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Location: Online

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ETIP Hydropower

Boosting hydropower with good practices for research

Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

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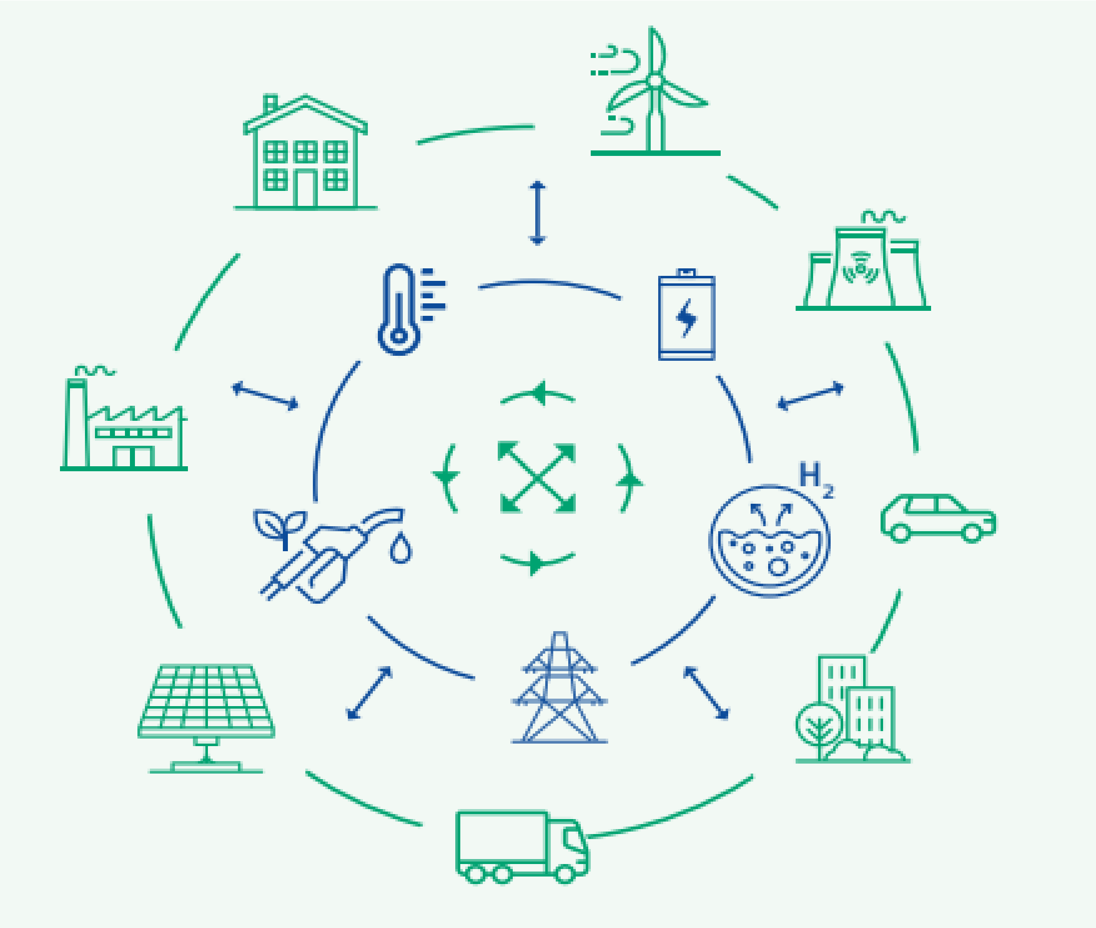
Introduction

Digitalisation of the energy system

- EU electricity sector undergoing a fundamental change with the increase of digitalisation
- Digitalisation means embedding sensors, data collection and amassing big data resources for the optimisation of energy systems
- EU's digital strategy aims to achieve its target of a climate-neutral Europe by 2050
    - Investing €250 billion to boost digitalisation
    - Improving the way we use energy
    - Supporting decarbonising of energy systems
    - Infrastructure fit for the future



Introduction

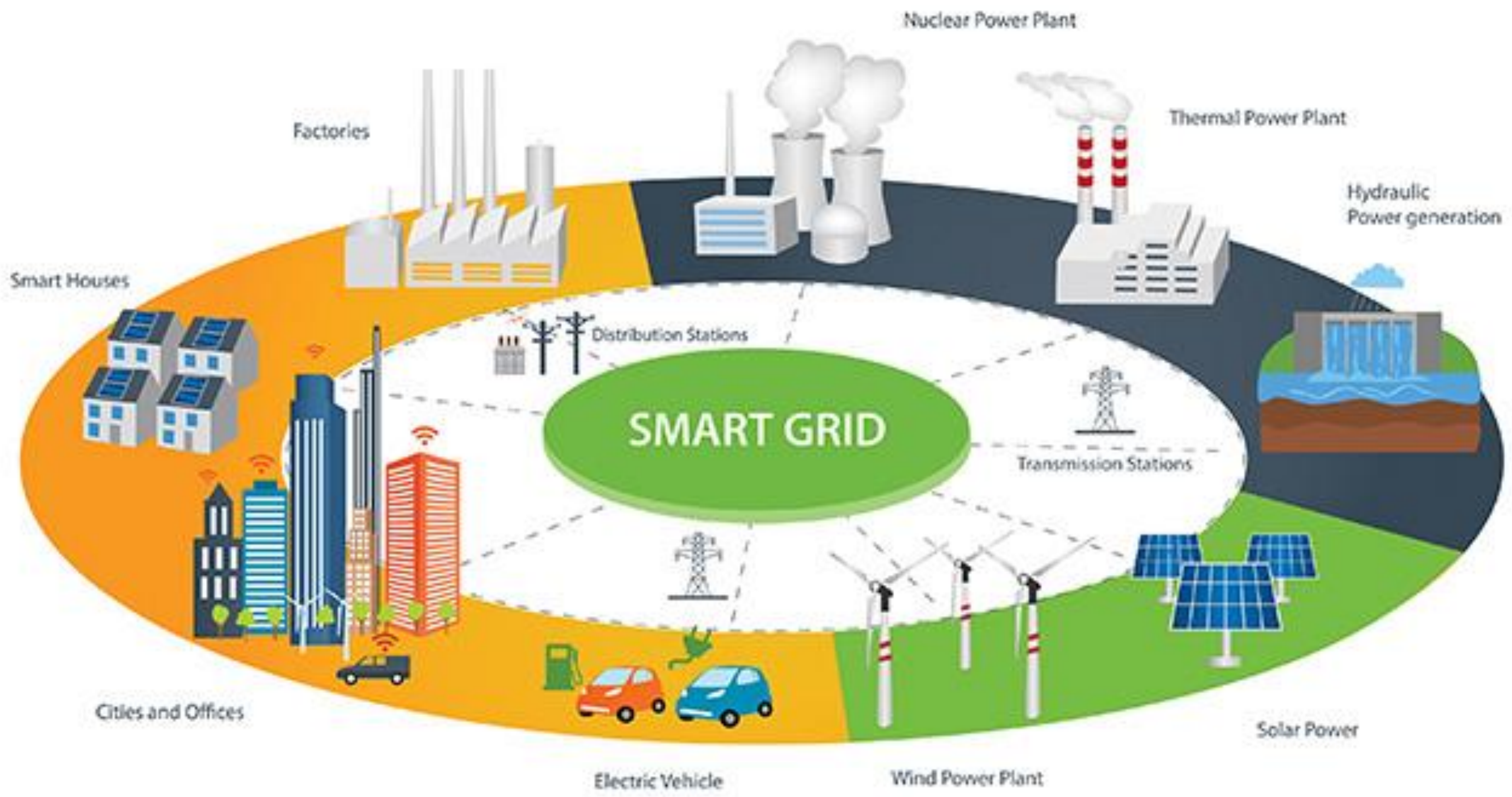
Grid Flexibility, Renewable Energy & Electrification

Challenge

- More variable source renewables
- Less conventional sources
- Greater demand for electricity

