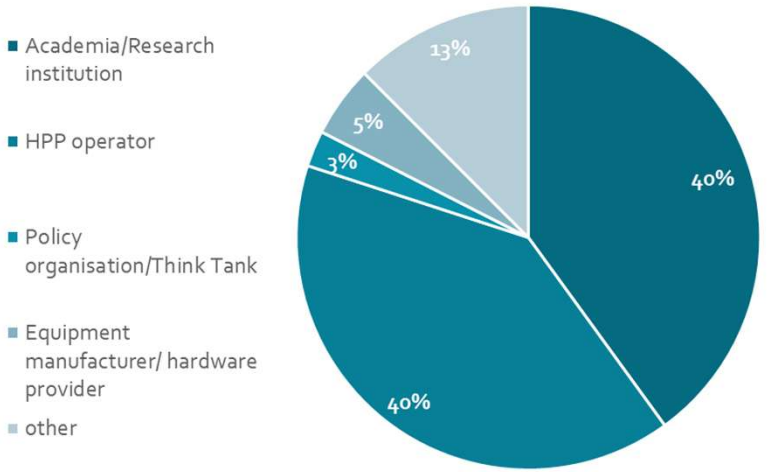
Demo use cases:

- Predictive maintenance and operational efficiency maximization in HPPs
- Hybridization of HPPs utilizing on-site hydrogen production in small HPPs
- Anomalies and intrusions detection in HPPs local networks
- Increasing HPPs' readiness for integration & operation into local smart grids
- Environmental impact monitoring in RoR plants

D-HYDROFLEX survey on trends & barriers

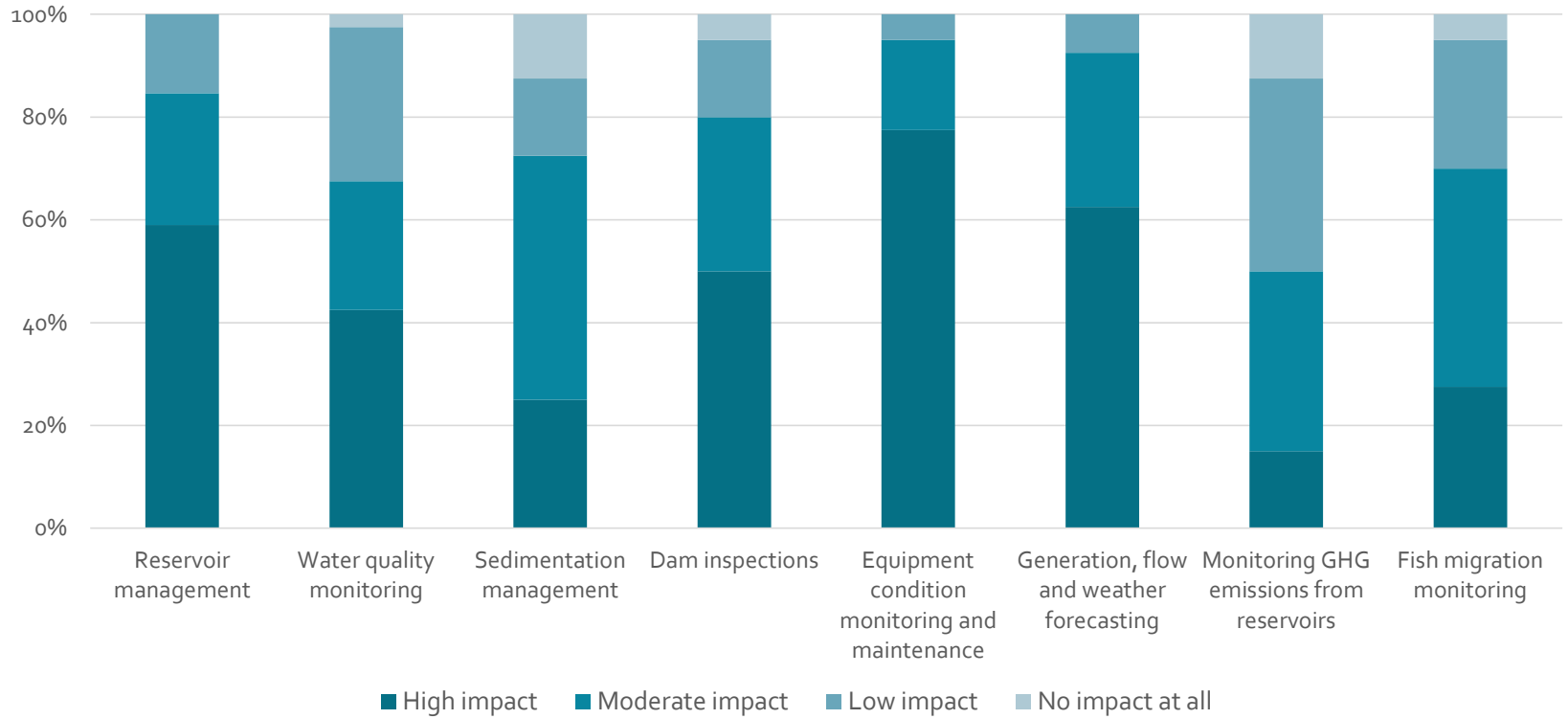


Respondent's profile



↳ 40 responses (almost half of them outside the project's consortium)

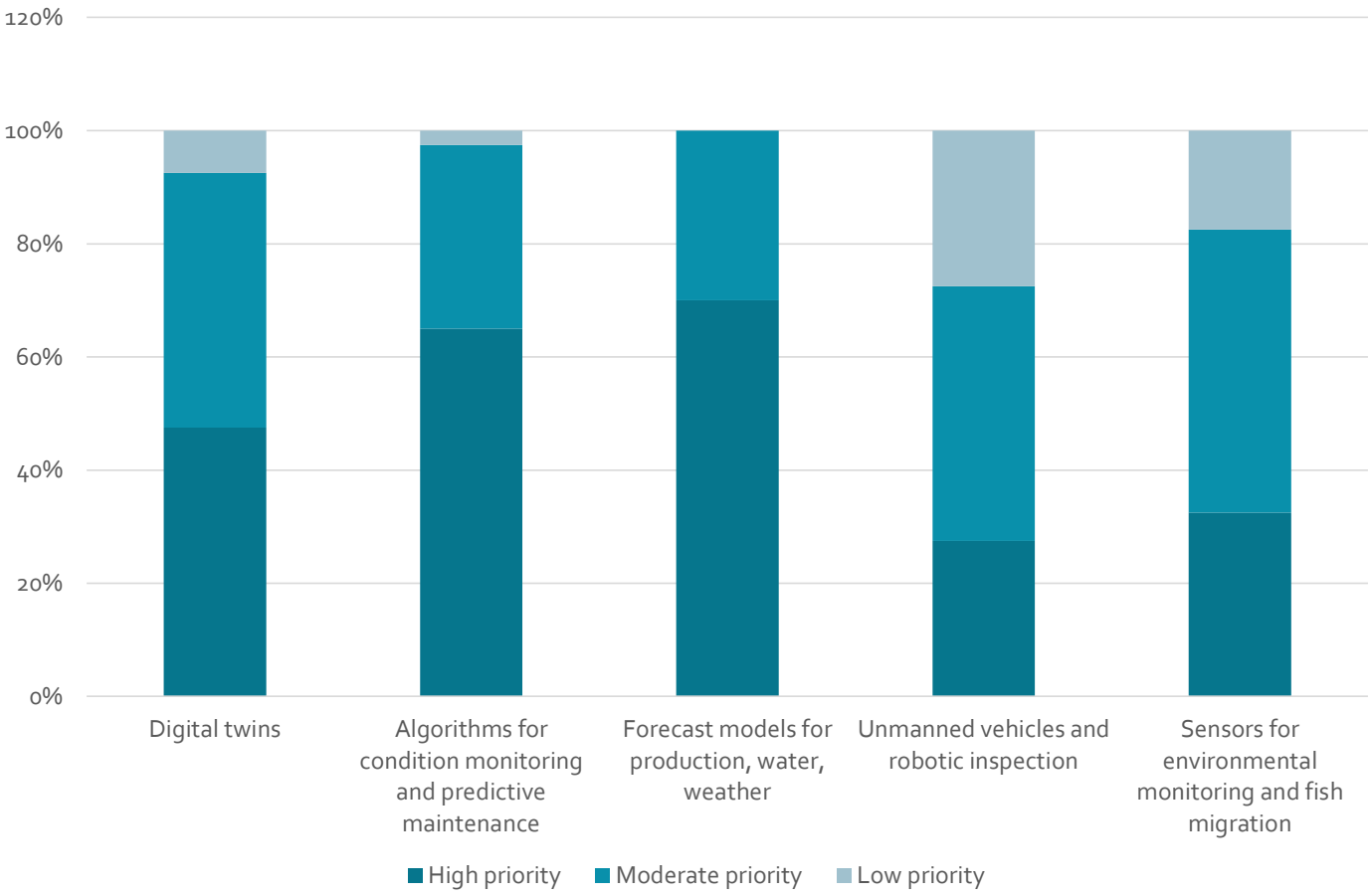
Indicate the level of positive impact that employing digital solutions will have on each of the following aspects of hydropower plants operation.



