IoT2024

FORTH
INSTITUTE OF COMPUTER SCIENCE

Di-Hydro

TELECOM SudParis

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UNIVERSITY OF CRETE

Session #5:
IoT for (Virtual) Reality

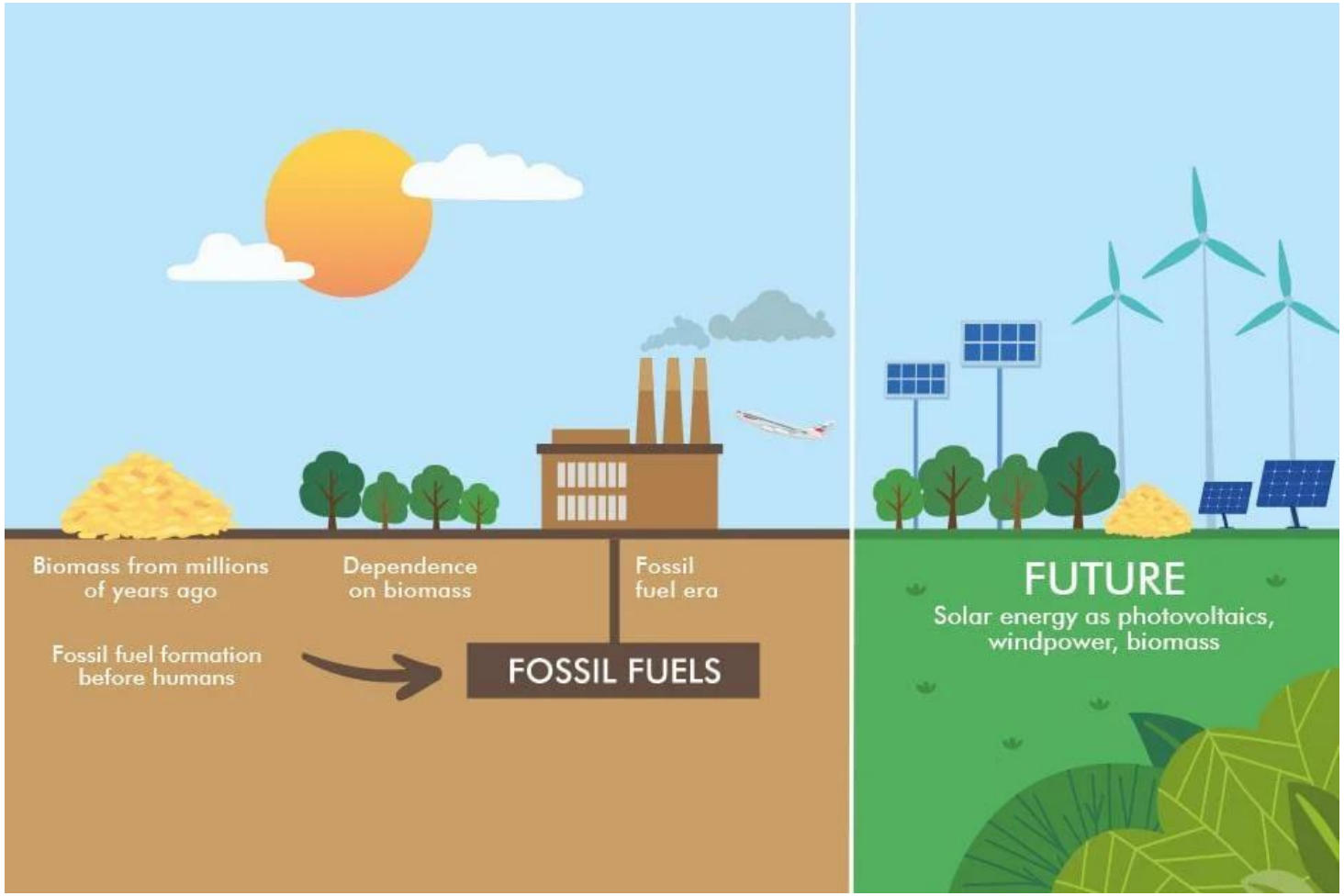
Enabling IoT-enhanced Data Models for Context-aware Hydropower Plants