Hydropower

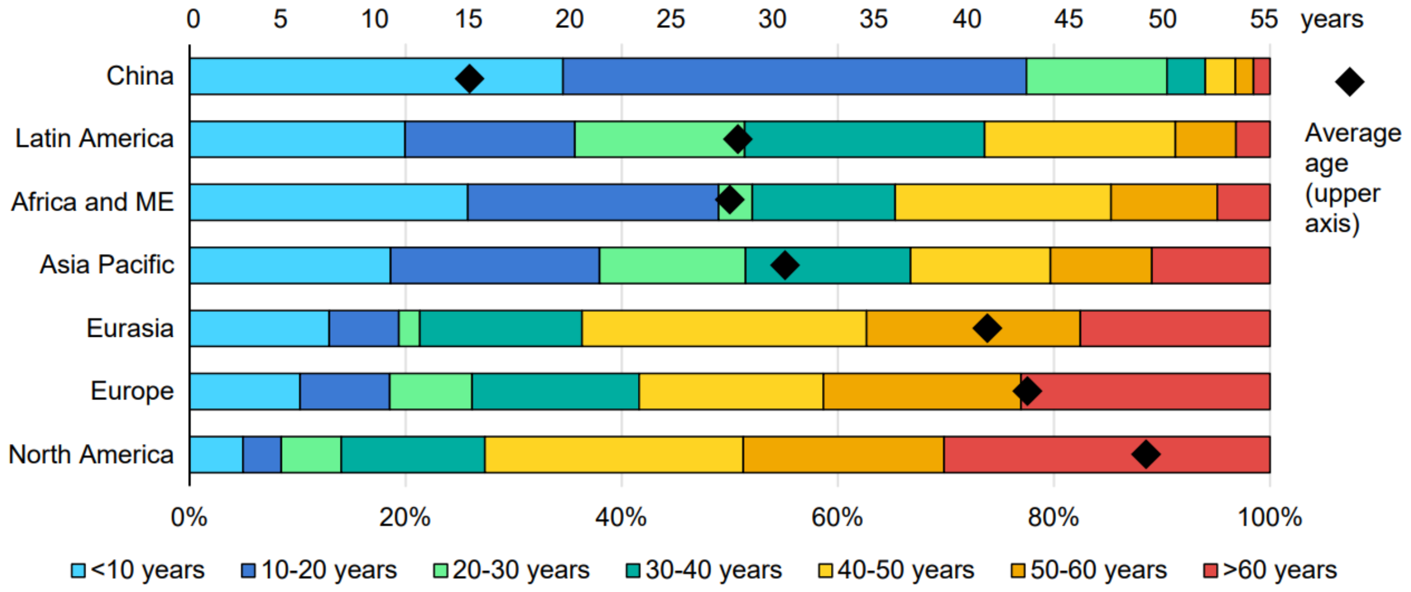
- Start/stop quickly (dispatchable)
- Energy Storage
- Predictable / less variable
- More off-design operation
- More hydro-peaking



Introduction

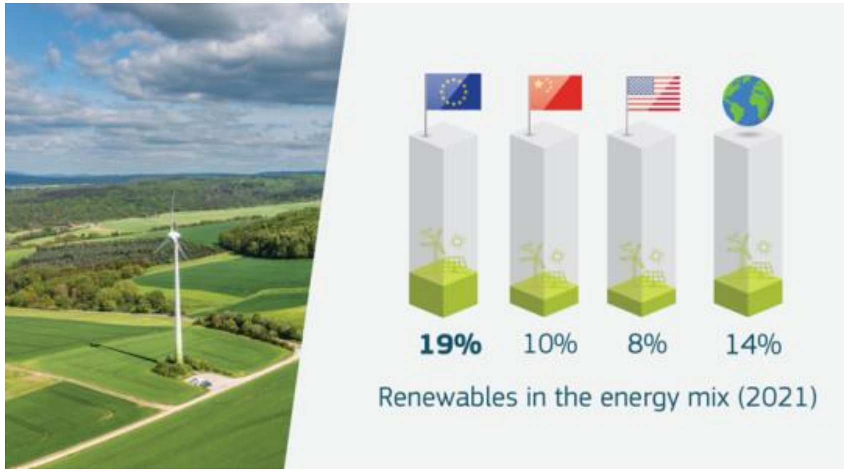
Hydropower & Digitalisation

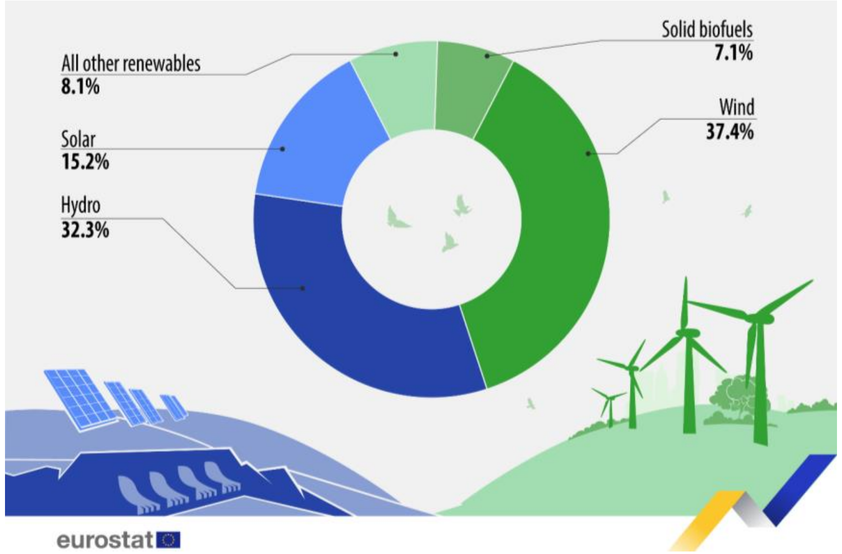
- Hydropower represents one sixth of global electricity generation
- Provides significant contribution to grid flexibility and security
- However the fleet is aged and requires significant modernisation works



Age profile of installed hydropower capacity, 2020

(Source: Hydropower Special Market Reports, International Energy Agency)



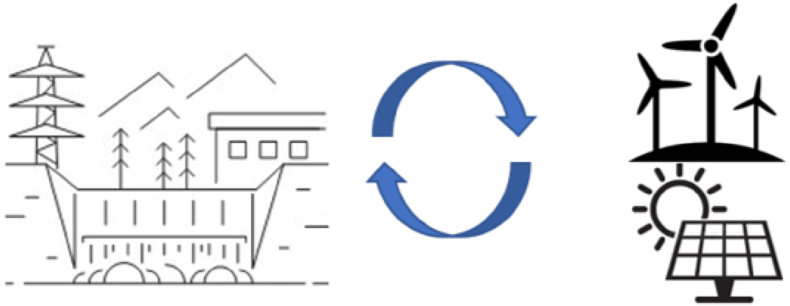
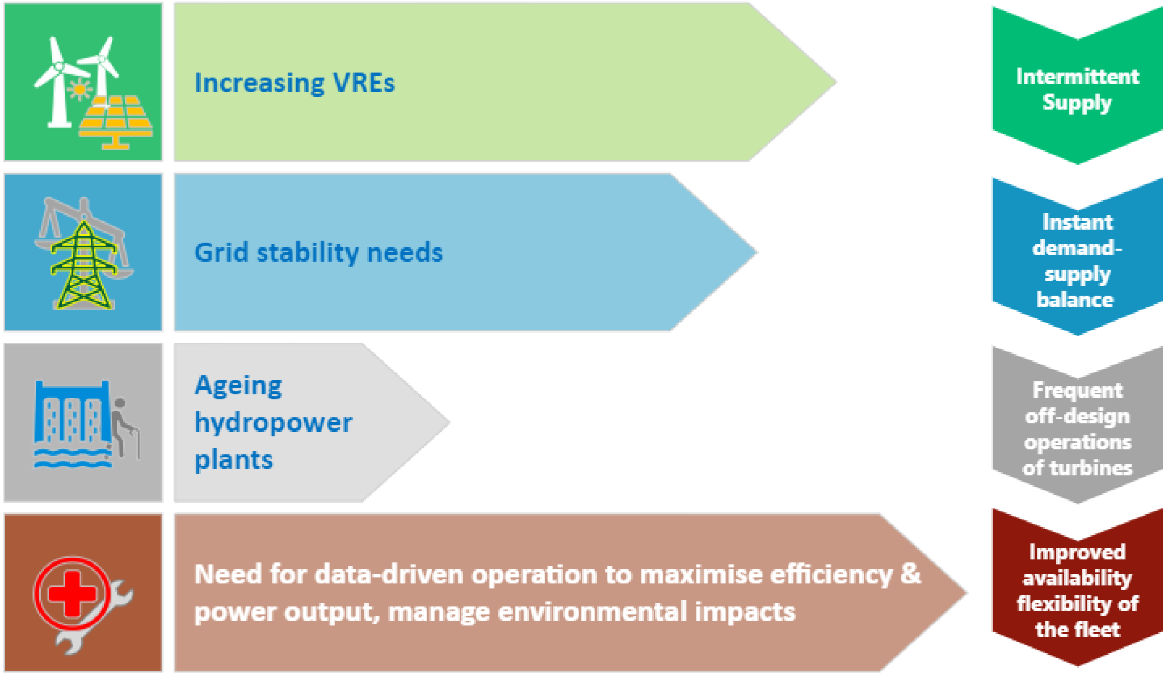


Sources of renewable energy in gross electricity consumption, EU 2021

Problem Statement

- Digitalisation required to increase grid flexibility, environmental and socio-economic sustainability and to foster the green and digital transitions in Europe.