Key takeaways

- Most of the respondents (78%) consider that equipment condition monitoring and maintenance will be impacted the most.
- 60% think that generation, flow and weather forecasting and reservoir management will be highly impacted.
- Less than half believe that sedimentation management (48%) and fish migration monitoring (43%) will be impacted moderately.

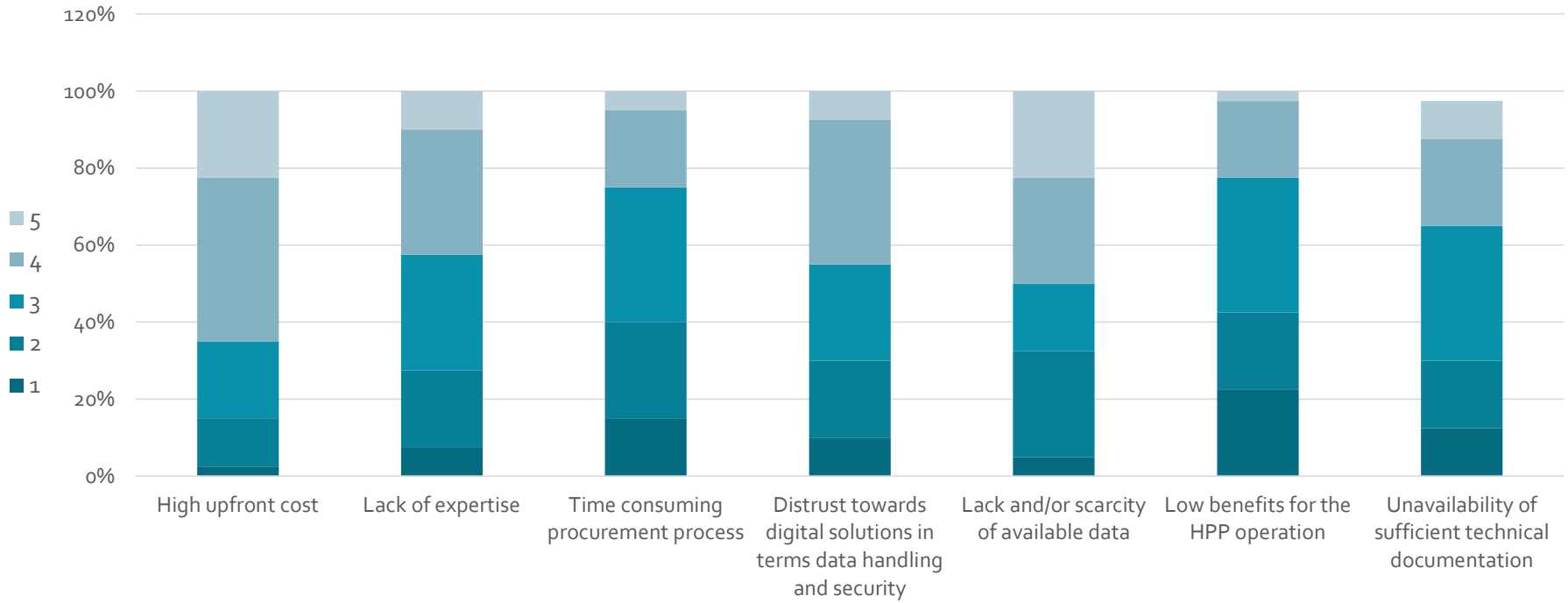
Indicate the priority level that employing emerging technologies should have for digitalising hydropower plants.



Key takeaways

- 70% of the respondents highly prioritized forecast models for production, water and weather and
- 65% highly prioritized the algorithms for condition monitoring and predictive maintenance.
- In third place in terms of priority, came the digital twins with the 48% assessing them as high priority.
- Around half of the respondents indicated unmanned vehicles and robotic inspection and sensors for environmental monitoring and fish migration as moderate priority.

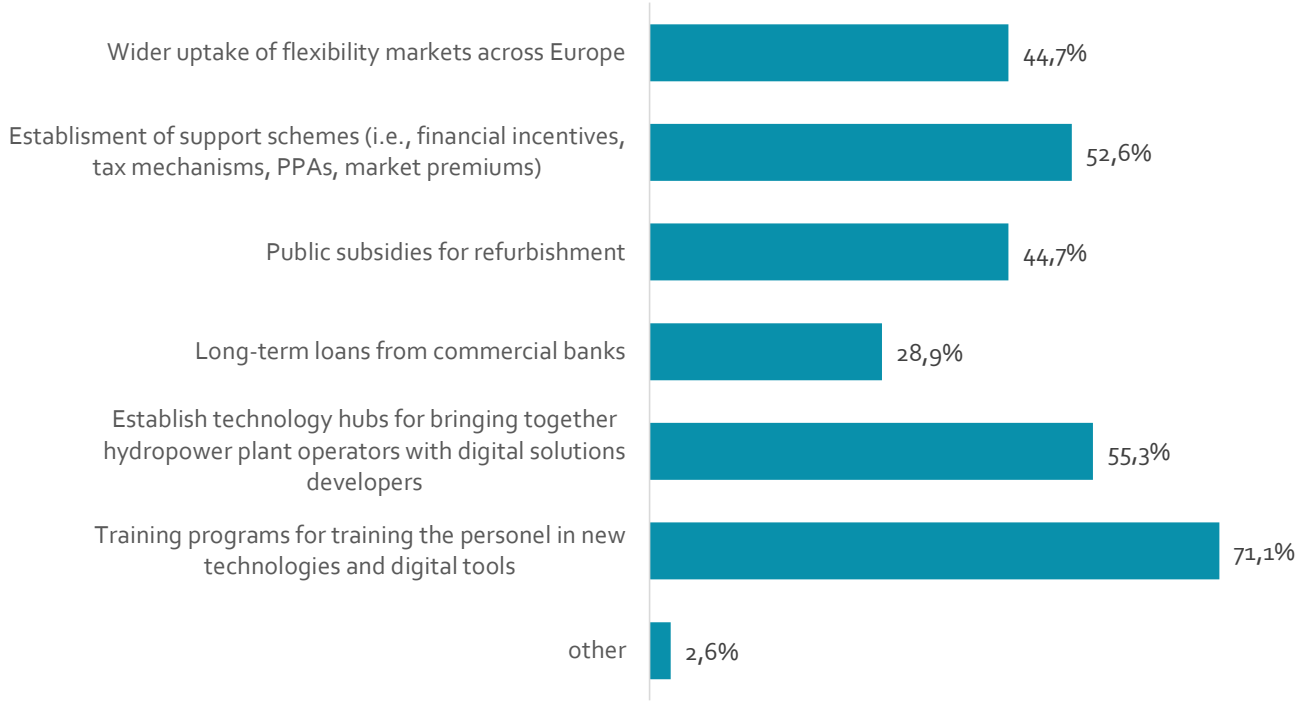
Rate the relevance of the following barriers in hindering HPP digitalization from 1-5, where 1 means not relevant and 5 extremely relevant.



Key takeaways

- High upfront cost seems to be the most relevant for respondents with 66% rating it in the scale of 4 and 5.
- Lack of expertise and distrust towards digital solutions in terms data handling and security are rated as relevant mostly in the scale of 4 and 3
- Time consuming procurement processes, low benefits for the HPP operation and unavailability of sufficient technical documentation are mostly rated as relevant in the scale of 3 and 2.

Which of the following measures you think that can be more effective in incentivising hydropower plants digitalization and refurbishment?