Nikolaos Papadakis, Georgios Bouloukakis, Kostas Magoutis

The 14th International Conference on the Internet of Things

22th November 2024 Oulu, Finland

The Renewable Imperative: A Call for Action



Carbon Footprint

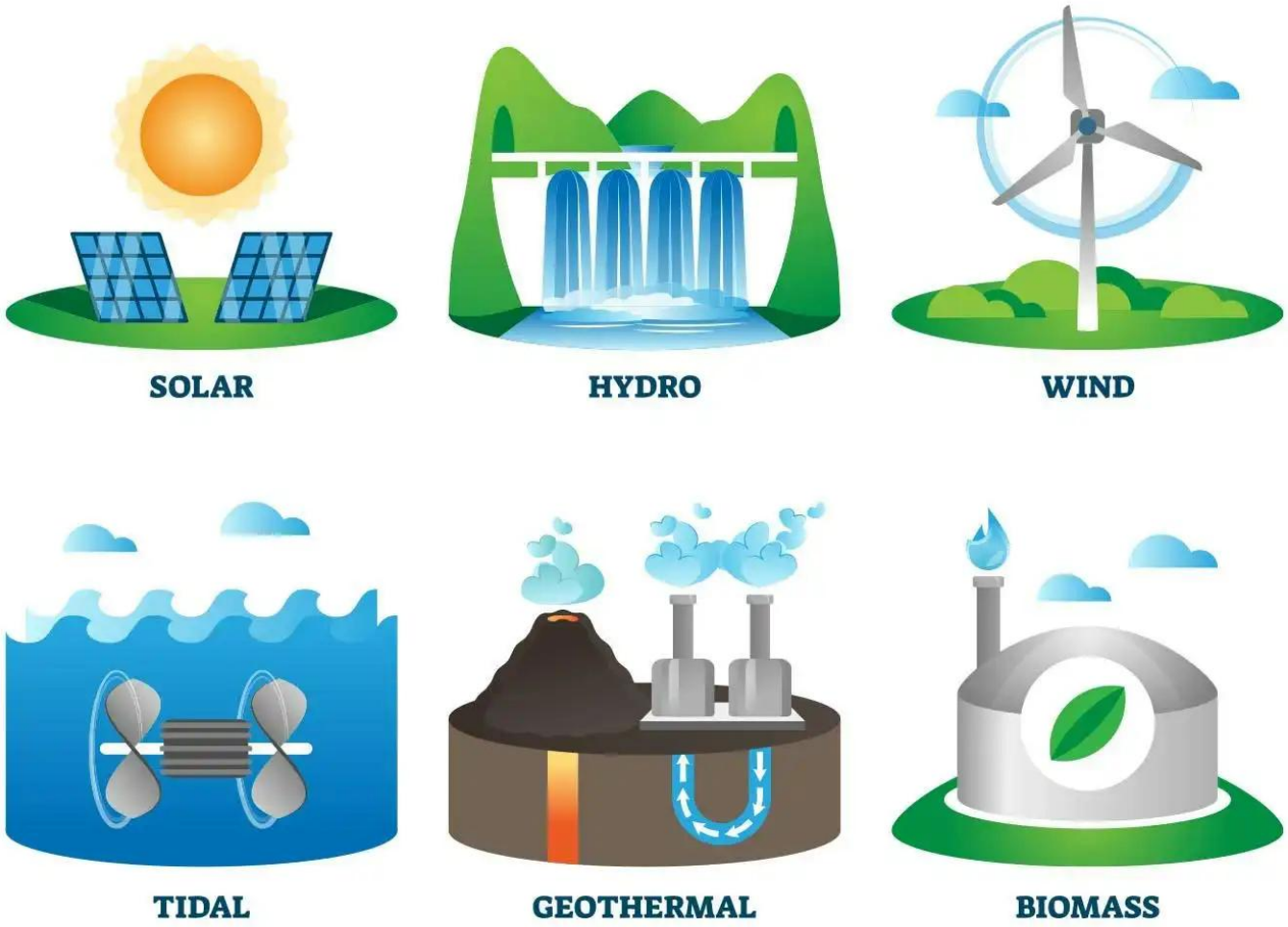
Public Health

Energy Security

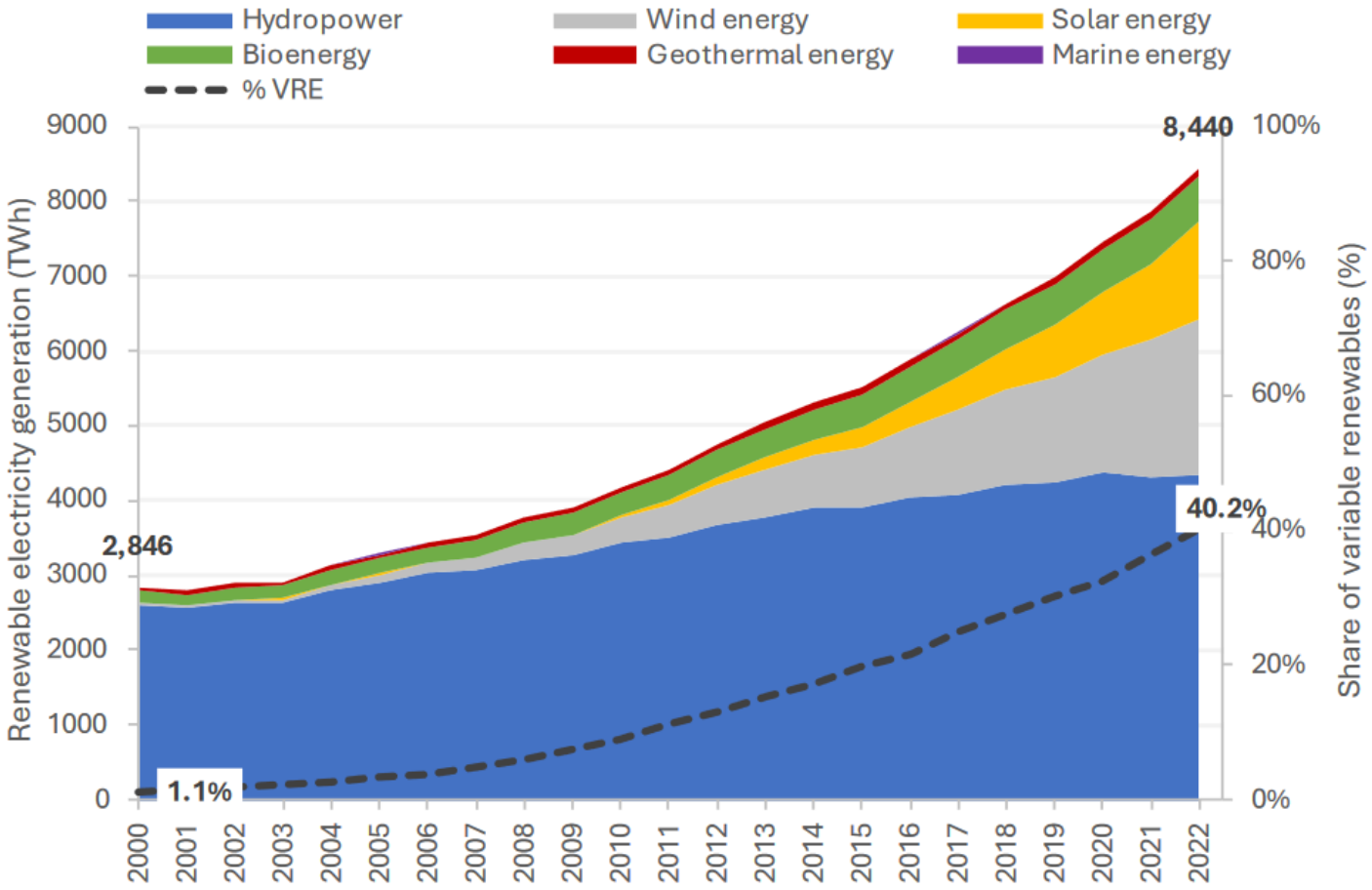
Local Jobs

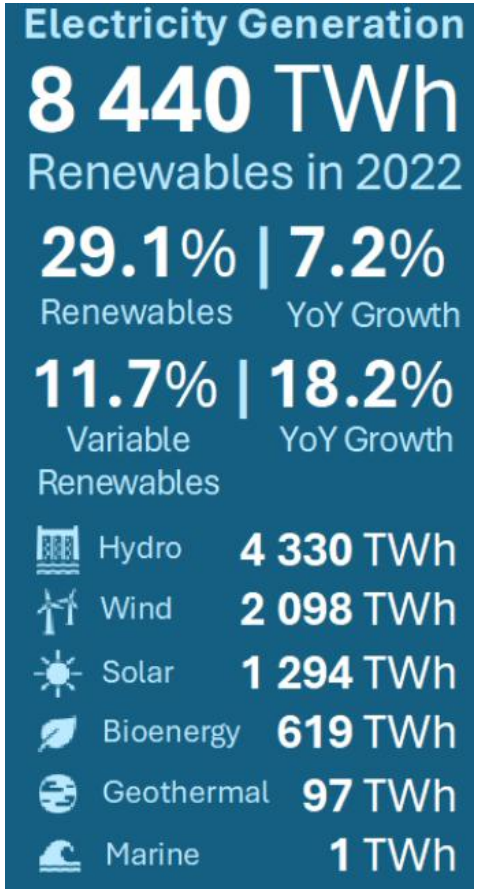
Source: https://www.routledge.com/blog/article/what-is-sustainable-energy-and-why-do-we-need-it

The Leading Sources of Renewable Energy



Hydropower: Renewable Energy's Silent Giant



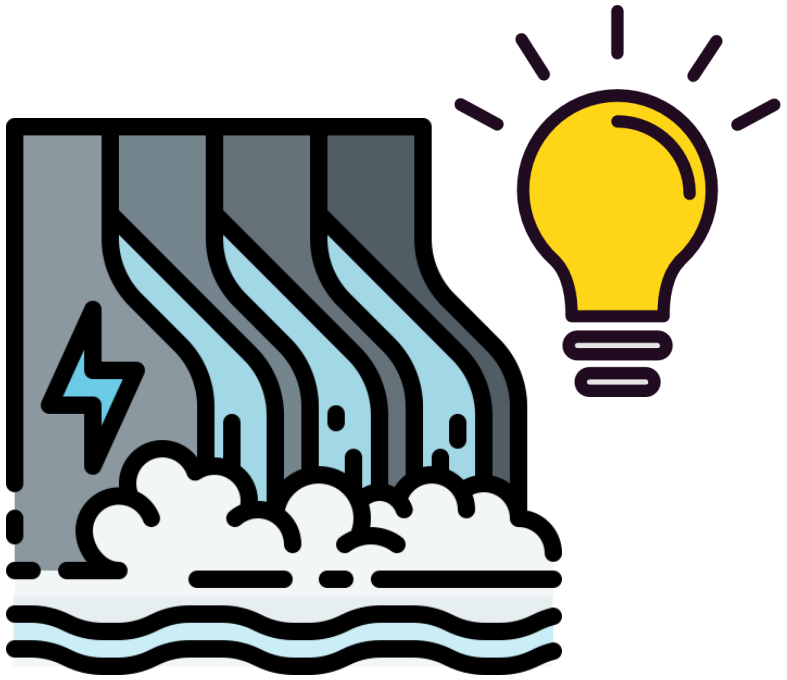


IRENA (2024), Renewable energy statistics 2024, International Renewable Energy Agency, Abu Dhabi.