- The digitalisation of the world's 1225 GW of existing hydro could increase annual production by 42 TWh, amounting to 5 billion USD in annual operational savings and significant reductions of greenhouse gas emissions

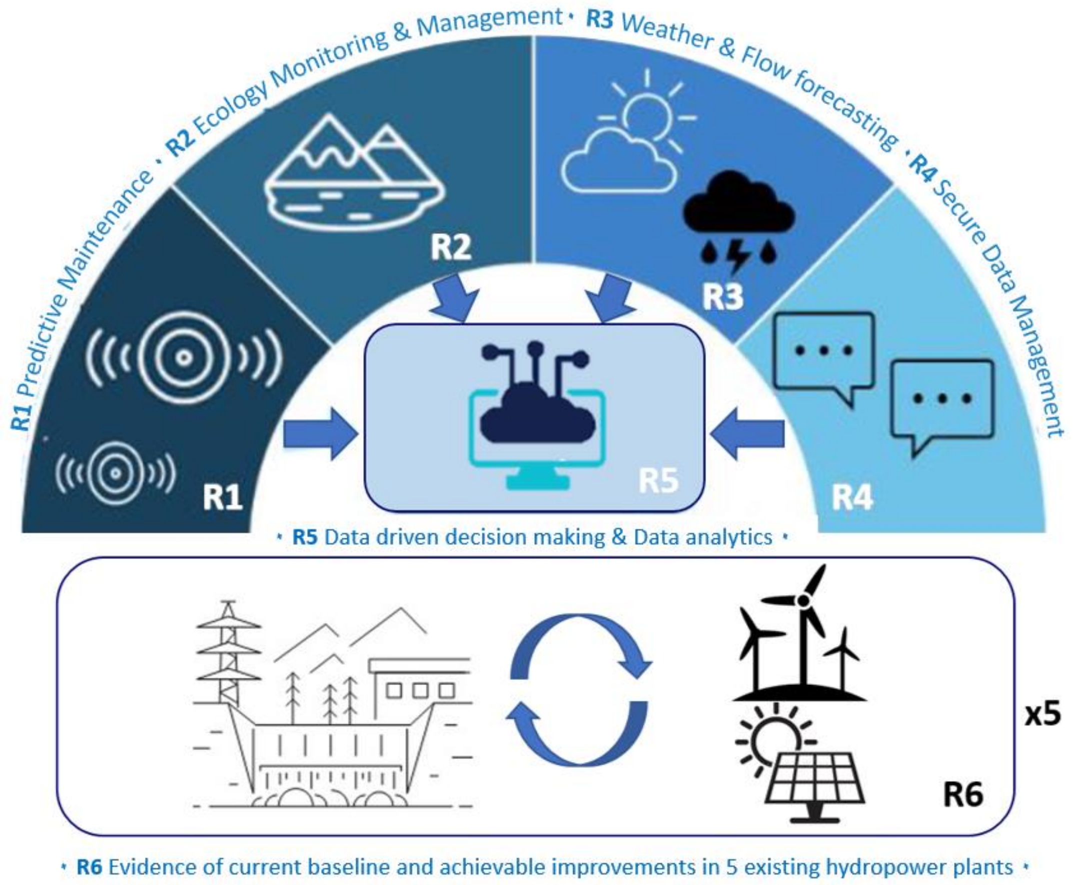
Project Objectives

1. **Co-develop** and **validate** novel condition monitoring and predictive maintenance digital solution at TRL5 for hydromechanical and electrical equipment.

2. **Co-develop** and **validate** advanced sensors and models for the monitoring of biodiversity parameters for an ecologically optimised hydropower operation to improve biodiversity, environmental and socio-economic sustainability of existing plants

3. **Co-develop** and **validate** enhanced weather and flow forecasting models for improvement in reservoir inflow, outflow and water balance prediction accuracy

intelligent Asset Management Platform



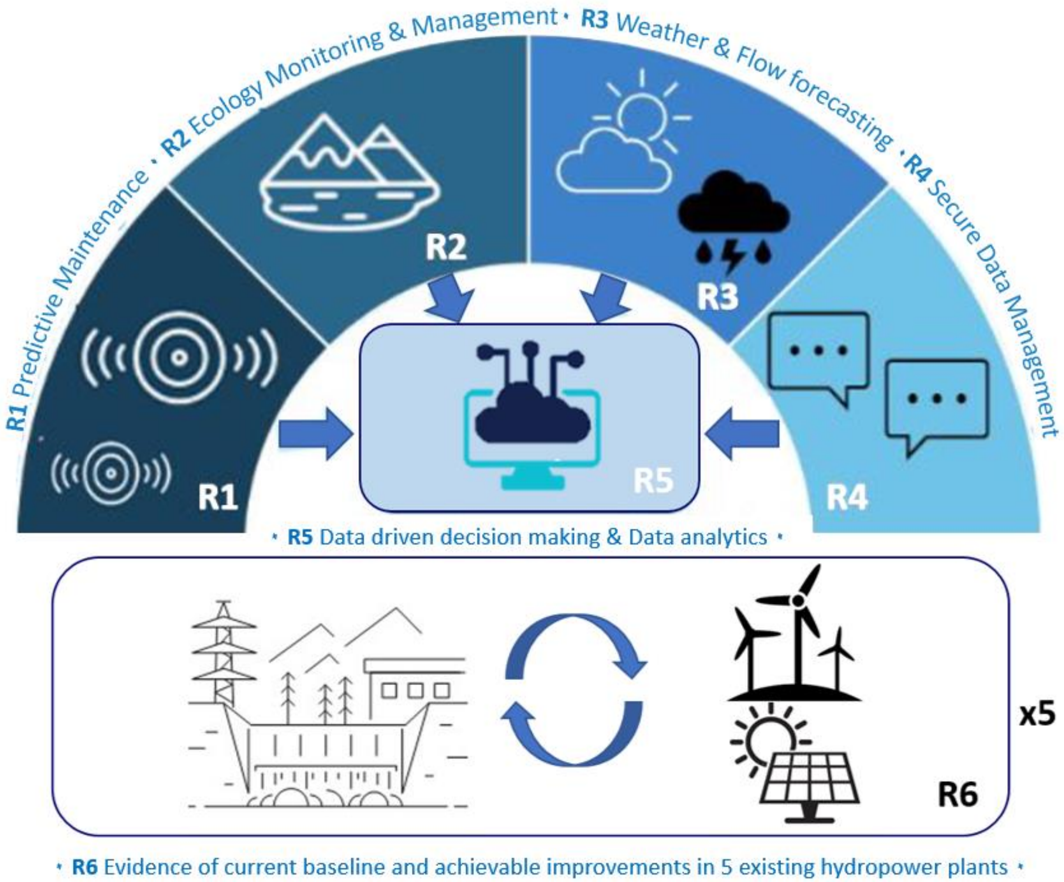
Project Objectives

intelligent Asset Management Platform

4. **Co-develop** secure data collection, communication, storage and sharing protocols and standards to enable trusted data-driven operation and maintenance, and interoperability between hydro operators, and with other renewable energy sources

5. **Co-develop** and **validate** iAMP decision-making algorithms for data-driven O&M, including integration of operations with other renewable energy sources to increase flexibility and optimise hydro positioning in energy markets

6. Widespread dissemination and communication of the potential benefits of digital solutions & gathering evidence for policy makers



Methodology

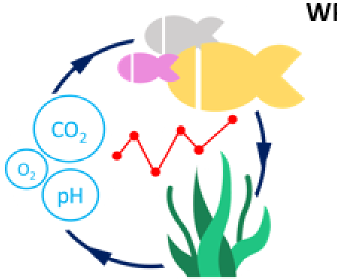
Digital Solutions

Advancing the Scientific Basis, technology base & leadership

WP2-3

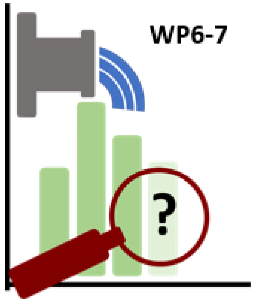
R1. Condition Monitoring & Predictive Maintenance

WP4-5



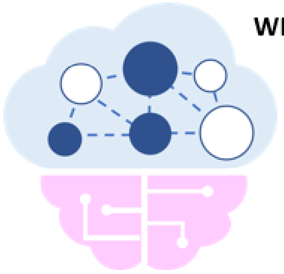
R2. Ecological Status Monitoring & Management