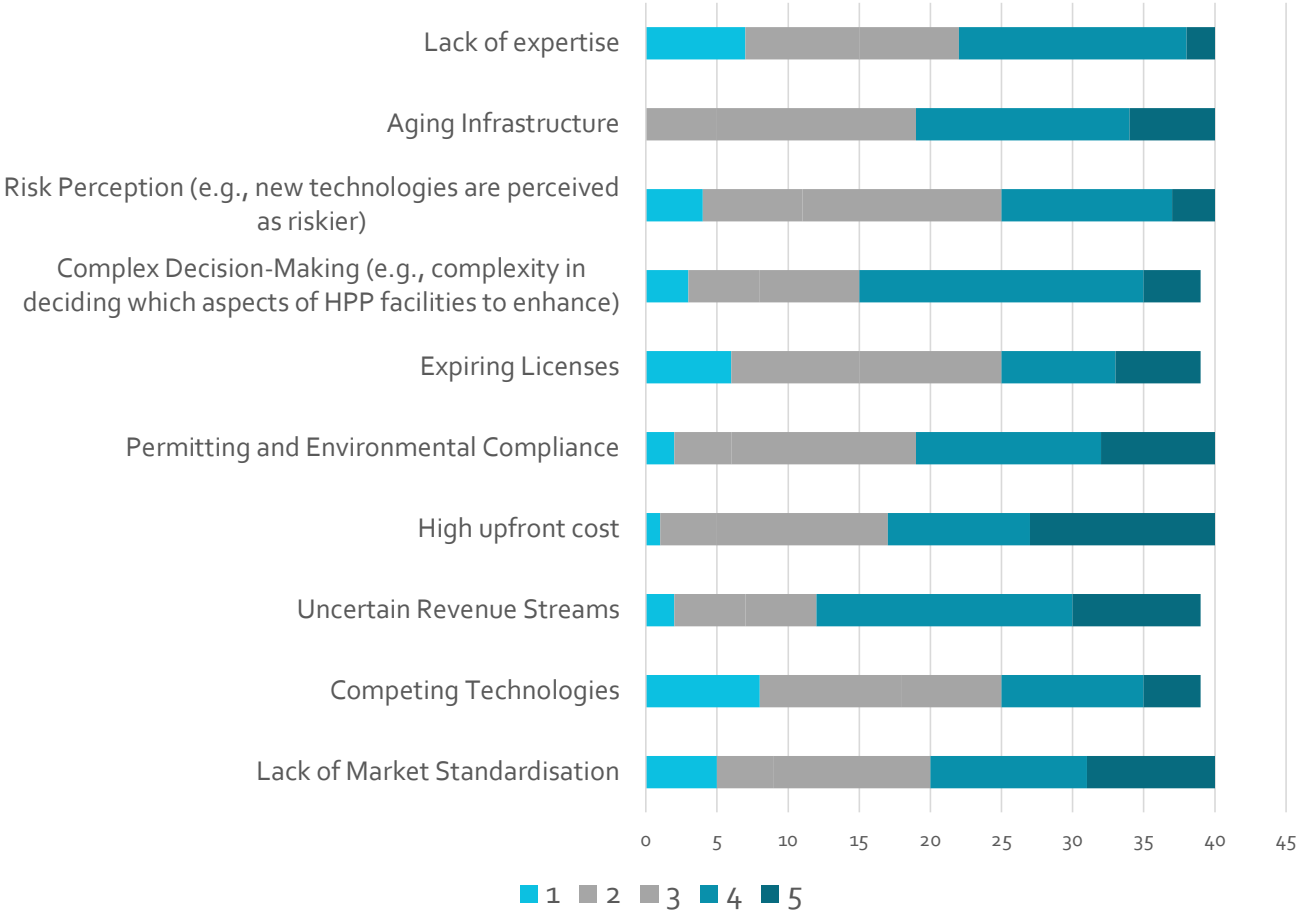


Key takeaways

- Training personnel in new technologies, was the most voted measure deemed as effective in incentivising plants' refurbishment (71.1%)
- 52.6% indicated the establishment of support schemes such as tax incentives and market premiums, while 55.3% the establishment of technology hubs for bringing together HPP operator and IT providers.
- Long-term loans from commercial banks, was the least voted measure.

Rate the barriers hindering the deployment of hydropower flexibility technologies from 1-5, where 1 means not important and 5 means extremely important.

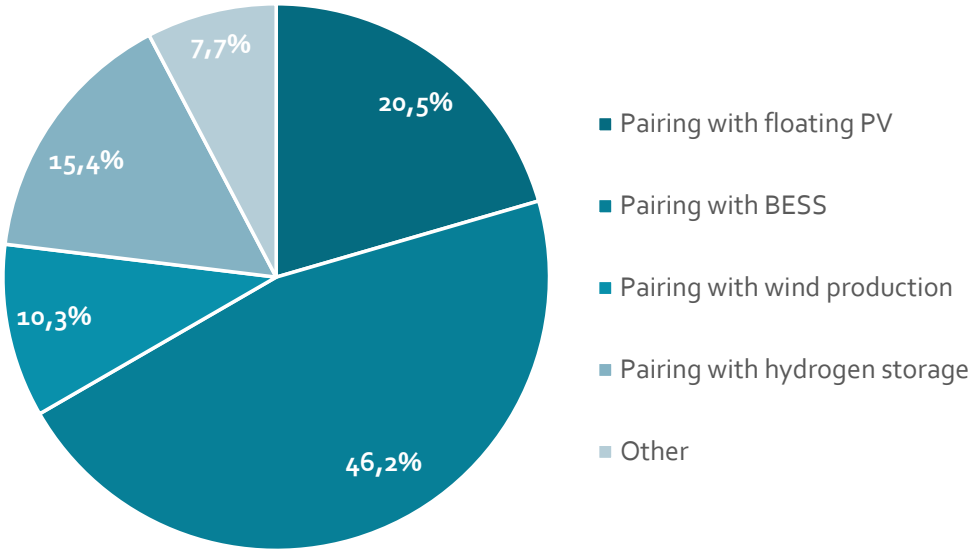
** hydropower flexibility technologies (i.e., technologies that allow more flexible generation and operation such as hybridization with H_2, turbine digital twins, real-time monitoring)*



Key takeaways

- 51% of the respondents indicated the complex decision-making, 46% indicated the uncertain revenue streams and 40% the lack of expertise as important in the scale of 4.
- 33% rated permitting and environmental compliance in the scale of 3-4,
- 38% rated aging infrastructure in the scale of 4 and
- 35% rated the risk perception in the scale of 3.
- Lack of market standardisation, competing technologies and expiring licenses are rated as less important by the respondents compared to the other barriers.

Which of the following hybridization concepts of hydropower you consider that will have the highest growth in the next 5 years?



Key takeaways

- almost half of the respondents indicated pairing with battery energy storage systems (BESS) as the hydropower hybridization concept that will have the highest growth in the next 5 years
- 20.5% pairing with floating PV
- 15.4% indicated the pairing with hydrogen storage and 10.3% the pairing with wind production
- 7.7% indicated other hybridization trends such as hydro storage with two reservoirs, reversible pumping-storage plants and small scale, modular Pump as Turbine (PaT) plants.

Indicate best practices that can be adopted to ensure the sustainability of a hydropower plant's operation.

- Use of **predictive tools** and regular testing and **maintenance** of devices, regular inspections and maintenance of equipment
- **Digitalization of processes** and implementation of advanced monitoring systems for optimal management of the HPP
- Monitoring, maintenance and forecast of generation to maintain ecologic flow and to **optimize water usage**
- Introduction of fish passages, **fish migration monitoring,** temperature and salination monitoring.
- **Adaptation of the HPP operation** with the evolution of the environmental conditions of the river (global change, river discharge, water temperature)
- **Lower environmental impact** by increasing the flexibility of the production, pairing with renewable energy,
- Finding a good **cooperation between operator and NGO´s** regarding environmental needs
- Establishing **relationship with local communities** near the powerplants engaging in continuous stakeholder communication

Thank you!

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D-HYDROFLEX

D-HYDROFLEX project has received funding from the European Union's HORIZON Research and Innovation Action under Grant agreement No 101122357

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D-HYDROFLEX Toolkit & Reference Architecture

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Agenda

- D-HYDROFLEX Pillars and Objectives
- D-HYDROFLEX Concept and Domain Model
- D-HYDROFLEX Toolkit
- D-HYDROFLEX Reference Architecture

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D-HYDROFLEX Objectives

Design the digitalized hydropower plant of the future based on **D-HYDROFLEX Hydropower 4.0 toolkit for real-time system management and remote monitoring** that will support plant operators in participating to wholesale power markets and will increase the efficiency of the plant operation.

Develop **IoT and digital twin technologies**, as well as **AI-based techniques for data ingestion, analysis, advanced hydro power production, weather and flow forecasting**, that will increase the cost-efficiency and operational efficiency of HPPs and facilitate their optimal hybridization with other RES and hydrogen gas

Develop **novel sensor-based modelling** and **image processing algorithms** that will reduce the HPPs' impact on fish migratory species, minimizing their environmental impact and increasing their sustainability

Introduce and test **AI-based intrusion detection and explainability techniques** for detecting and discriminating various kinds of cyberattacks and anomalies in hydro-energy operational environments, ensuring both confidentiality of data and openness of IT solutions, while increasing the reliability and resilience of the future digitalised hydro plants

Demonstrate the **applicability and value of the D-HYDROFLEX Hydropower 4.0 toolkit** through industrial and real-world applications across Europe, being evaluated in different climatic zones, operating conditions and hydro generation capacity volumes

D-HYDROFLEX Pillars

Flexibility

- Optimized operation planning
- Hydropower plant hybridization
- Energy/hydrogen production forecasting and modeling