Hydropower: Flowing Waters, Flowing Energy

***Hydropower**, or **hydroelectric power**, is a renewable source of energy that generates power by using a dam or diversion structure to alter the natural flow of a river or other body of water.*

Towards “Smart” Hydropower



‘Smart’ hydropower

IoT

AI

Data Analytics

Example Features

Real-Time Monitoring and Automation

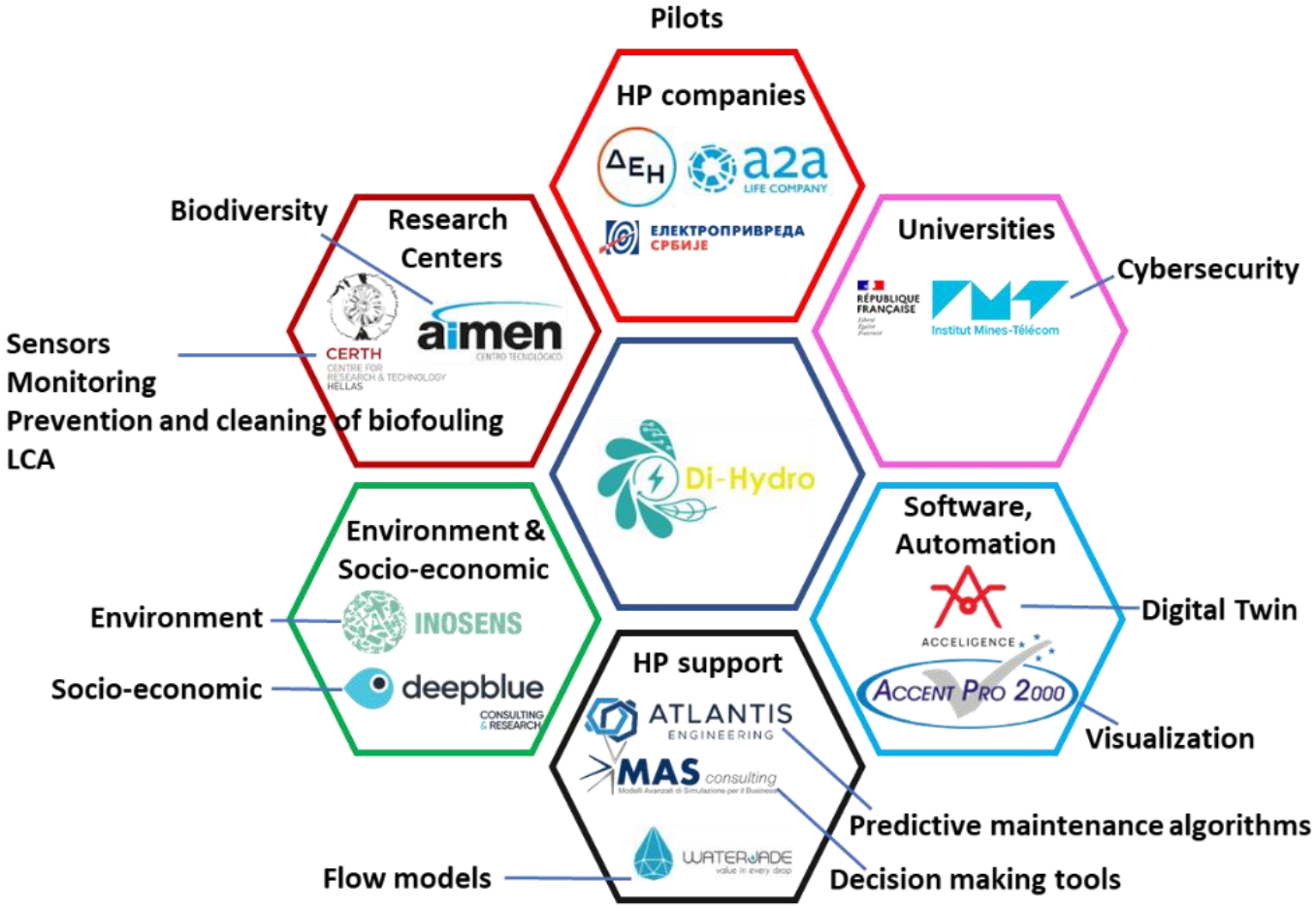
Predictive Maintenance

Reducing Environmental Impact

The Di-Hydro Project: Digital maintenance for sustainable and flexible operation of HYDROpower plants

Di-Hydro

Di-Hydro, an EU-funded project, is focused on advancing hydropower plants to align with the European Green Deal and the Paris Agreement. Its goal is to revolutionize plant operations by making them smarter, more efficient, and environmentally friendly



This project has received funding from the European Union's Horizon Europe Research and Innovation Programme under grant agreement N° 101122311

How Di-Hydro Transforms Hydropower: Use Cases

Use Case 1 - *Greece*

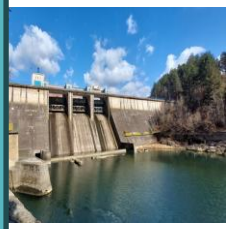
Ilarionas HPP

Digital Twin/Pred
Decision support platform

Use Case 2 - *Italy*

Use Case 3 - *Serbia*

…uvršje HPP



…me water quality
monitoring system

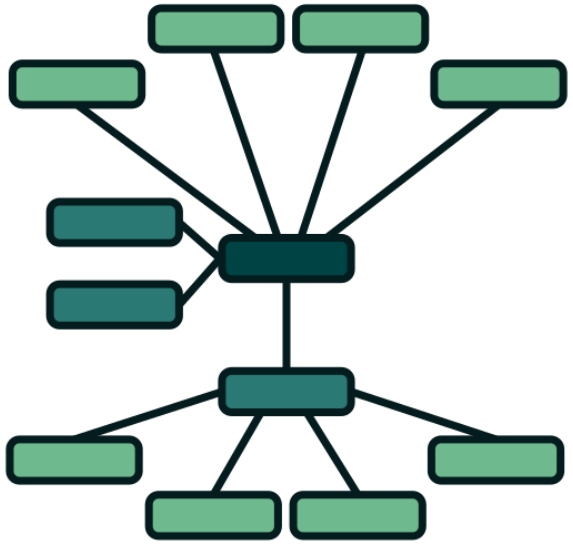
Powered by Data!

How to represent data: Smart Hydropower Data Models

Building Information Modeling

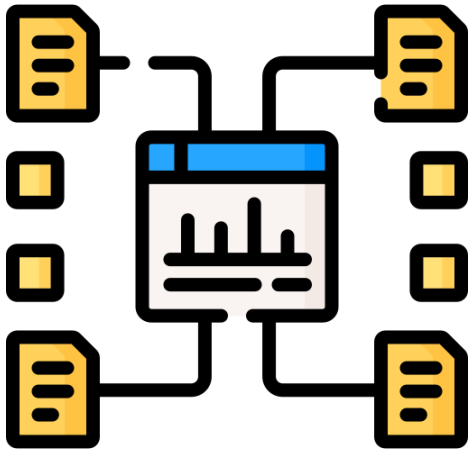
Wangchuk et al. 2024

Energy Ontologies



Booshehri et al. 2021, Kofler et al. 2012

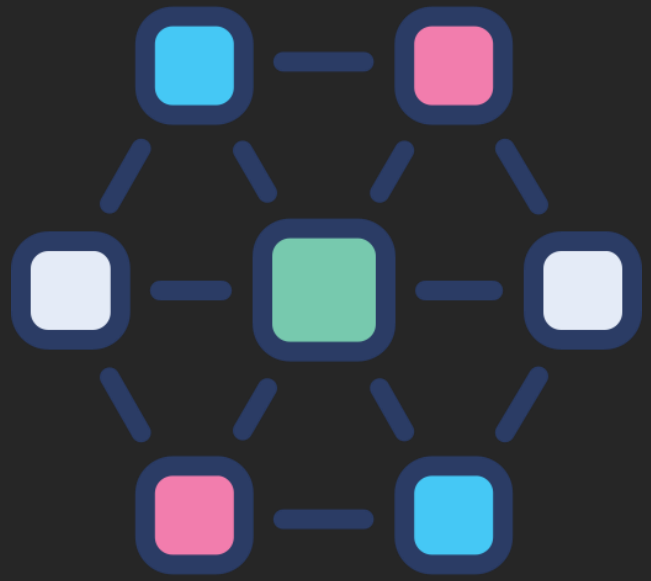
IoT Device Data Models and standards



https://smartdatamodels.org/

Data Modeling Issues and Needs

Data Model 1
Data Model 2
Data Model 3
Data Model ??



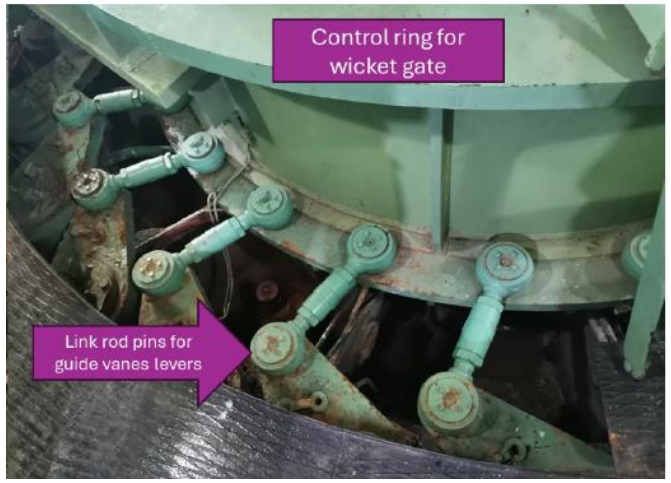
Common functionalities and components of energy management systems

Concepts of specific Hydropower Plant components and applications

No Industry “Standard” Data model exists here!