WP6-7



R3. Weather & Flow forecasting

WP8

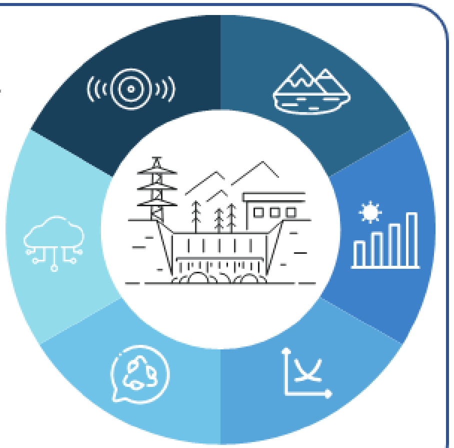


R4. Data Standards & Protocols

WP9 10 & 11

R5. Intelligent Asset Management Platform

integration



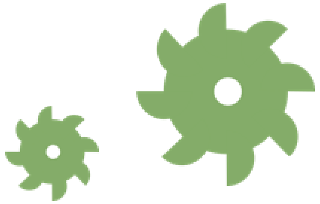
Validation

Increasing the technology competitiveness of the existing hydropower fleet

Validation

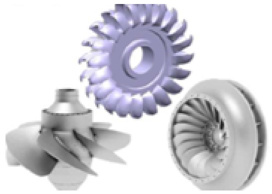
WP12

Wet & Dry Climates

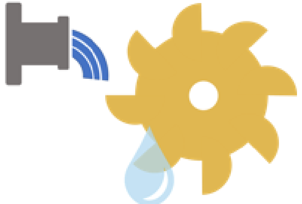


Large & Small Hydro

Multi-purpose

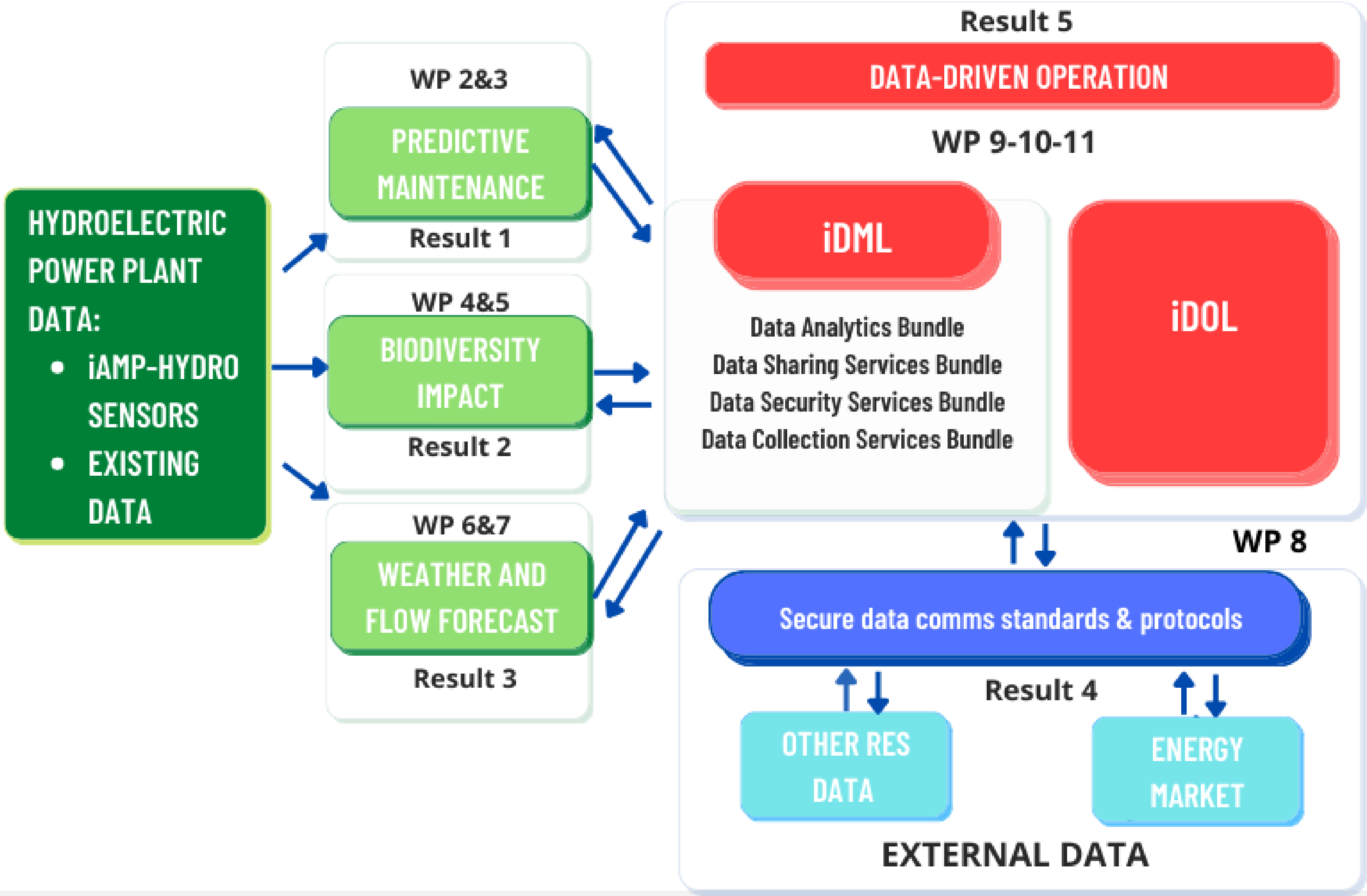


Differing Machine types

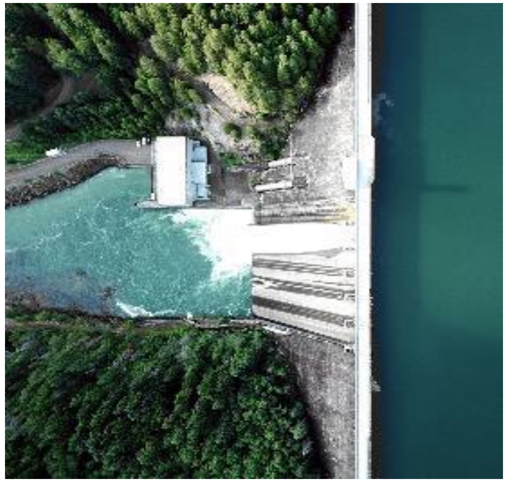


Differing flow regimes

iAMP-Hydro platform



iAMP-Hydro Validation Site



Berchules (0.8 MW)

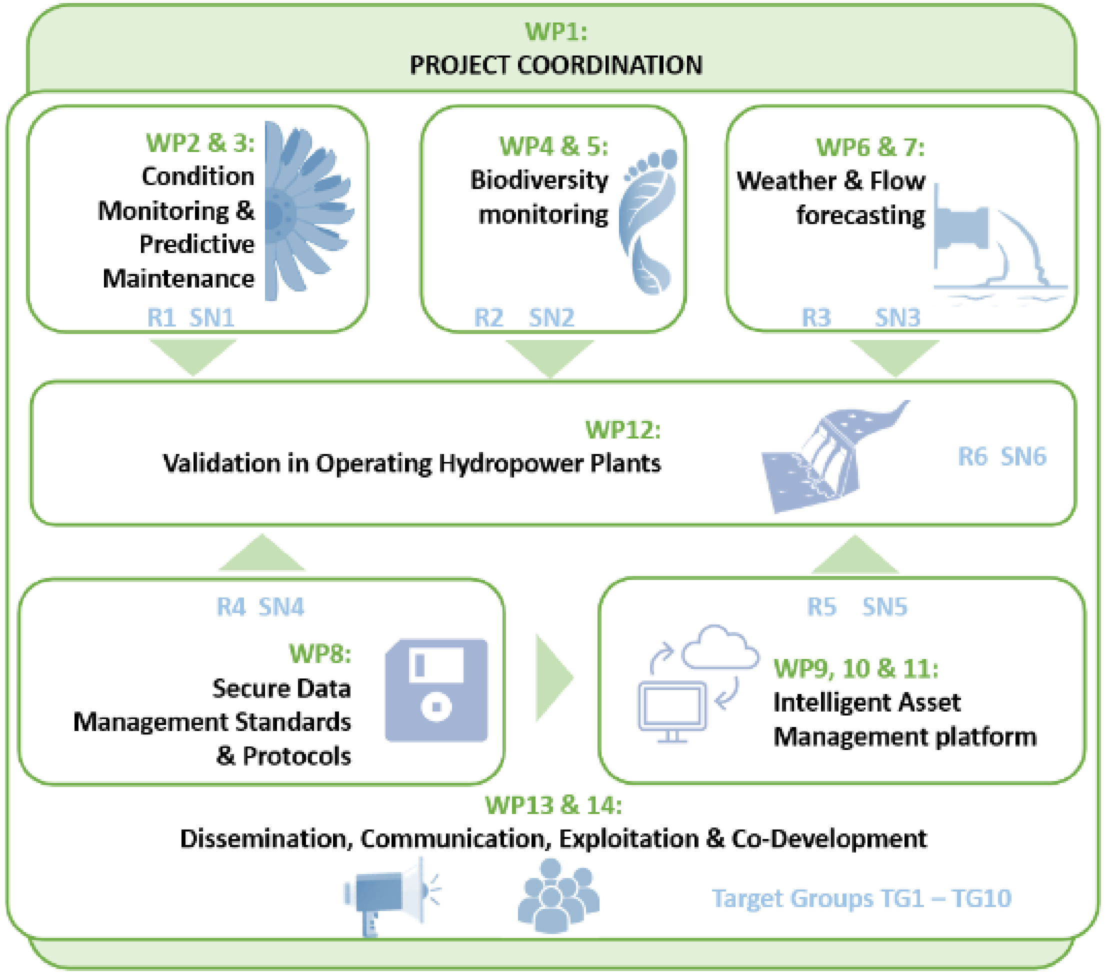
Bermejales (2.1 MW)

La Vega (2.4 MW)

Makrochori (10.8 MW)