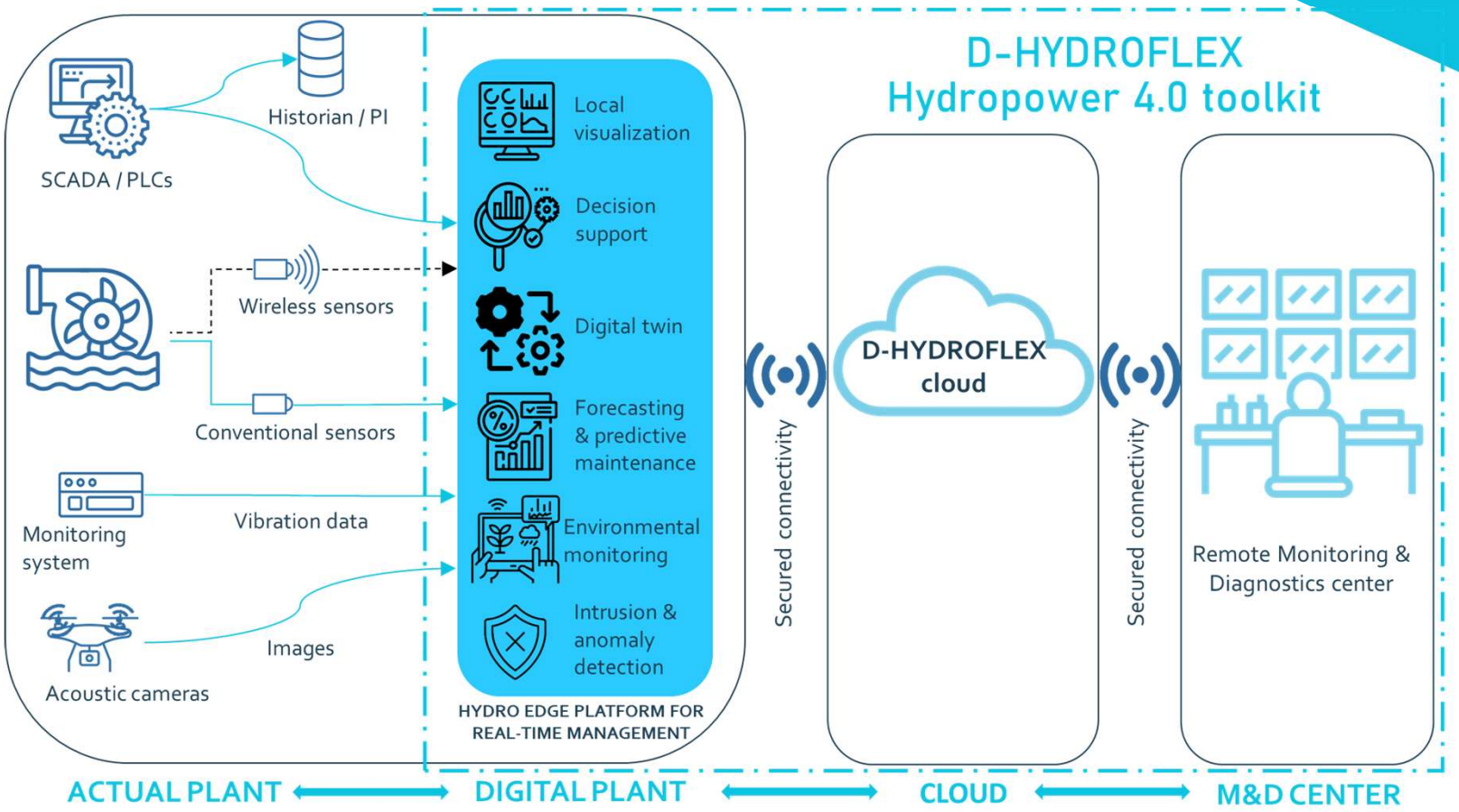
Digitalization

- Digital twin technology
- Predictive maintenance algorithms
- AI analytics and image processing
- Smart sensoring
- Intrusion Detection System

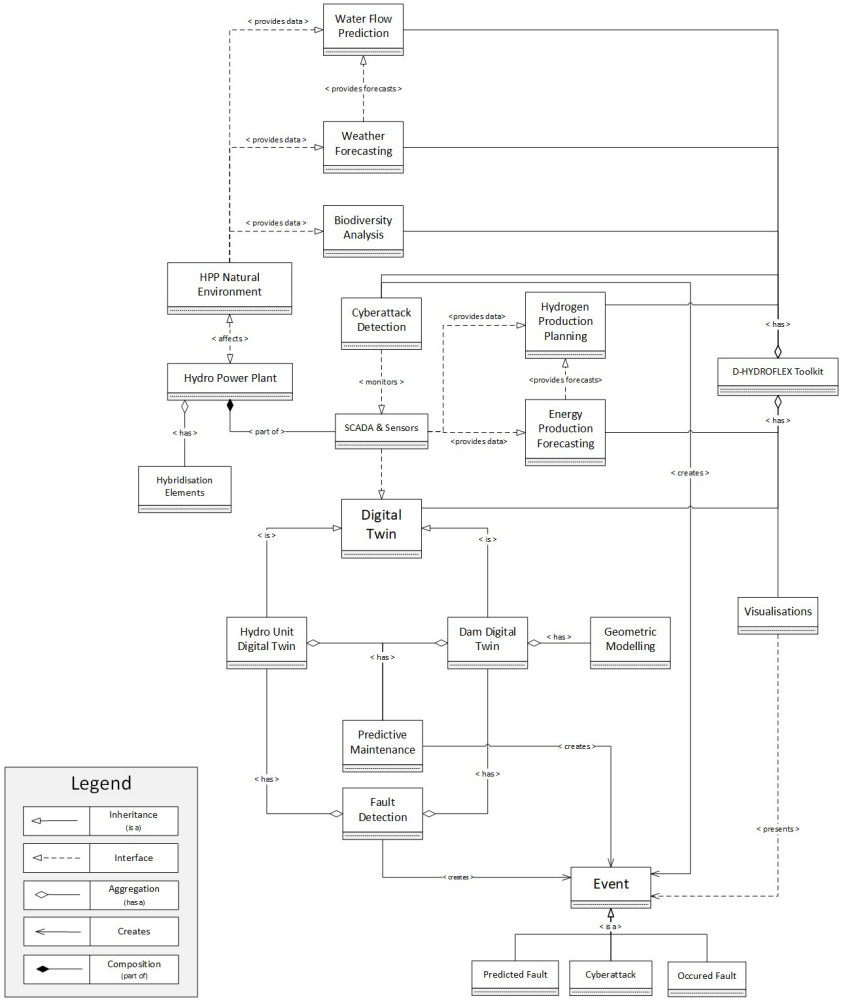
Sustainability

- Biodiversity monitoring
- Environmental indications monitoring

D-HYDROFLEX Concept



D-HYDROFLEX Domain Model



D-HYDROFLEX Toolkit

Hydro Unit Digital Twin Framework

HYDRO-TIN

- Provides numerical data for operational parameters (e.g., water level, turbine rotational speed, turbine blade angles)
- Provides efficiency metrics for turbine operation

HYDRO-HMP

- Processes real-time and historical hydrological data (e.g., flow rate, rotational speed)
- Provides predictive analytics and real-time conditions

HYDRO-PVIL

- Processes vibrational and temperature data
- Provides vibration analysis, anomaly detection, and predictive maintenance insights

HYDRO-VIS

- Visualization data for hydro unit performance (hydrological forecasts, CFD simulations, etc.)

D-HYDROFLEX Toolkit

Dam Digital Twin Framework

HYDRO-DAM

- Processes geometric data, foundation data models
- Generates a digital twin of the dam infrastructure
- Facilitates the monitoring of dam's physical components.

HYDRO-GDDT

- Processes different data modalities such as point clouds, color images, and thermal images.
- Provides the dam as-is geometry and the spatial relationship between dam objects.

D-HYDROFLEX Toolkit

Predictive Maintenance and Operational Efficiency Maximization

HYDRO-Predict

- Processes data such as temperature, generated power and operational parameters.
- Detects and predicts potential failures of different HPP components.

HYDRO-DEFM

- Processes turbine performance data and generated power.
- Predicts the amount of produced electrical energy, considering turbine aging.

D-HYDROFLEX Toolkit

Forecasting and Decision Support for HPP Hybridization

HYDRO-H2DSM

- Processes data such as turbine flow, generated power, mean water level, and data related to H2 and other fuels.
- Predicts the amount of hydrogen that could be produced and creates a decision support plan on when to produce it.

HYDRO-SDS

- Processes data from SCADA systems, and parameters of hybridization elements such as PV or electrolyser.
- Simulates and predicts plant performance and energy efficiency balance.
- Provides recommendations on energy hybridization decisions.

HYDRO-WFF

- Processes real-time and historical meteorological data, topographical data, and runoff river historical data.
- Provides forecasts for the water flow at the HPP river

D-HYDROFLEX Toolkit

Biodiversity Monitoring

HYDRO-RecoFish

- Processes acoustic video for fish identification, via computer vision methods.
- Provides automatic counting and identification of fish species.

Cyber-shielding

HYDRO-FBOX

- Processes network traffic of the industrial networking infrastructure (e.g., network traffic in PLCs).
- Detects cyber attacks and anomalies on the networking infrastructure of the HPP.