Context Data we would like to have represented

Penstock valve



Guide vane link rods

Pipes with potential biofouling

Data Modeling: Importance of Context

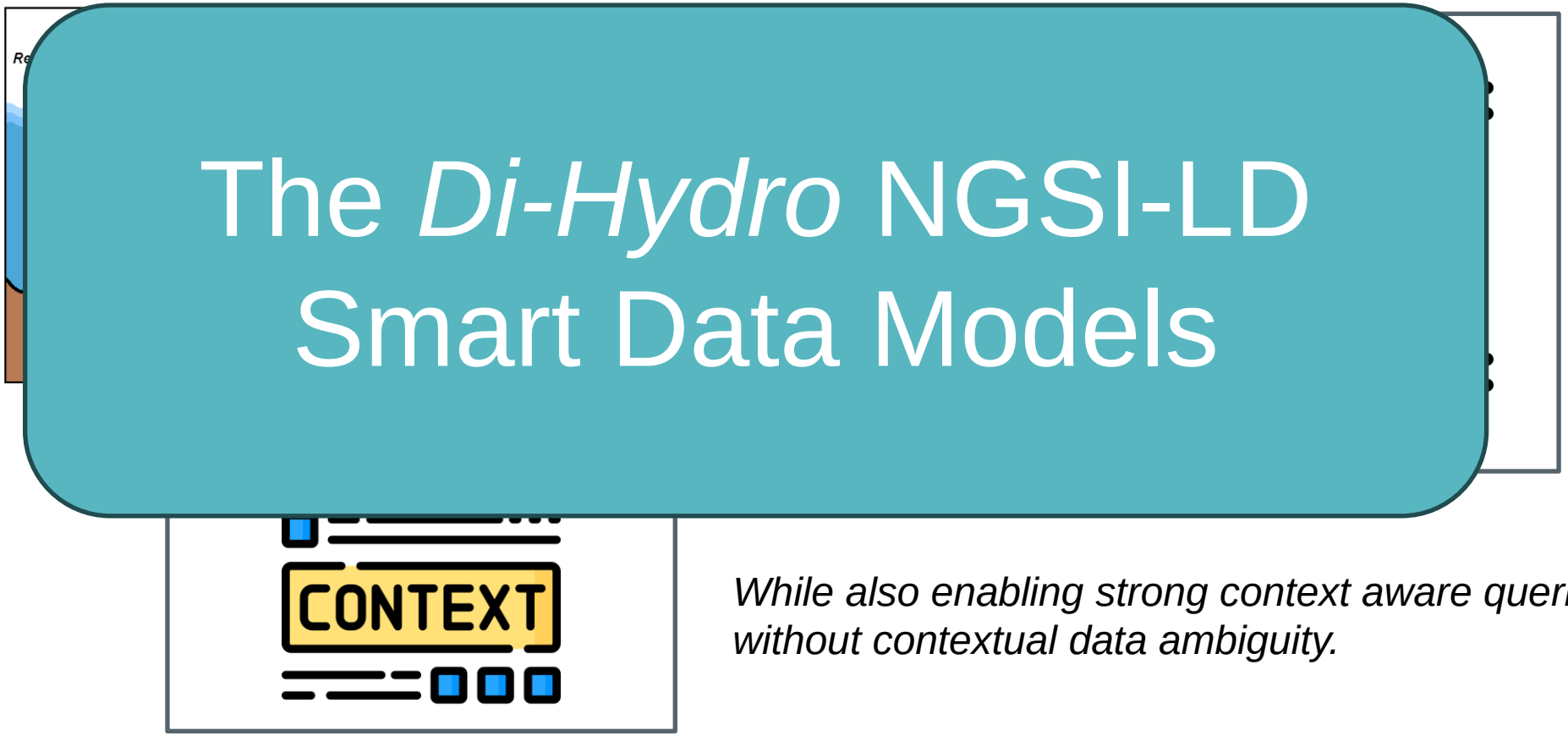
Context Ambiguity!

Country	"Small-scale hydro" hydropower plant capacity (MW)
Brazil	≤ 30
Canada	< 50
China	≤ 50
European Union	≤ 20
India	≤ 25
Norway	≤ 10
Sweden	≤ 1.5
United States	5-100

What we want to have…

A way to model the structural and operational components (Static Data) …

A way to model the IoT components, their measurements and their actuations (Dynamic Data) …



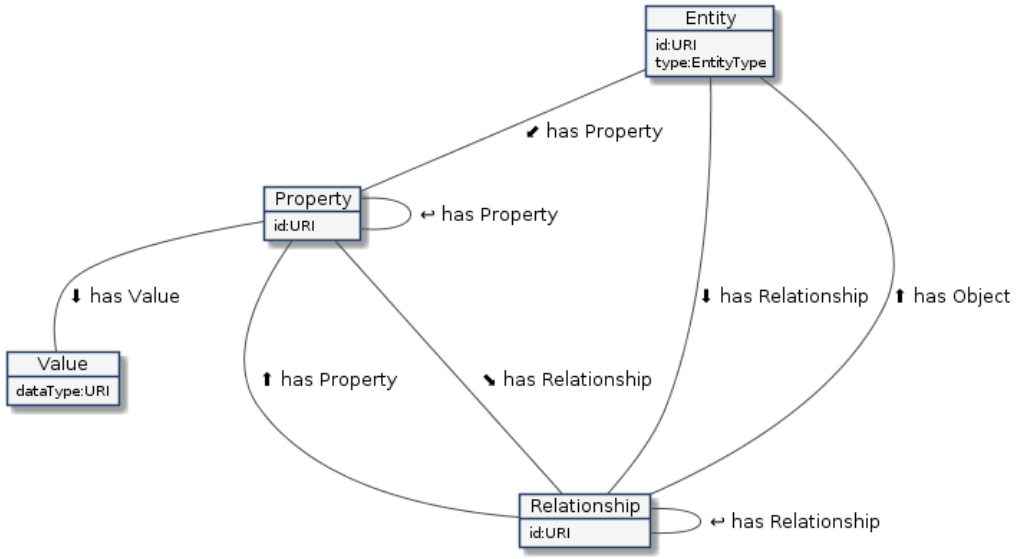
The *Di-Hydro* NGSI-LD Smart Data Models

While also enabling strong context aware queries without contextual data ambiguity.