Asomata (108 MW)

iAMP-Hydro Work Packages and Partnership

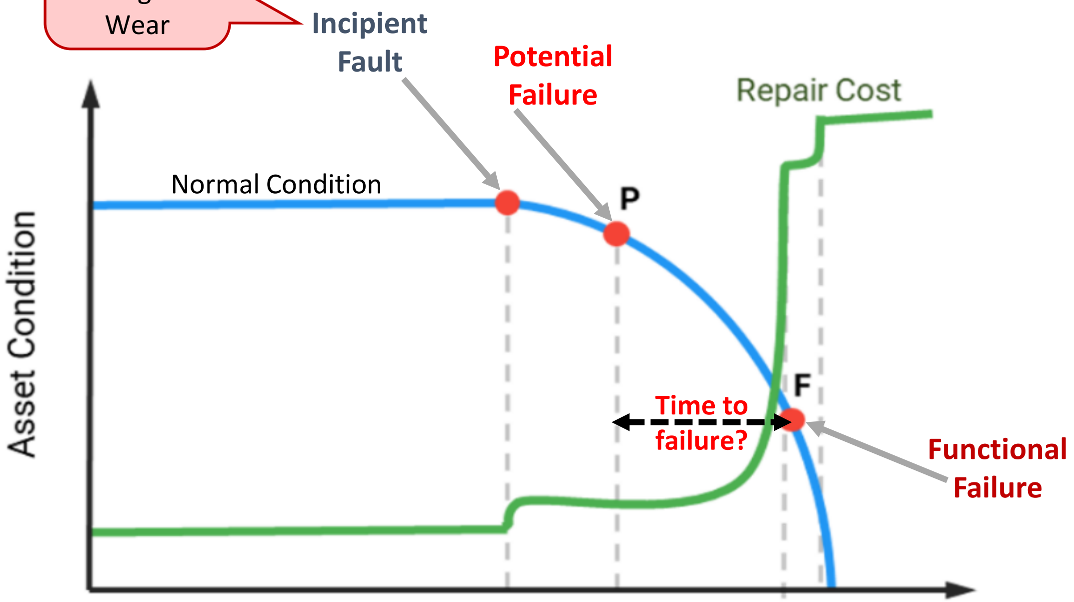


Condition Monitoring

Predictive Maintence – Caviation, Fatigue & Wear

- Facilitate fault diagnosis and prognosis of turbines
- Maintenance planning, scheduling and risk assessment
- Supporting efforts on climate change and energy security

Causes?
Cavitation
Fatigue
Wear



The P-F Curve
(Source: https://power-mi.com/)

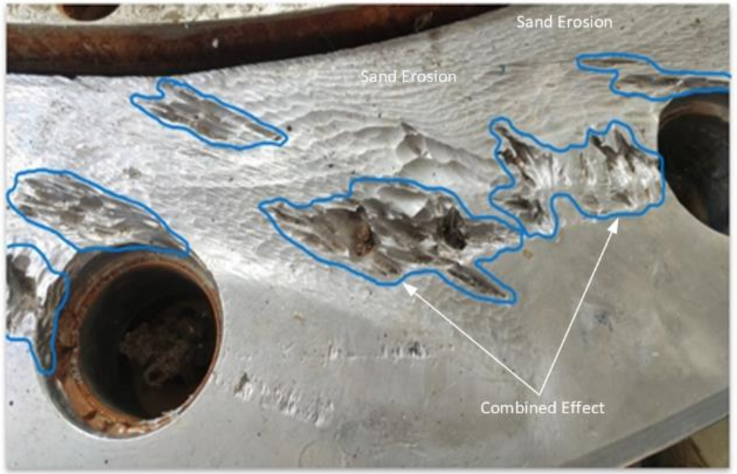
Variables?
- Location of damage
- Damage evolution
- Extent of damage

When to stop and overhaul the machine?

Variables?
- Market need
- Energy prices
- Resource availability

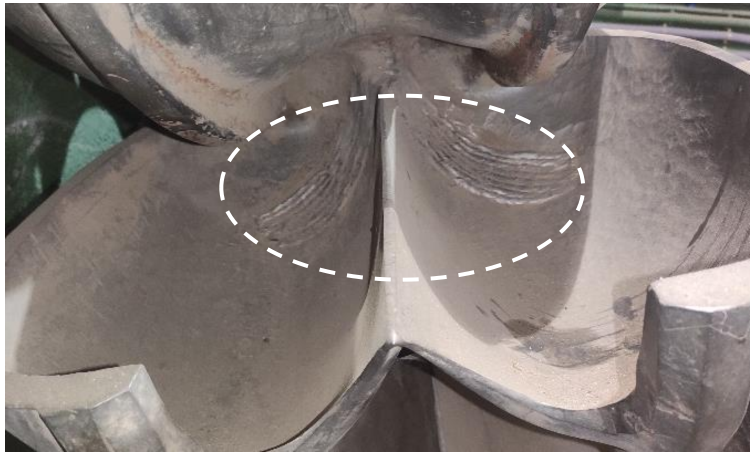
Condition Monitoring

Common failure mechanisms



Hydro-abrasive erosion of Francis turbine seal ring

Bagmati Hydropower Project, 22MW Nepal



Fatigue cracks repaired by welding in Pelton runner

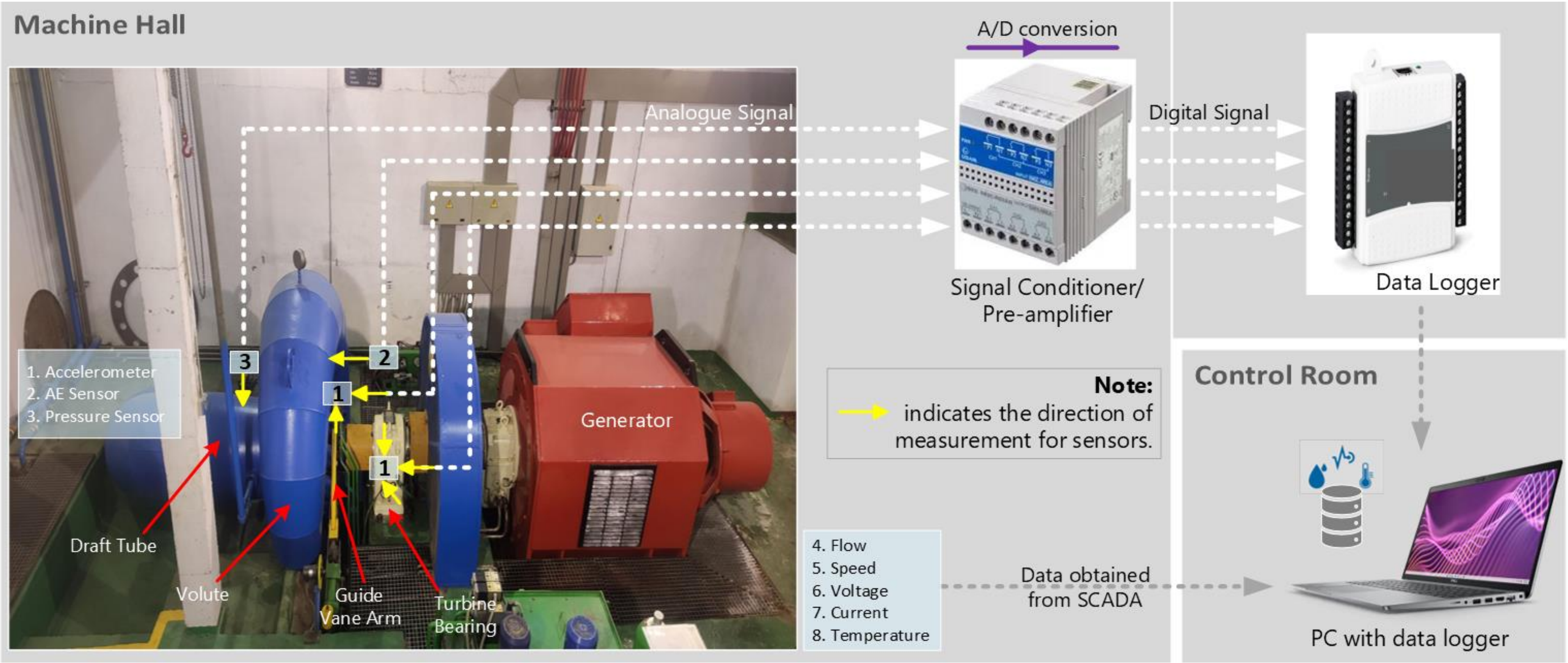
La Vega HEP, 2.4MW
Spain

Some types of damage found: (a) **Fatigue crack** in a bucket; (b) **Cavitation erosion**; (c) Runner with a **broken bucket**; (d) **Broken needle**
Egusquiza et. al, 2018

Condition Monitoring

Sensor Development, Specification & Deployment (Bermejales)