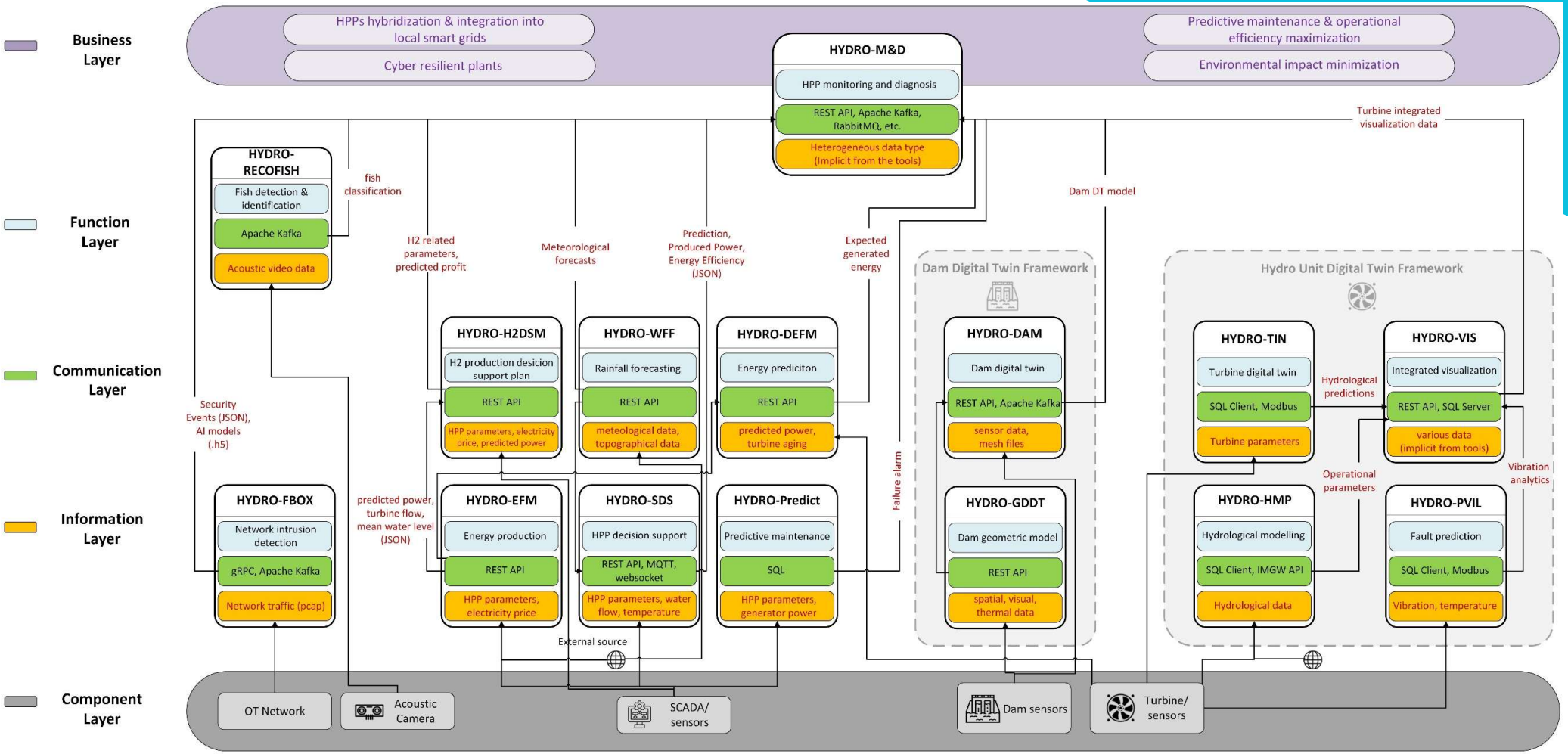
D-HYDROFLEX Toolkit

Remote Monitoring and Diagnostics Center

HYDRO-M&D

- A web-based dashboard that integrates D-HYDROFLEX tools.
- It aims to unify the output of the D-HYDROFLEX tools and provide a central reference point for HPP operators to get real-time insights about the overall HPP operation and status

D-HYDROFLEX Reference Architecture



Thank you!

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Digital maintenance for sustainable and flexible operation of HYDROpower plant

Di-Hydro project: Digitalization Solutions and Tools

Alkiviadis Tromaras, CERTH

18/02/2024

D-Hydroflex webinar series #1

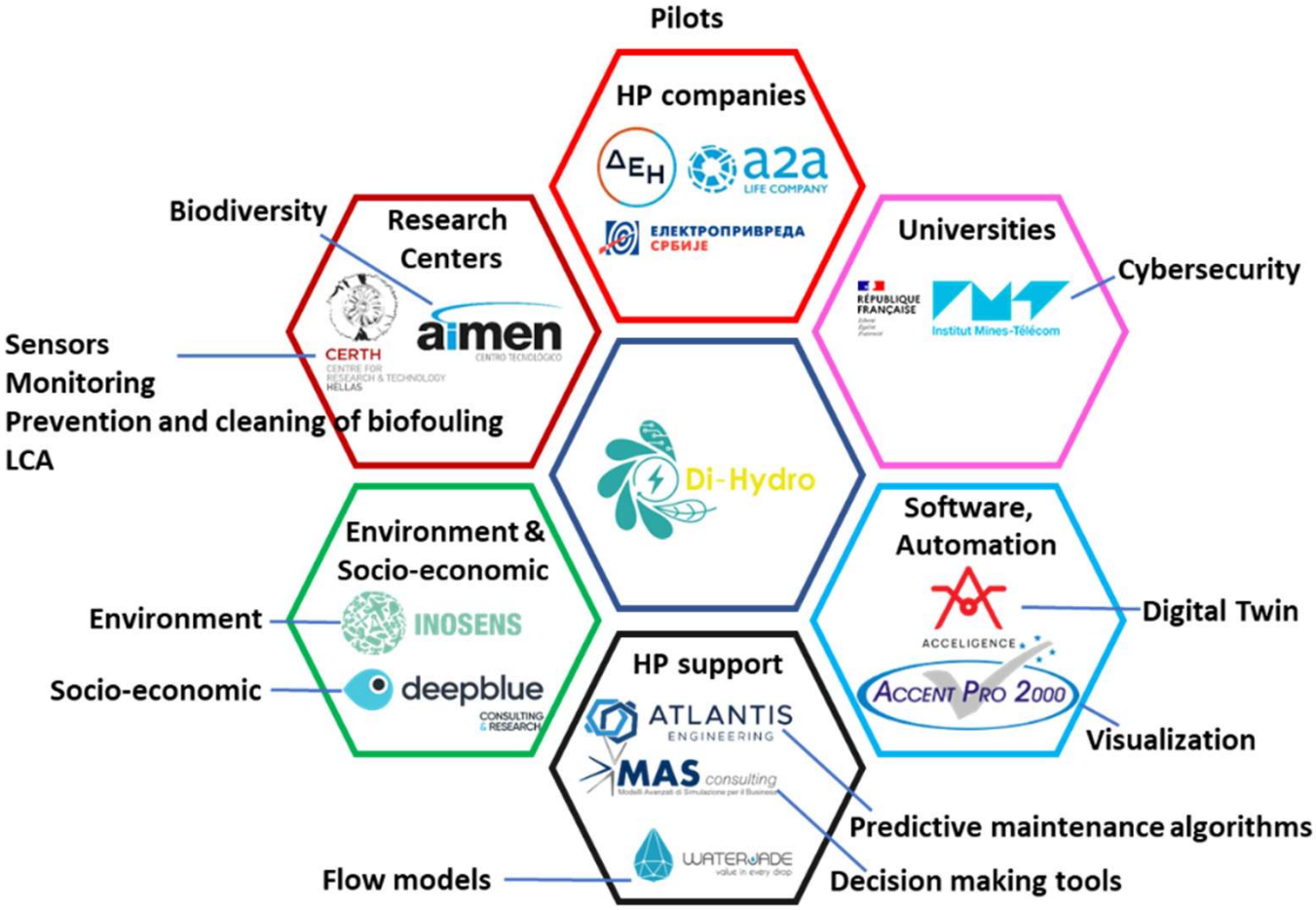
This project has received funding by the European Union's Horizon Europe research and innovation programme under Grant Agreement N° 101122311

GENERAL PROJECT INFORMATION

PROJECT DURATION
36 months - from 1/10/2023 to 30/09/2026

BUDGET
~ 4.5 M €

PARTNERS
13 partners



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Main aims and objectives

MAIN THEME

Digitisation of O&M for hydropower plants & clusters

MAIN OBJECTIVES

1. **Develop practical solutions**, for HP plants and clusters across the EU, regardless of their digitisation level

2. **Combine innovative sensor technologies and digital adaption** for energy production

3. **Create *Digital Twins*** and a **Decision-Making Tool** for HPPs by combining :
   - Historical data
   - Sensory data
   - AI based weather and/ water flow, environmental, biodiversity modelling and forecasting
   - Socioeconomic parameters

4. **Optimise O&M practices** based on cutting-edge information technologies

5. **Assist HP companies to plan and manage production**, based on foreseen needs and their intended commercial strategy

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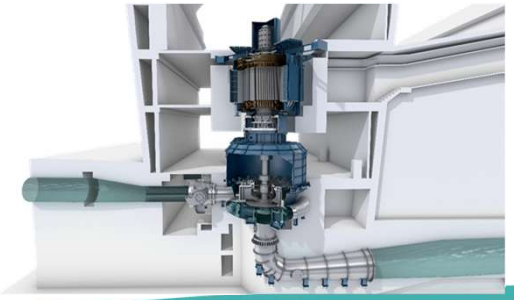
What is digitization in the Hydropower sector

Digitisation can be multifaceted in the hydropower sector

Digital technologies (sensors, connected devices, network equipment, infrastructure and systems) that can reduce cost or may change a company's business model that may create new revenue streams.