NGSI-LD in a nutshell

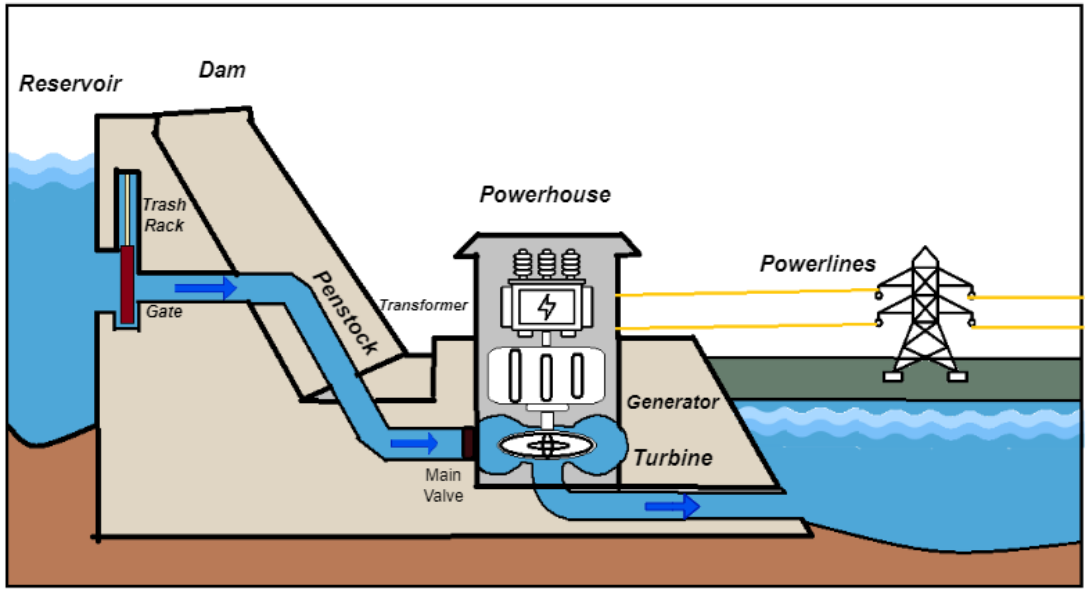
World Class Standards

JSON-LD

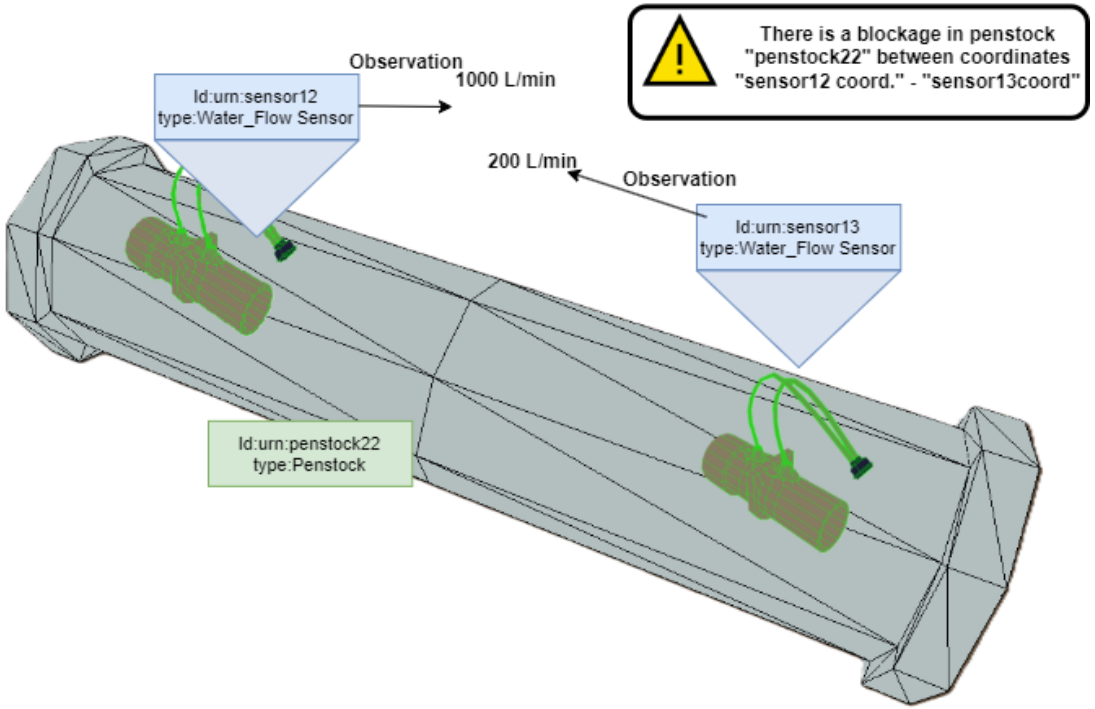


Two Types of Entities in Hydropower Data Modeling

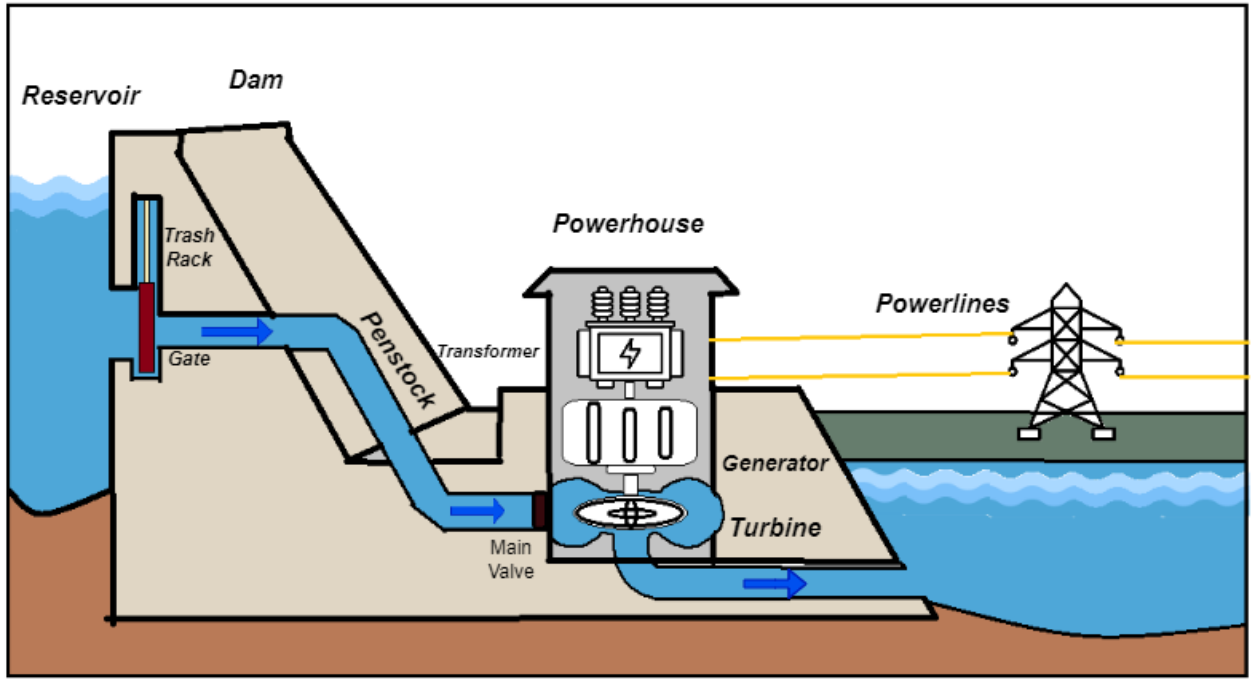
Static Data



Dynamic Data



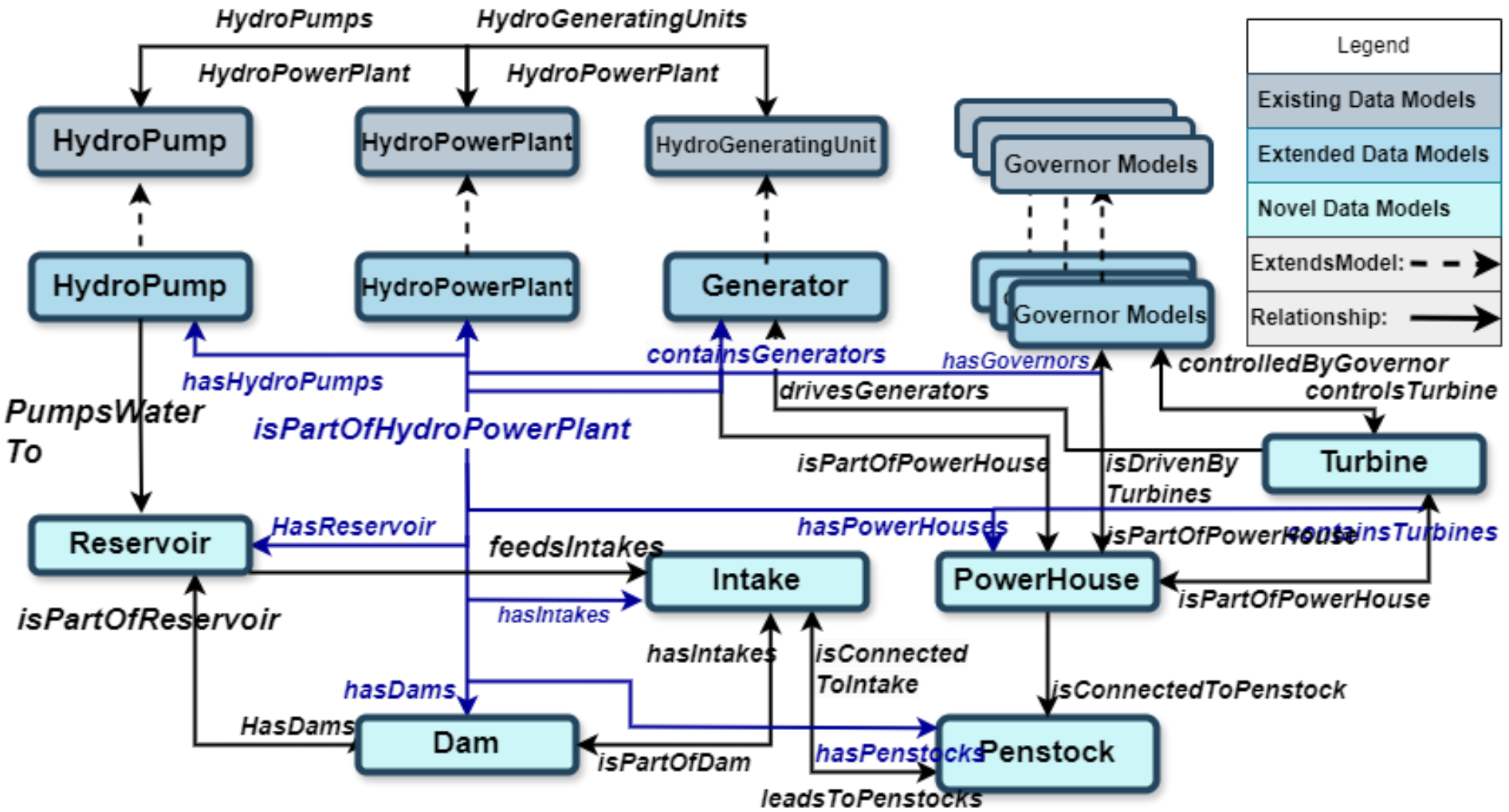
Di-Hydro Data Models: Static Data



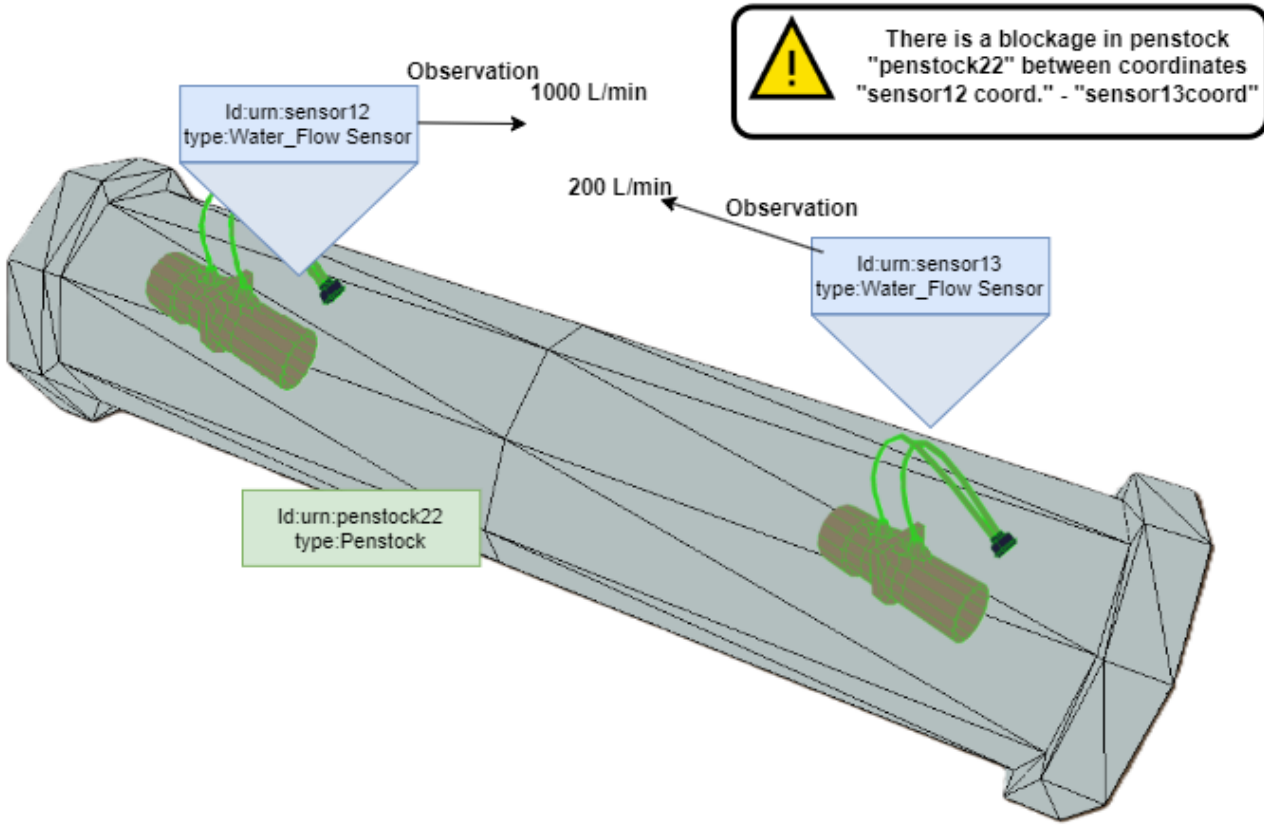

```
"id": "urn:ngsi-ld:Dam:001",
"type": "Dam",
"name": "Main Dam",
"damType": "Earthfill",
"damVolume": {
  "value": 8,
  "unitCode": "MCM"
},
"damHeight": {
  "value": 130,
  "unitCode": "MTR"
},
"damLength": {
  "value": 540,
  "unitCode": "MTR"
},
"context": "https://raw.githubusercontent.com/satrai-lab/di-hydro-data-models/main/context.jsonld"
```

"HydroPowerPlant has Dams"
and "Dam is part of HydroPowerPlant,"

Di-Hydro Data Models: Static Data



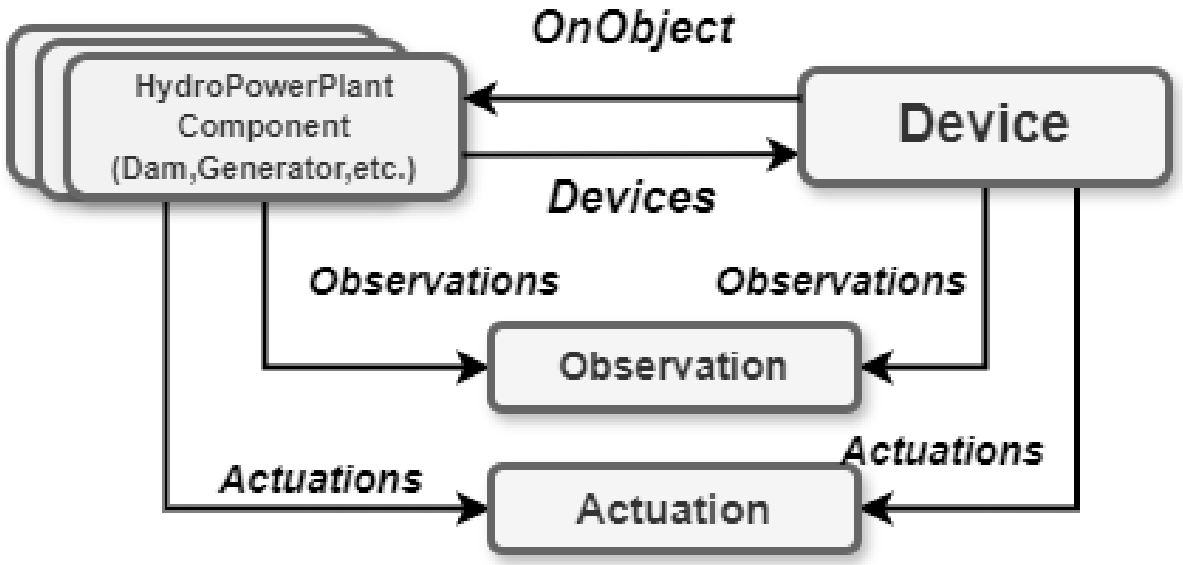
Di-Hydro Data Models: Dynamic Data




```
{ "id": "urn:ngsi-ld:WaterFlowSensor:001",
  "type": "WaterFlowSensor",
  "name": "Main Penstock Water Flow Sensor",
  "relativePosition": {
    "type": "Point",
    "measurementUnit": "m",
    "Dimensions": "3D",
    "coordinates": [45.0,9.0,3.0]
  },
  "OnObject": "urn:ngsi-ld:Penstock:001",
  "observations": "urn:ngsi-ld:Observation:WaterFlow:001",
  "context": "https://raw.githubusercontent.com/satrai-lab/di-
       hydro-data-models/main/context.jsonld"
},
{ "id": "urn:ngsi-ld:Observation:WaterFlow:001",
  "type": "Observation",
  "name": "Water flow rate measurement in Penstock Section 1",
  "category": "PhysicalObservation",
  "dateModified": "2024-07-17T13:20:30Z",
  "measurement": {
    "waterFlowRate": {
      "value": 120,
      "measurementUnit": "m^3/s"
    }
  },
  "measurementType": "waterFlow",
  "context": "https://raw.githubusercontent.com/satrai-lab/di-
       hydro-data-models/main/context.jsonld"}
```