- 1 x Francis Turbine
- Irrigation
- 2.1 MW, 4.8 m^3/s & 56m
- Climate impacts

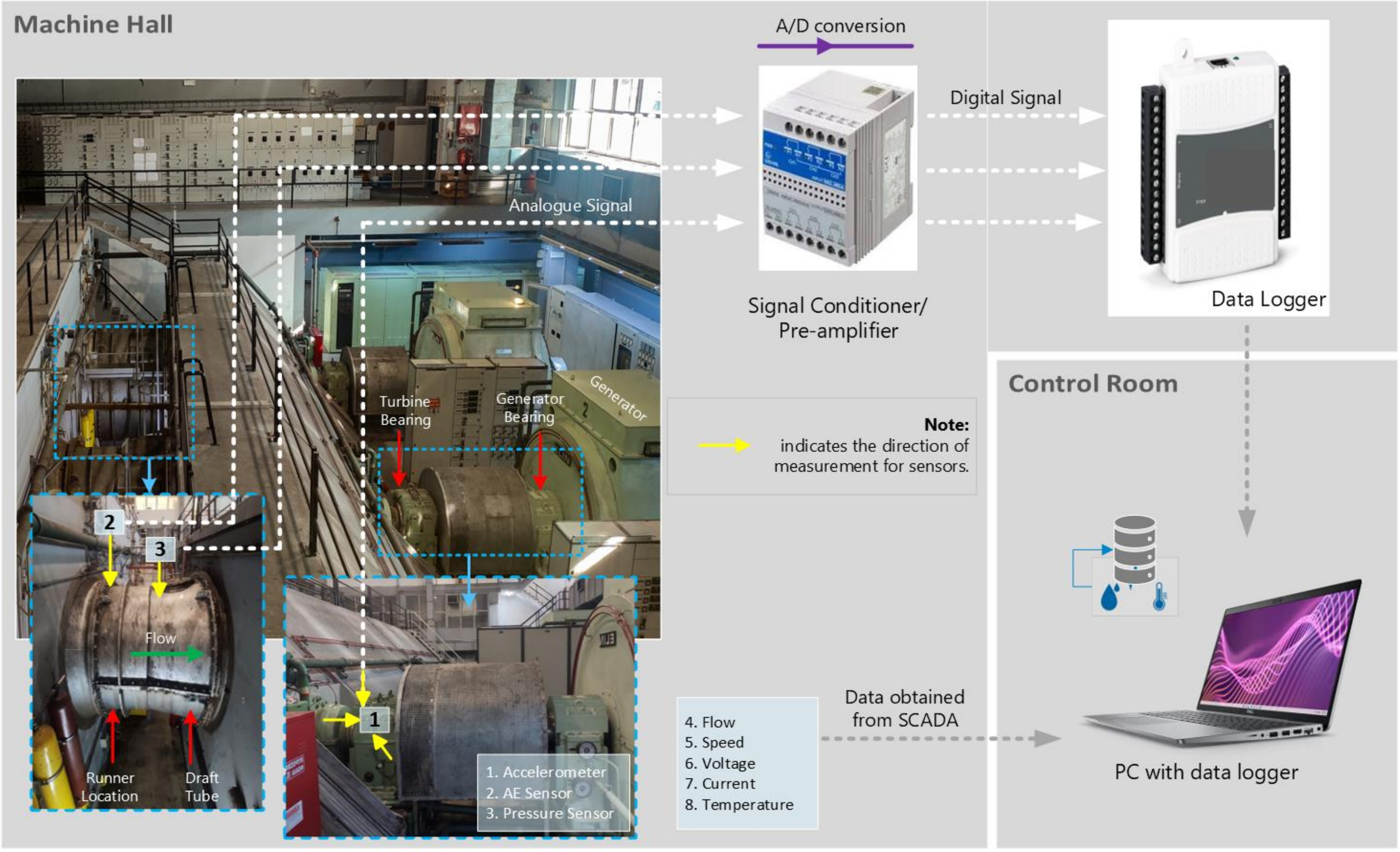


Cuerva
Energía Transparente

Condition Monitoring

Sensor Development, Specification & Deployment (Makrochori)

- 3 x Kaplan Turbines
- Irrigation Channel
- 10.8 MW, 32 m^3/s & 15m

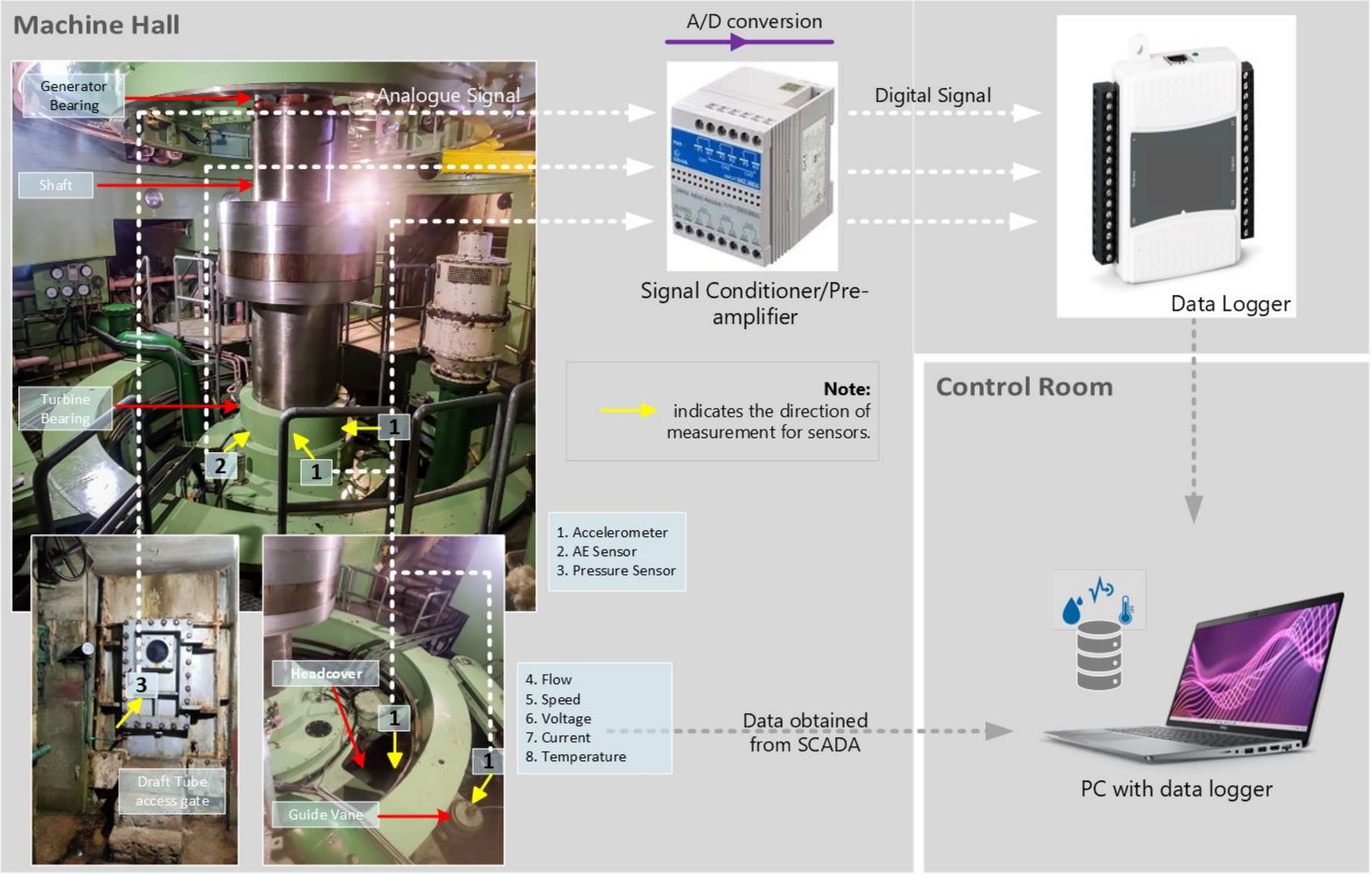


PPC Renewables
Innovation • Development • Environment

Condition Monitoring

Sensor Development, Specification & Deployment (Asomata)

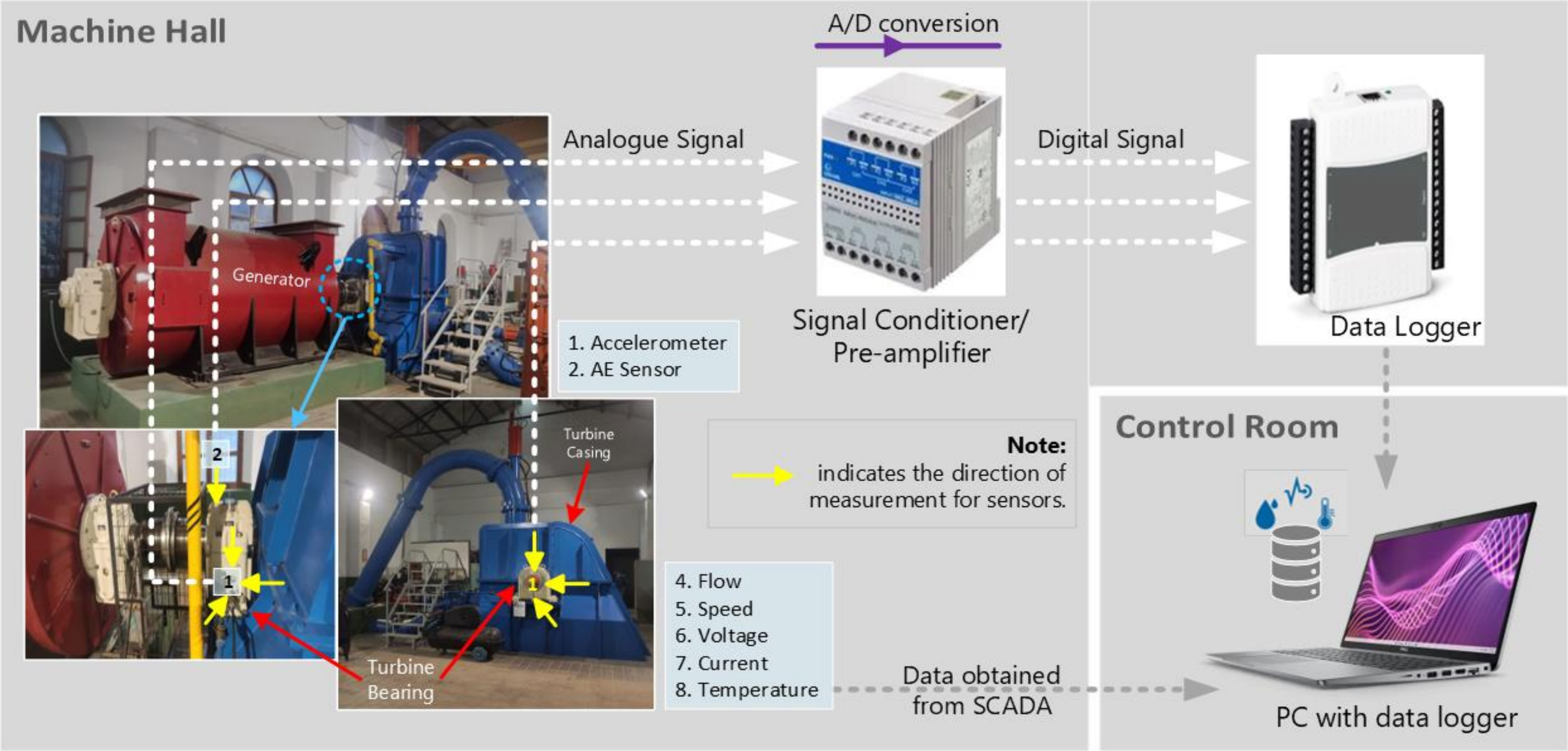
- 2 x Francis Turbines
- Cascade System
- (2 x 55.7) MW, 166.5 m^3/s & 42m