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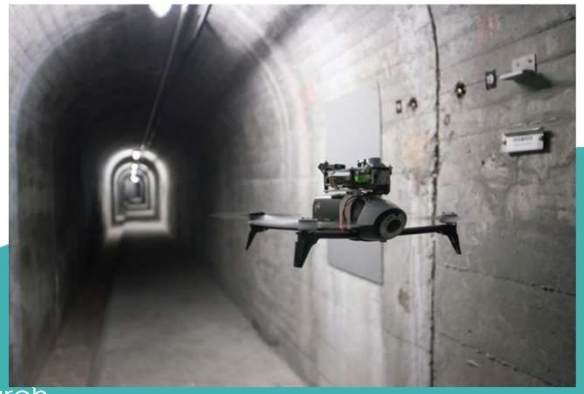
What is digitization in the Hydropower sector

What does digitisation include?

- Digital Twins
- Inflow forecast modelling
- Condition monitoring/Predictive maintenance
- Real time KPI monitoring
- Augmented and virtual reality
- Unmanned vehicles and robots
- Environmental monitoring
- Digital solutions for fish monitoring
- Cybersecurity
- Digital workforce management



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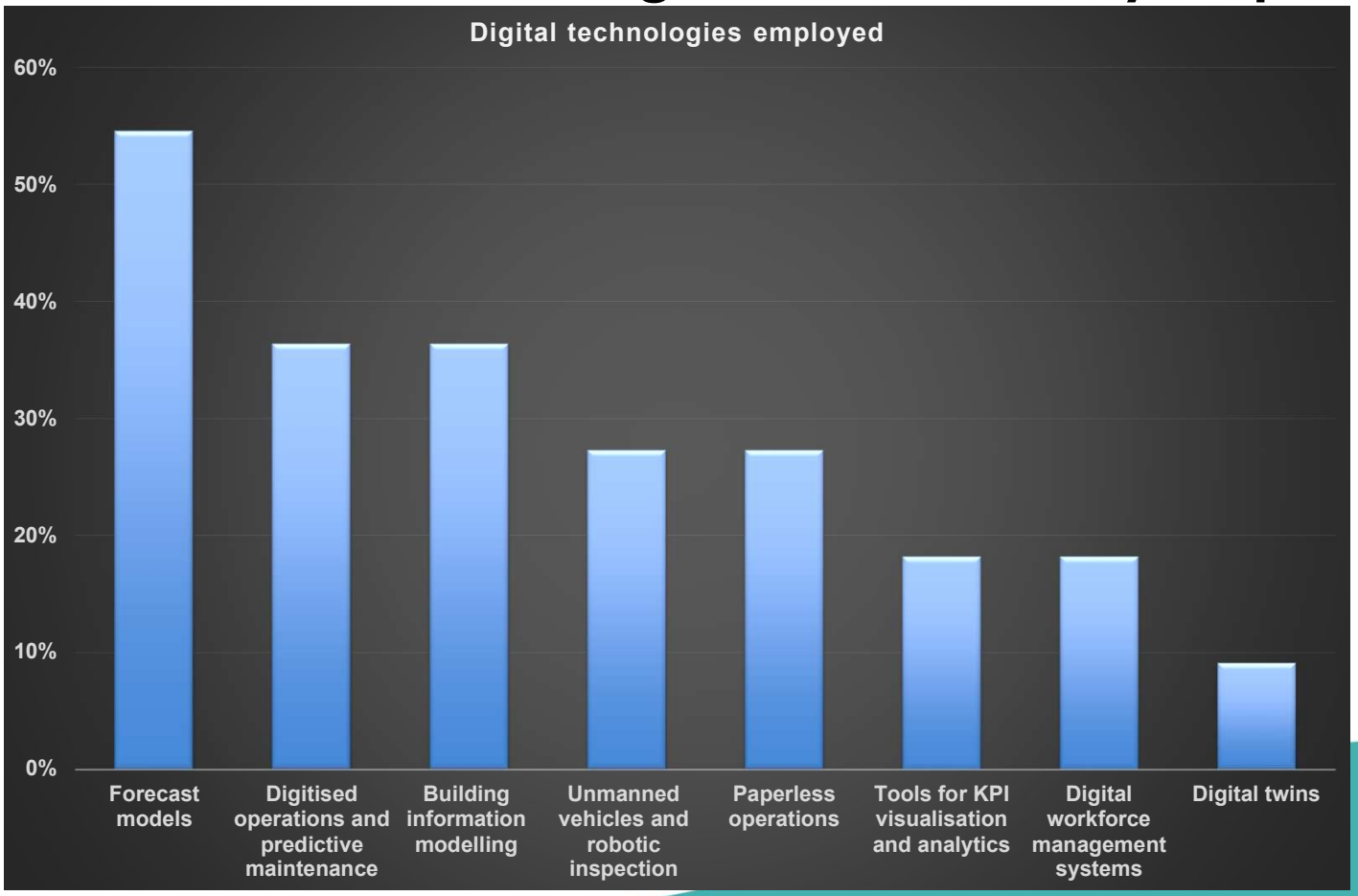
Digitisation in the hydropower sector



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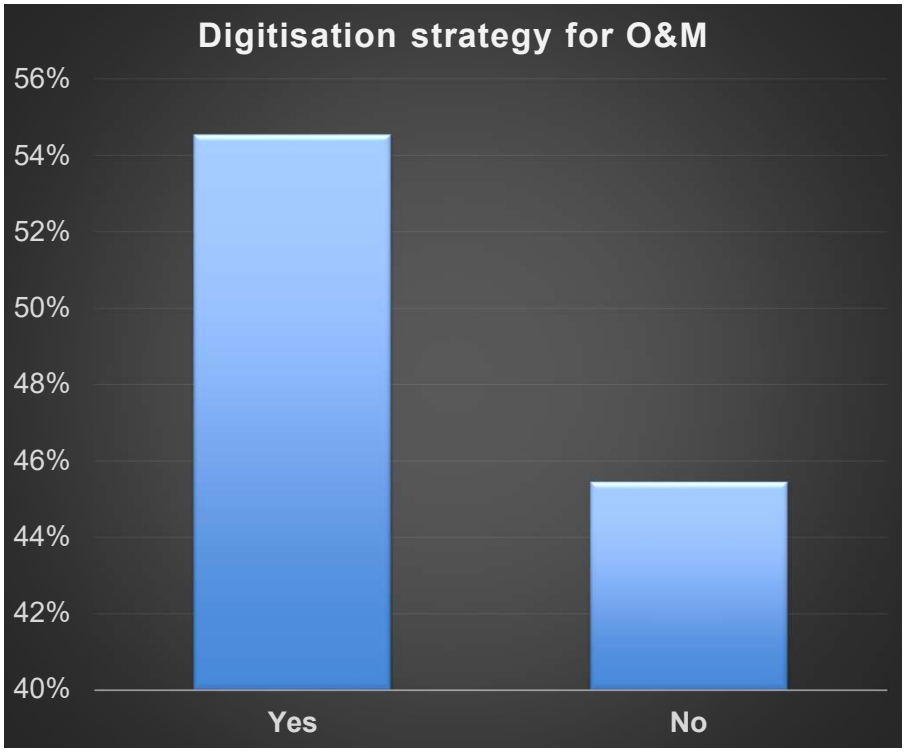
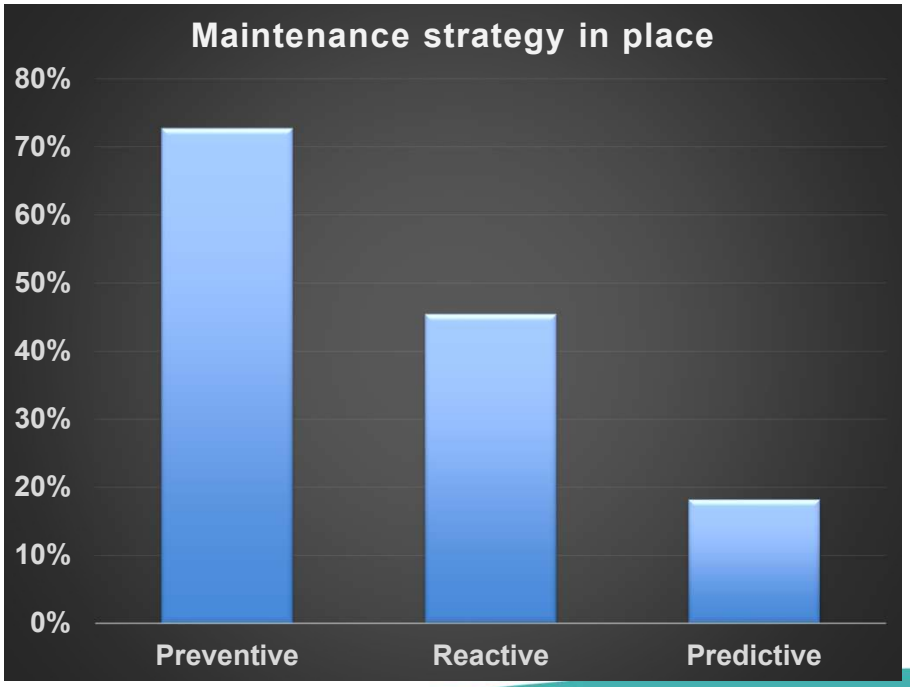
Digitisation in the hydropower sector