Bouloukakis et al. IoT'22

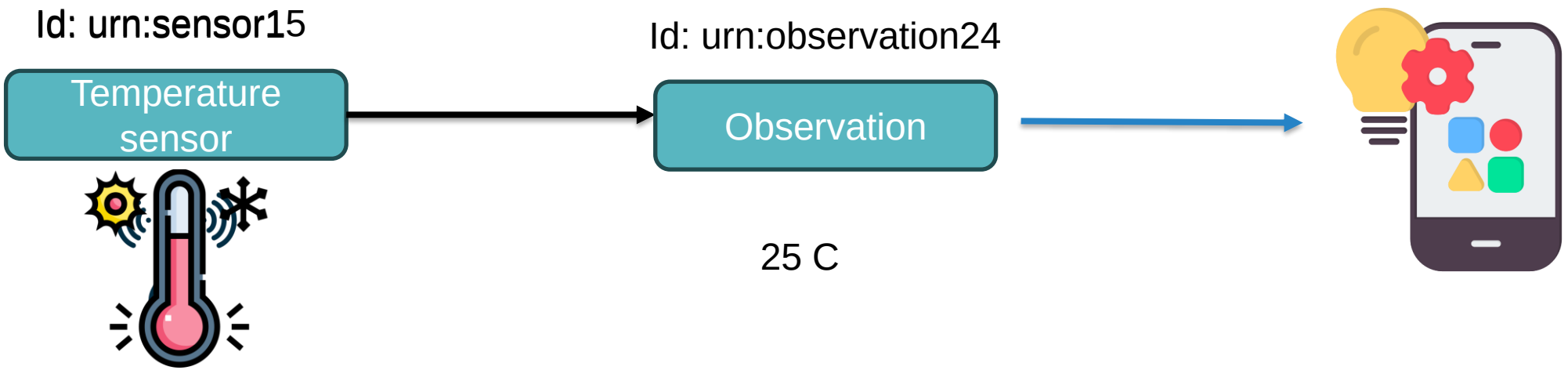
Di-Hydro Data Models: Dynamic Data



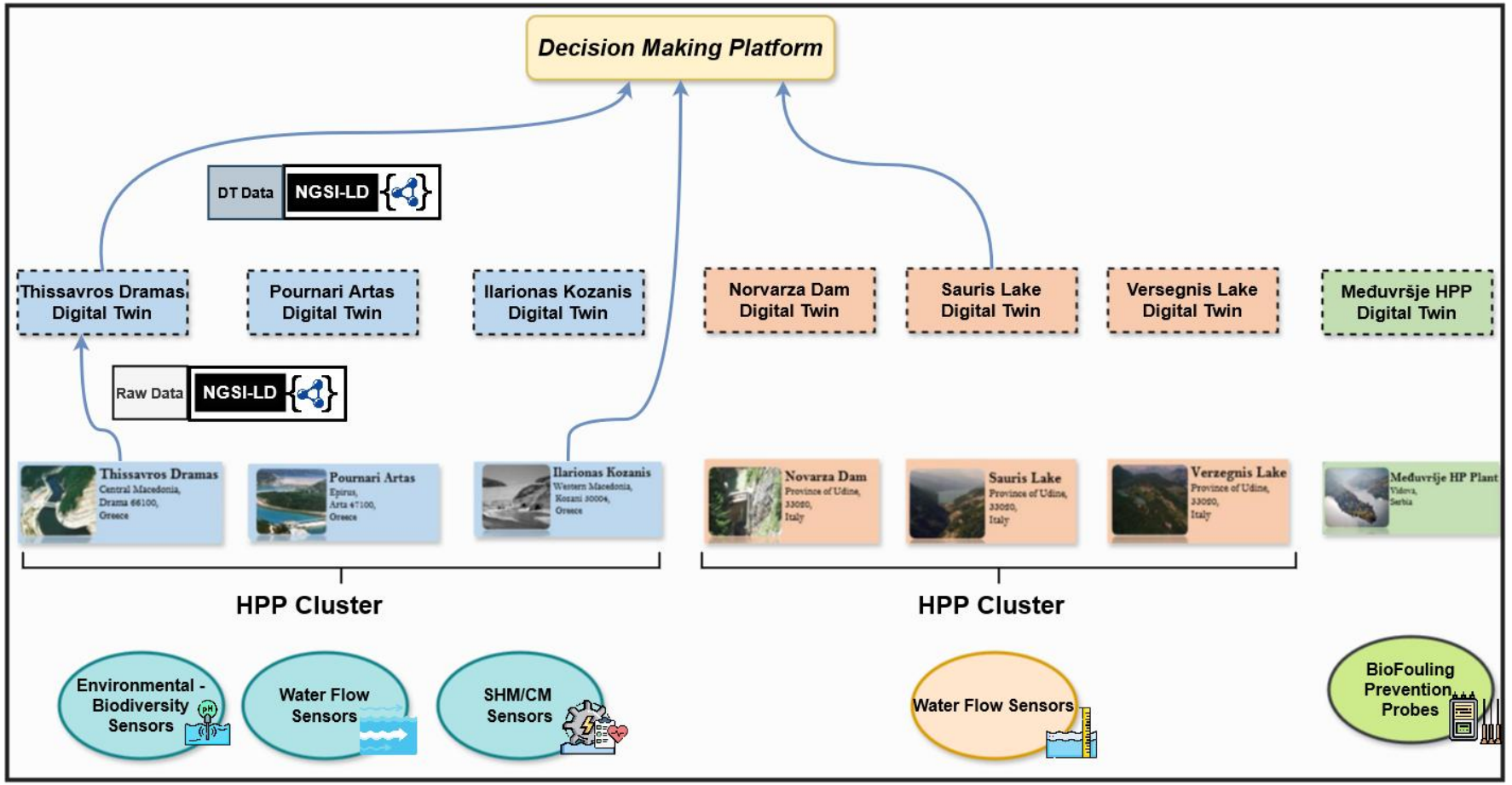
Based on Papadakis et. al. CSWI'2022

Decoupling of device data from observartions

Di-Hydro Data Models: Dynamic Data

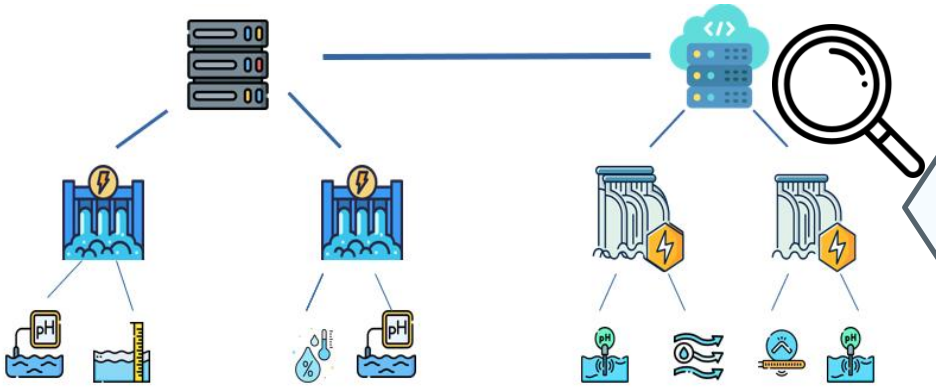


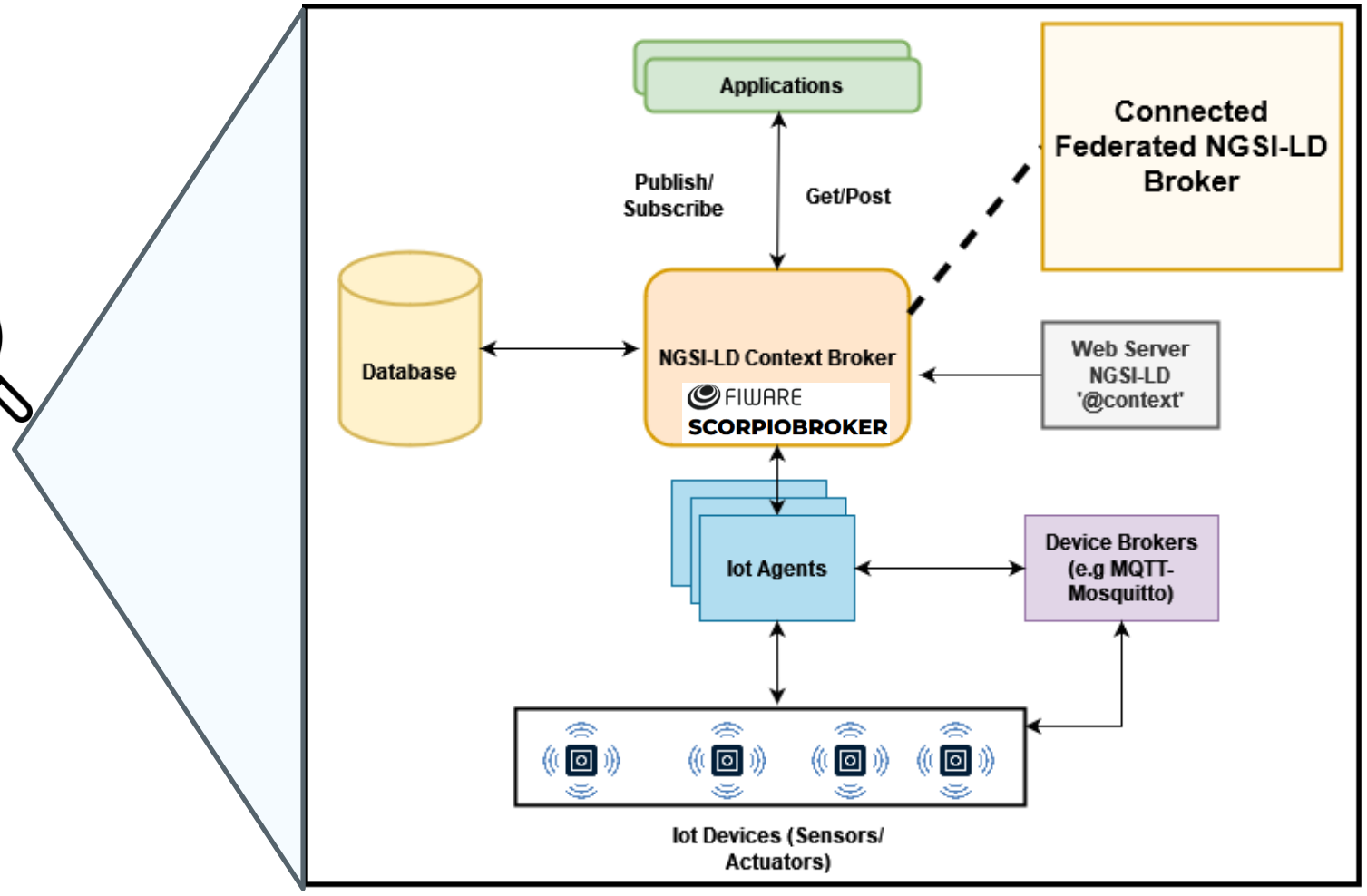
The Di-Hydro Envisioned Federated Ecosystem



Implementation in a Federated Context

Federated "Node" Design

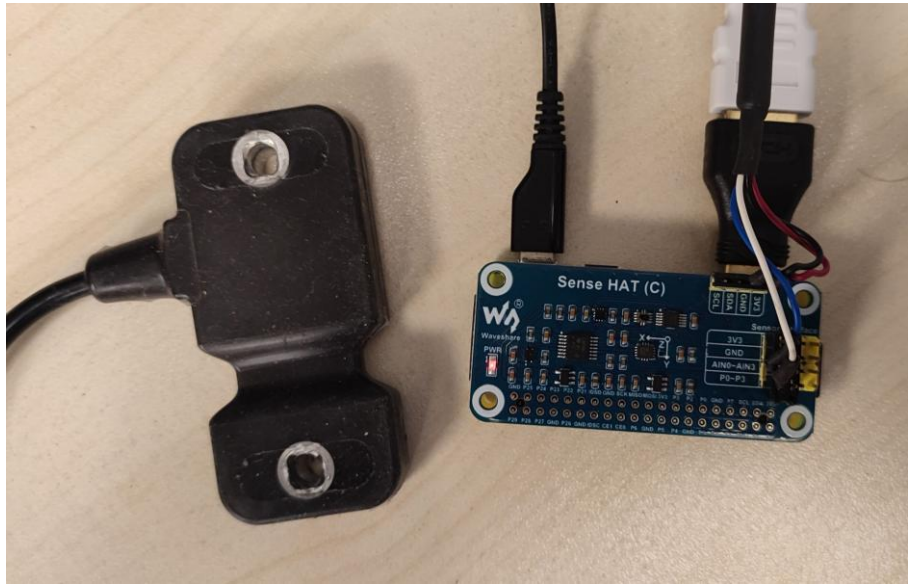




Modeled and deployed real Smart Hydropower Plant Data

Example "Anonymized" Version of Subset of technical description of Hydropower Plant data

	HPP A	HPP B	HPP C
Installed Capacity	160MW	380MW	310MW
Turbine type	Francis	Kaplan	Pelton
Num. of Turbines	2x80MW	4x95MW	3x103MW
Yearly production	340GWh	460GWh	250GWh
Net Head	105m	152m	85m
Dam Type	Rockfill	Rockfill	Arch Dam
Dam Volume	8.3m.c.m.	13.1m.c.m.	8.8m.c.m.
Dam Height	128m	168m	92m
Dam Length	550m	490m	570m
Reservoir Volume	408m.c.m.	683m.c.m.	712m.c.m.
Reservoir Useful Volume	315m.c.m.	570m.c.m.	299m.c.m.
Avg Yearly Water Intake	1027m.c.m	962m.c.m	1467m.c.m
Reservoir Min Op Lvl	367m	322m	101m
Reservoir Max Op Lvl	397.5m	378m	122m
Reservoir Max lvl	401m	384.8m	127m



Multi sensor module and crack growth meter

“Validation”, examples of enabled Queries

NGSI LD

Query: Get Real-Time and Historical Water Flow Rate Measurements for a Specific Penstock. Filtering by Date Range:

```
curl -X GET 'serveraddr/ngsi-ld/v1/entities/urn:ngsi-ld:
      Penstock:001?attrs=observations'
curl -X GET 'serveraddr/ngsi-ld/v1/entities/?type=
      Observation&id=urn:ngsi-ld:Observation:WaterFlow:001,
      urn:ngsi-ld:Observation:WaterFlow:002&attrs=
      measurement.waterFlowRate&options=temporalValues&
      timerel=between&time=2024-07-01T00:00:00Z&endTime
      =2024-07-31T23:59:59Z'
```

Query: Find all turbines and their efficiency metrics within a specific powerhouse’ showing which governors control them:

```
curl -X GET 'serveraddr/ngsi-ld/v1/entities/?type=Turbine&q
      =isPartOfPowerHouse==urn:ngsi-ld:PowerHouse:001&attrs=
      efficiency,controlledByGovernor'
```

Query: Retrieve all dams and their properties within a specific hydropower plant:

```
curl -X GET 'serveraddr/ngsi-ld/v1/entities/?type=Dam&q=
      isPartOfHydroPowerPlant==urn:ngsi-ld:HPP:001'
```

The Road Ahead…

Continuous refinement and feedback from partners

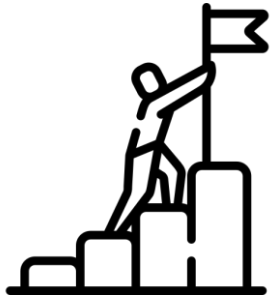
Today!

Di-Hydro Data Model V 0.1

The future

Di-Hydro Data Model V 1.0

Available as Open Source!



Industry Adoption

Thank you all for Listening! Let's Stay in Touch

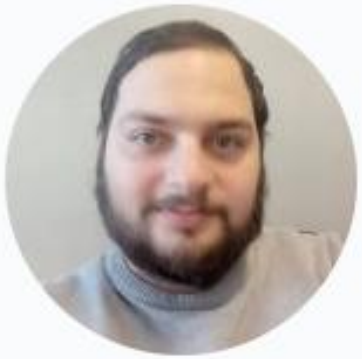
Di-Hydro

@DiHydro_project

Di-Hydro Project - Digital optimisation for hydropower plants

SATRAI

Check out our Lab and more of our works !



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