Condition Monitoring

Sensor Development, Specification & Deployment (La Vega)

- 1 x Pelton Turbine
- Run-of-river
- 2.4 MW, 1.5 m^3/s & 185m

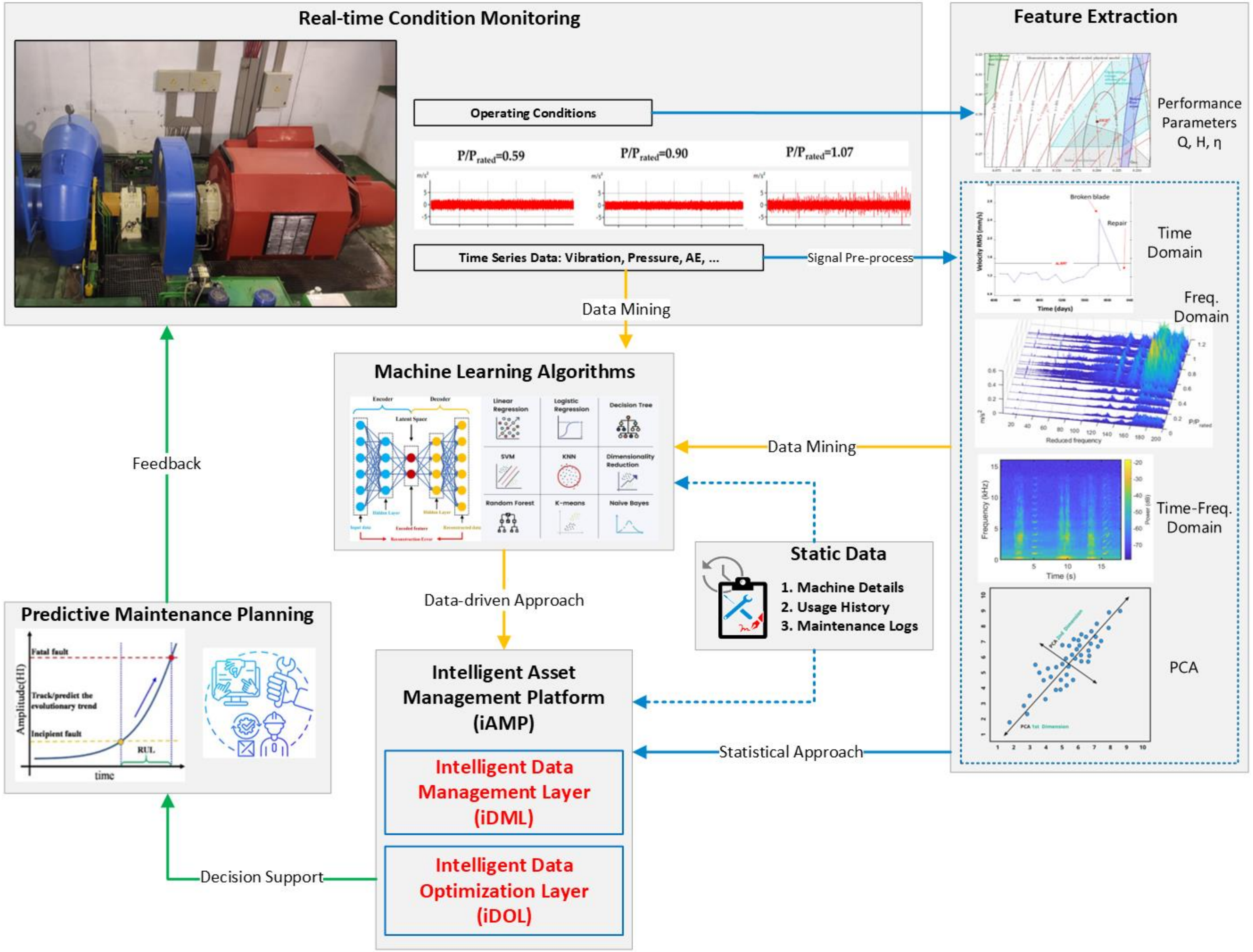


Condition Monitoring

Data Analysis Methodology

- Customizable sensor suite for hydro turbine condition monitoring

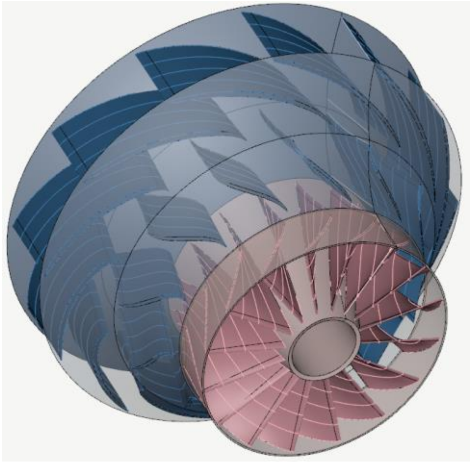
- Developing a tool to predict time-to-failure of hydropower turbines

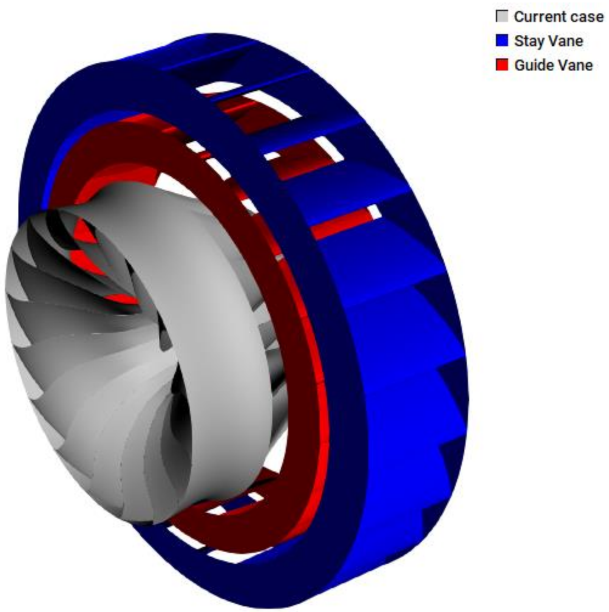


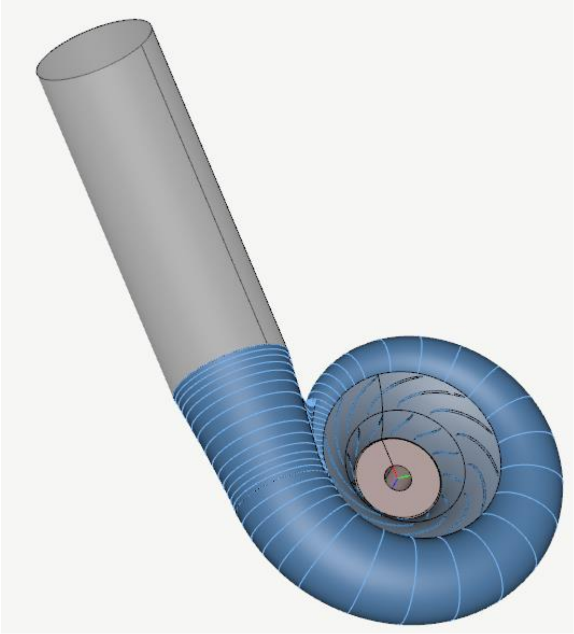
Condition Monitoring

Predicitve Maintence Modelling – CFD Analysis

- Creating CFD models of turbines in all five sites
- Generating models from limited available geometric data
- Simulating failures to supplement data recorded from installed sensors
- Feeding data into iAMP-Hydro AI Platform