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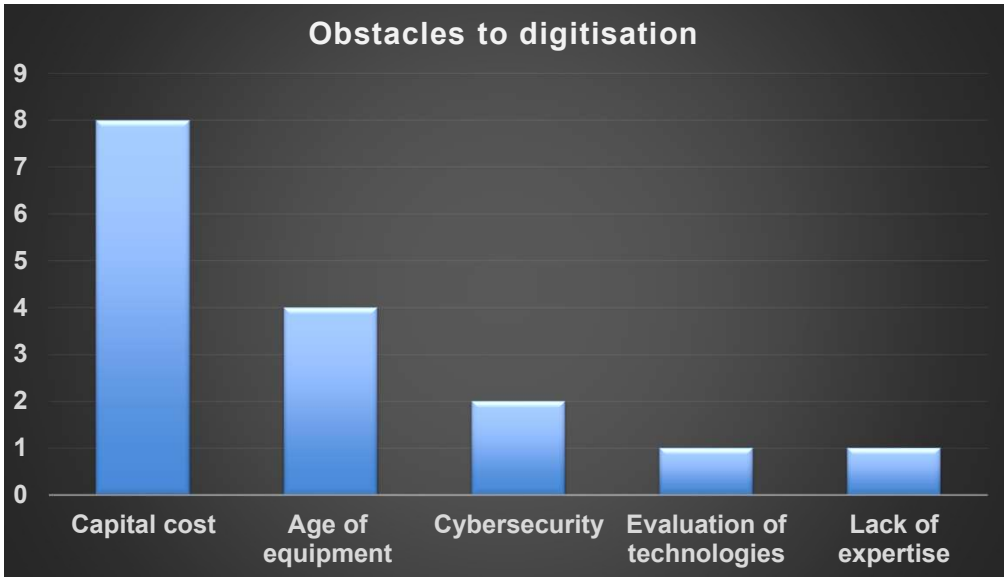
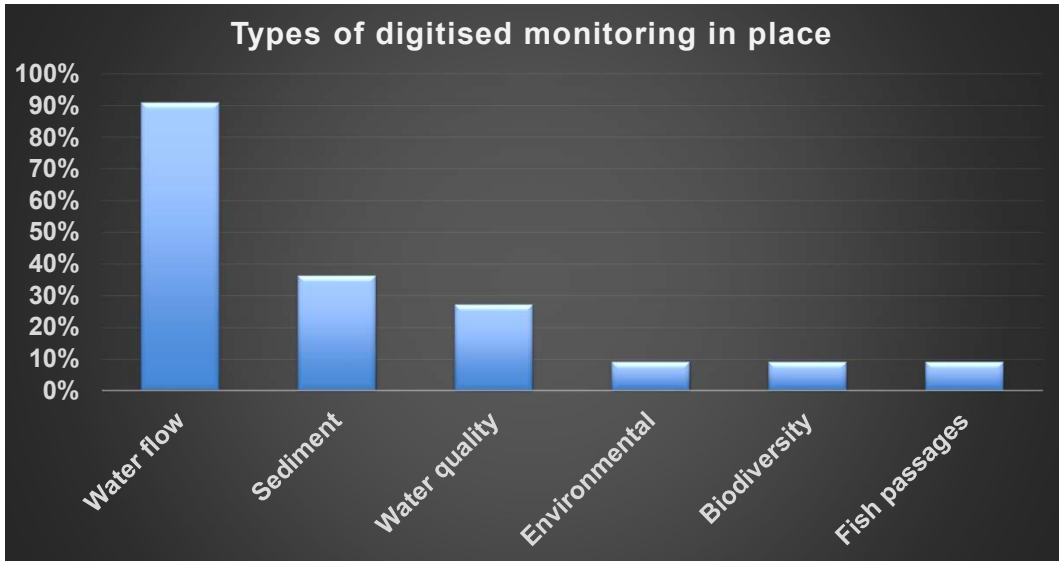
Digitisation in the hydropower sector





Which of your operations remain purely manual/ non digitised that are critical and you would like to automate?

- Water flow is not properly monitored.
- Forecasting still requires better accuracy probably due to less accurate inflow monitoring.
- Solutions for trash rack monitoring.
- Digitisation of analogue gauges and automated readings.

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Main technical issues respondent HPPs faced in the last 5 years

- **Failures in hydraulic turbines, electrical generators, protection and control systems**
- **Failures** in hydraulic structures **due to severe weather** events
- Inflow forecast
- Mechanical **failures due to aging** of equipment, bearings, generator, etc
- **Downsizing of turbines due to the recurring drought**s and lower reservoir levels
- Silt
- Deposit of unwanted material between interfacing areas which restricts movement
- **Changing automation** systems
- **Obsolete technologies** which render less support from suppliers.

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Main technical issues respondent HPPs faced in the last 5 years

- Material savings in the electrical equipment which leads to localised heating and shortened life of equipment
- Penstock creep, **malfunction of safety** equipment
- Mechanical problems to the generator's components
- **Premature wear** of the bushings that regulate the position of the turbine blades and dirt accumulated in the alternator windings
- **Environmental impacts**
- Vibration and cavitation
- **Lack of automation**
- Natural disaster
- Civil work infrastructure failure

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Use Case 1 - *Greece*

Application of Di-Hydro DT and integration in HP digital cluster. Calibration of Di- Hydro Decision Making Platform for HPPs and cluster

- Structural Health Monitoring- Condition Monitoring of machinery: Development and installation of sensors nodes
- Predictive algorithms for HP O&M
- Creation of plant replica (DT) and display of real time data from sensors and existing digitised equipment and telemetry
- Biofouling prevention using ultrasonic probes
- Unmanned underwater drone inspection and M/L for automatic detection.
- Creation of HPP grid communication cluster
- Calibration of Decision Support Tool

Ilarionas HPP

Capacity: 155 MW
Turbines: 2x Francis

Thisavros HPP

Capacity: 375 MW
Turbines: 3x Francis
Pumped storage type plant

Pournari I HPP

Capacity: 300 MW
Turbines: 3x Francis

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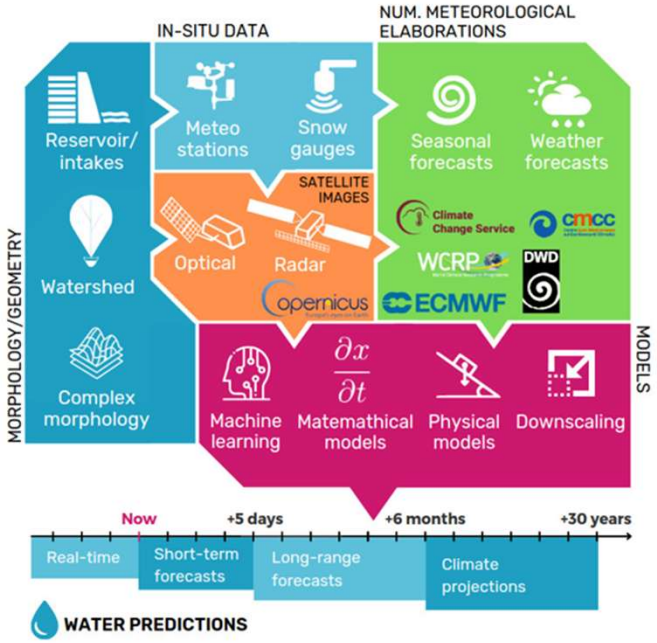
Use Case 2 - *Italy*

Inflow forecasts at flexible lead-times according to meteorological evolution in the upstream catchment.