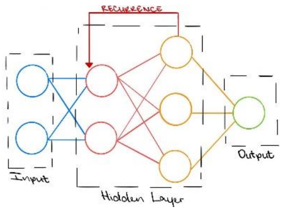


Flow Forecasting

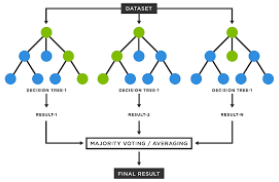
Data acquisition and modelling approach

- Standardized set of historical input **variables**: temperature, precipitation, solar radiation, water level, turbined flow.
- Study influence of **lagged variables** in the KPIs results
- Use of optimization algorithms such as DCSA to capture other physic relations in the models parameters

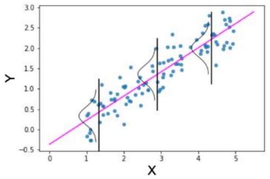
○ AI-based: Deep learning (DL): recurrent neural networks (RNN) → Long Short-Term Memory (LSTM) networks



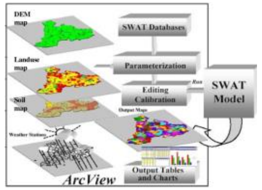
○ AI based: Machine learning (ML): classification algorithms → random forest or support vector machine



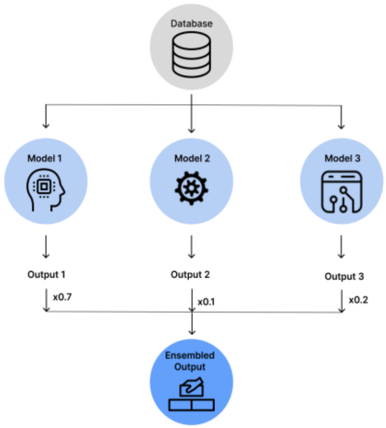
○ General linear model



○ Existing physical models (SWAT, HBV)



Ensemble



Biodiversity Monitoring

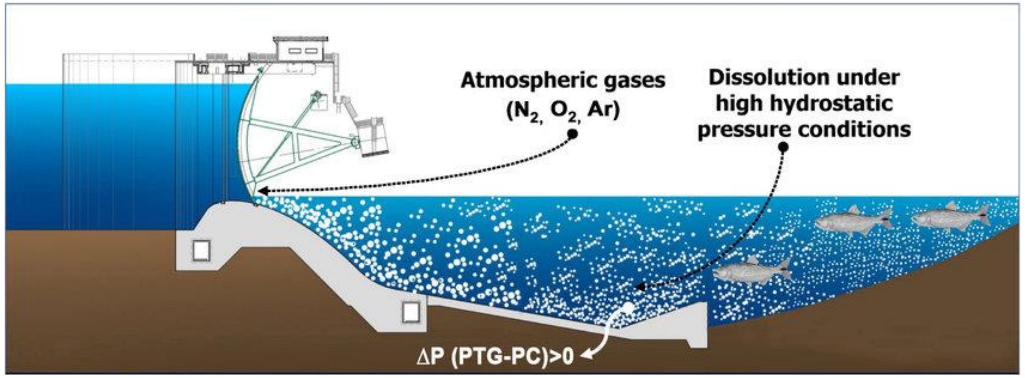
Gas supersaturation and affect on biodiversity

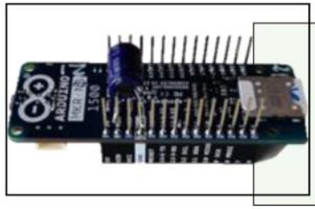
It occurs when the dissolved gases in a water body exceed the concentration of total gases that can be dissolved under normal circumstances.

- Sensor development on going
- Communication and monitoring protocol
- Lab test and validation will take 6 months from now

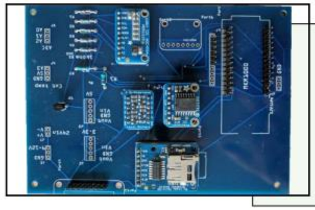
Effects:

- Bubbles formation under skin
- Exophthalmos
- High mortality

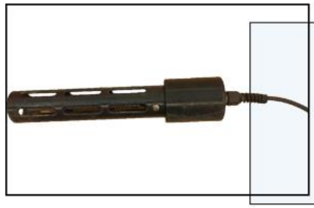




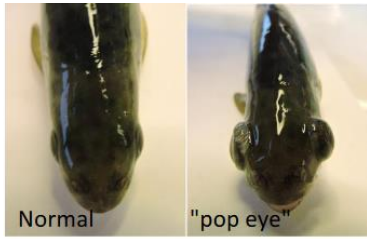
Arduino MKRNB 1500
CoAP protocol
NB- IoT to MIC



Pressure sensor
Temperature sensor



Analogue sensor
Weiss saturometer
Temperature sensor



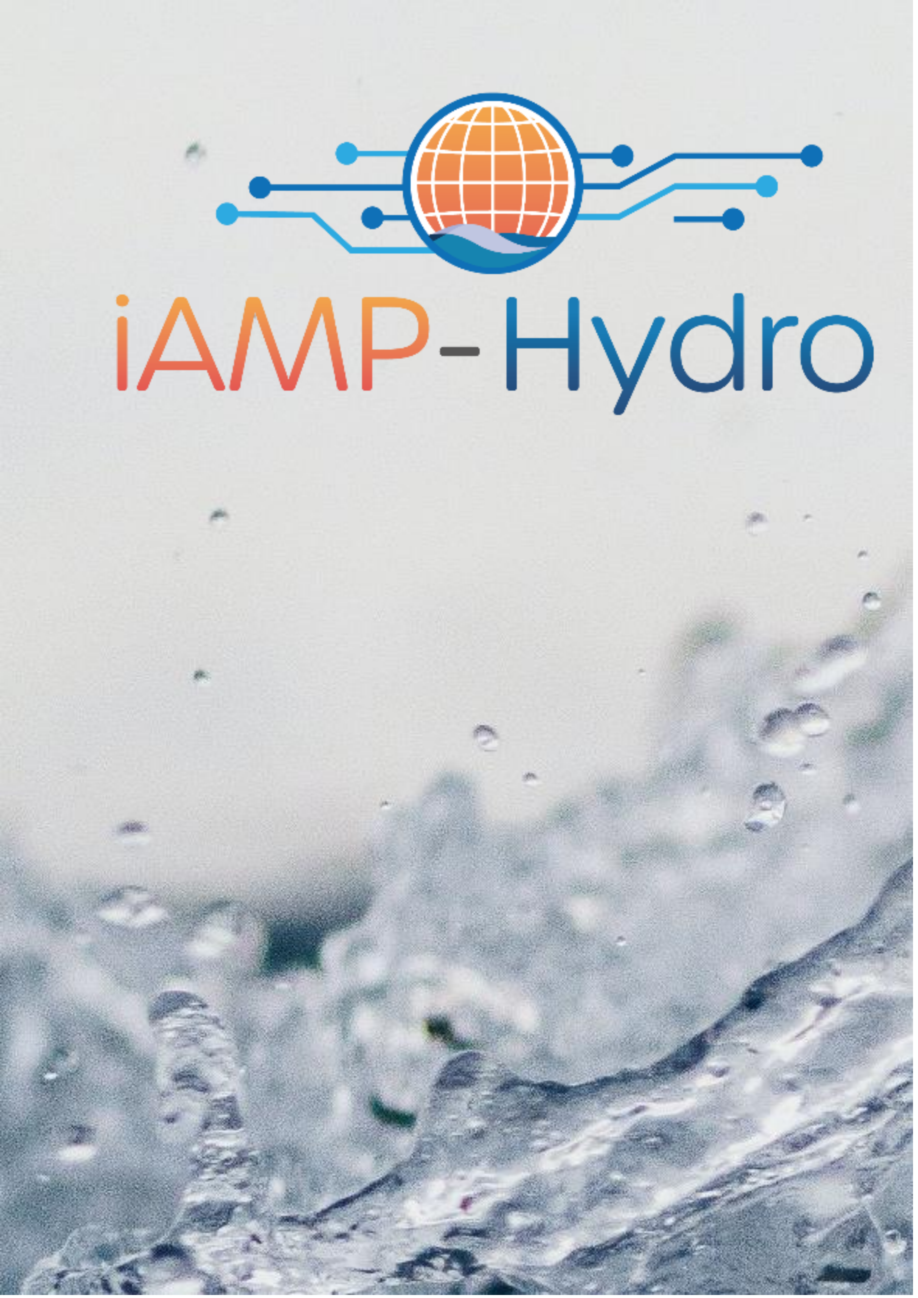
Co-development & Community of Practice

Methodology

- **Co-development R&D process**: involving industry, policy makers and users through action learning to enable co-development of sustainable improvements. Processes such as action and feedback, asking fresh questions, learning from and with each other in a learning group, the contribution of peers, and creating a multiplier effect, are central to action learning.

- **Co-development workshops**:
  - Learning in-action and hosted in hybrid mode at the five validation sites.
  - Presentation of planned work and updates on progress, tours of the technologies in practice (real & virtual), and industry and policy feedback and reflection.
  - Stakeholder feedback will be used to refine the development of the technologies to explicitly meet user needs and expectations.

- Widespread involvement of many stakeholders required: development an iAMP-Hydro **community of practice (COP)** including >500 technology providers, users and policy makers.



Thank you!

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Partners

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