- Collection of historical data
- Digitize all the components of the water cycle of the catchment area (Sauris and Verzegnis lake)
- Installation of flow meter sensors
- Weather and water flow predictive AI-based modelling and forecasting
  - Short-term forecasts +5 days
  - Long-term forecasts + 6 months

Ampezzo and Somplago HPPs

Total capacity: 235 MW
Turbines: 3x Pelton -Ampezzo,
3x Francis - Somplago



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Use Case 3 - *Serbia*

Development and implementation of a digital sensor-based real-time water quality monitoring system (with early warning)

- Collection of historical data
- Development of sensors for biodiversity and environmental monitoring

Međuvršje HPP

Capacity: ~10 MW
Turbines: 2x Francis, 1 Kaplan

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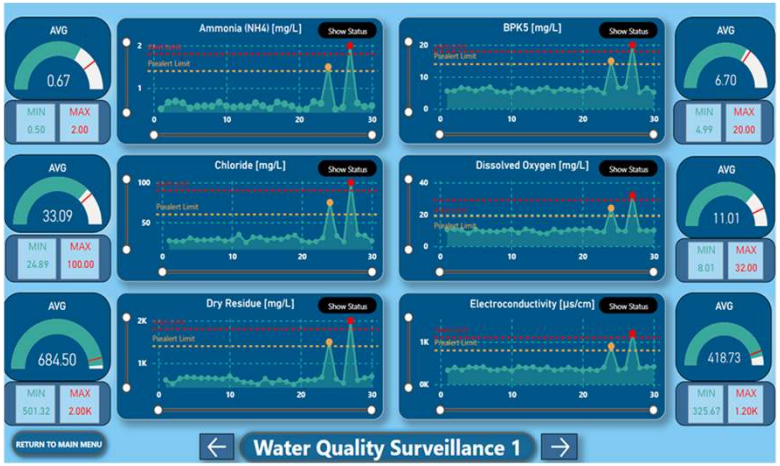
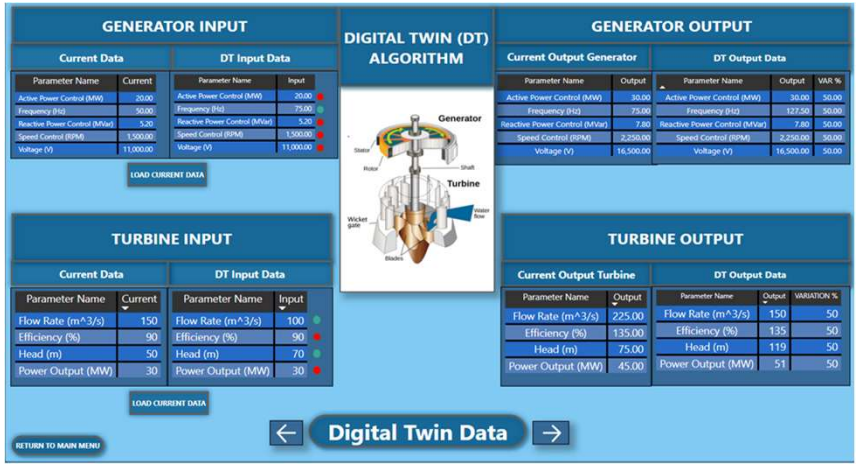
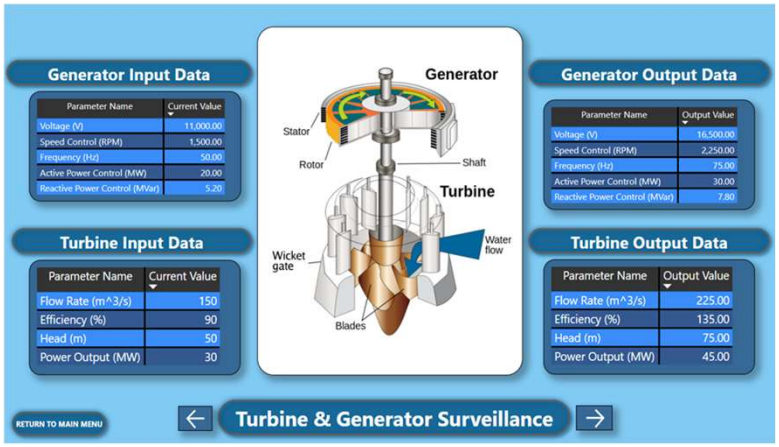
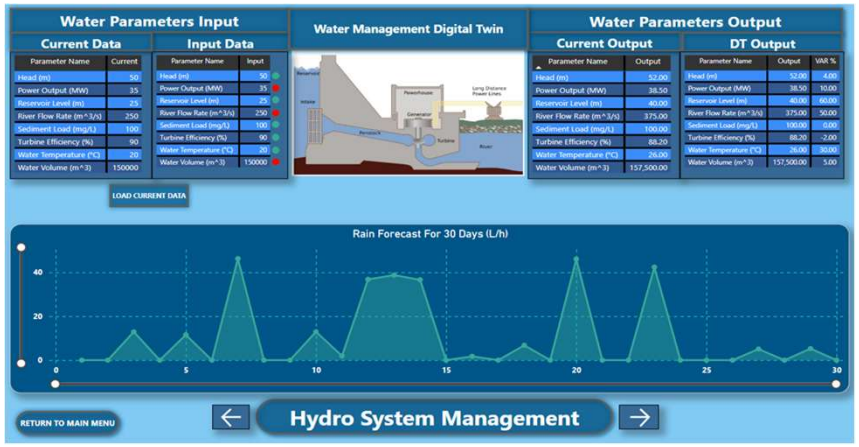
OPERATOR VISUALIZATION TOOL EXAMPLES

- ✓ Scalable
- ✓ Built in PowerBI
- ✓ Data Server Interrogation
- ✓ Forecast Visualization
- ✓ Digital Twin
- ✓ Database Compatible (Azure, SQL, .csv file)
- ✓ Flashing Warnings
- ✓ Big Size Screens
- ✓ Data Auto Refresh









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DIGITAL USER MANAGEMENT LEVEL

Di-Hydro DECISION MAKING PLATFORM

DT Data

ML Results

HPP DIGITAL TWIN LEVEL

- Ilarrionas Kozani Digital Twin
- Thissavros Dramas Digital Twin
- Pournari Artas Digital Twin
- Sauris Lake Digital Twin
- Verzegnis Lake Digital Twin
- Novarza Dam Digital Twin
- Međuvršje HPP Digital Twin

Raw Data

ML Models

HPP DIGITAL INTRASTRUCTURE LEVEL

HPP Cluster

Ilarionas HPP Kozani, Greece

Thissavros HPP Drama, Greece

Pournari HPP Arta, Greece

Ampezzo HPP Sauris Lake, Italy

Somplago HPP Verzegnis Lake, Italy

Novarza Dam, Italy

Međuvršje HPP Međuvršje, Serbia

HPP PHYSICAL INFRASTRUCTURE LEVEL

- *BioFouling prevention probes*
- *SHM/CM sensors*
- *Underwater inspection drone*
- *Water Flow and Level sensors*
- *Environmental and Biodiversity sensors*

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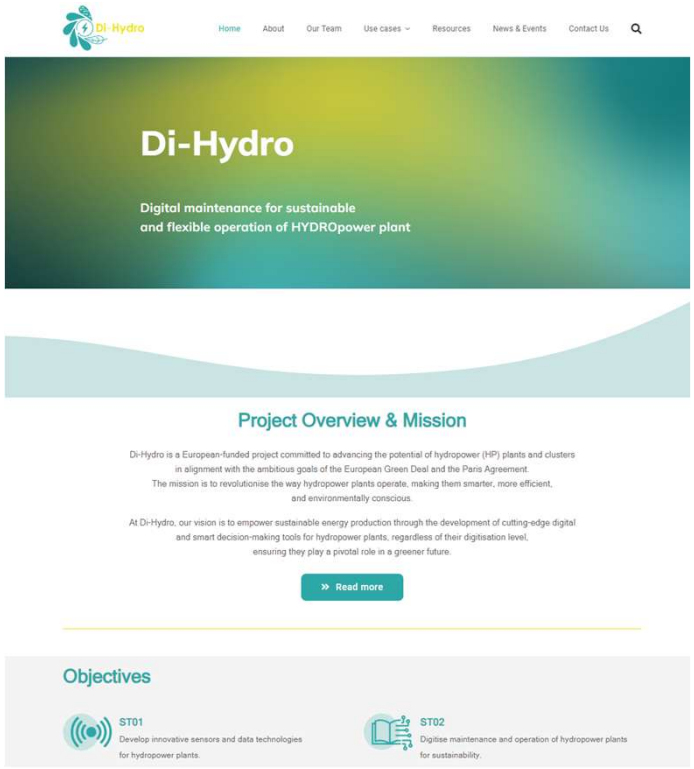

This project has received funding by the European Union's Horizon Europe research and innovation programme under Grant Agreement N° 101122311

Di-Hydro

Digital maintenance for sustainable and flexible operation of HYDROpower plant

Thank you.

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