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2ND BUILDING DIGITAL TWIN International Congress

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# “Simulation a BDT process”


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*Market manager of Buildings and Infrastructure*


ORGANIZED BY:

BUILDING DIGITAL TWIN ASSOCIATION

SPHERE


THIS PROJECT HAS RECEIVED FUNDING FROM THE EUROPEAN UNION'S H2020 PROGRAMME UNDER GRANT AGREEMENT NO. 820805.

Urban Ecosystem

# AREAS OF ACTION & VISION

CIRCULAR ECONOMY

SMART ECO-MATERIALS

SMART INFRASTRUCTURES

SMART BUILDINGS

URBAN MOBILITY

ENERGY EFFICIENCY FOR BUILDINGS AND CITIES

HEALTHY CITY

RESILIENCE AND CLIMATE CHANGE

URBAN AND TERRITORIAL TRANSFORMATION

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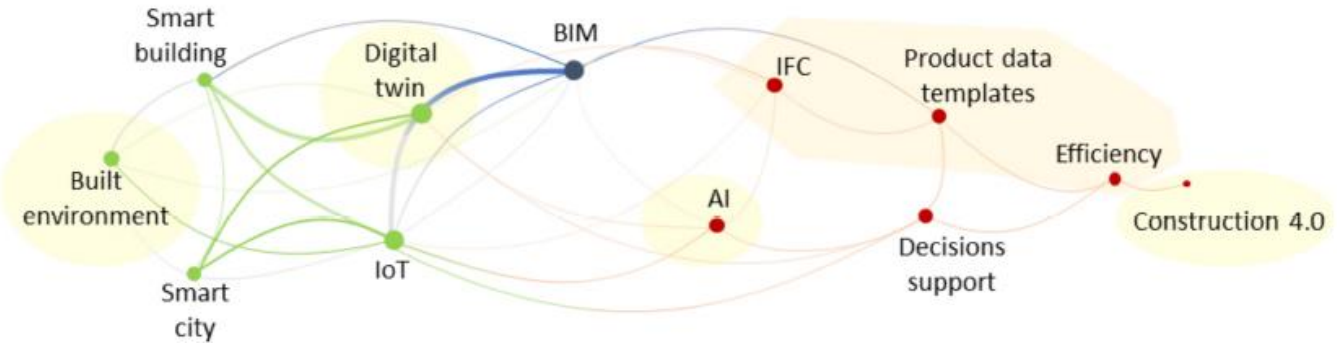
# What is a Building Digital Twin?






**A Digital Twin can model:**

- **A component**
- **A system of components**
- **A system of systems**

*A **Digital Twin** is an up-to date representation of an actual physical asset in operation or in construction process.*

*DT can be used to evaluate the current conditions of the asset and, more importantly predict future behavior, refine the control, or optimize operation It can be used in all building life cycle.*

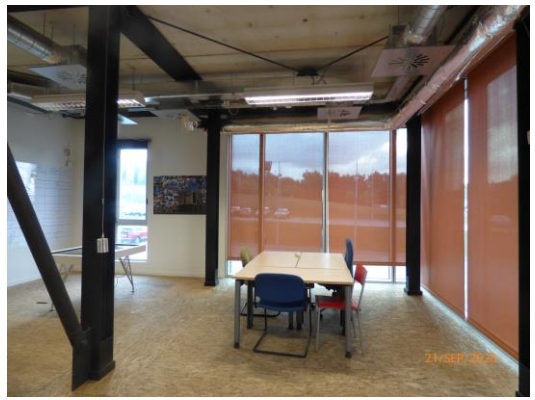
**With a BDT several predictive simulations could be done:**

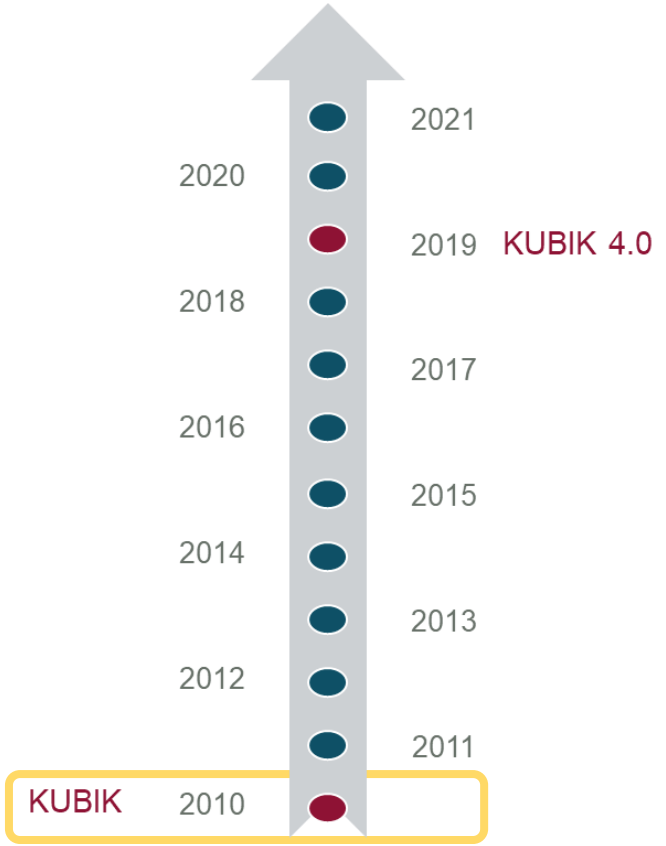
- **Energy predictions**
- **Construction processes**
- **Safety and security predictions**
- **….**

# What is KUBIK?

KUBIK by tecnalia

**KUBIK IS A FULL-SCALE R&D TEST FACILITY FOR THE DEVELOPMENT OF NEW CONCEPTS, PRODUCTS AND SERVICES IN ORDER TO IMPROVE ENERGY EFFICIENCY IN BUILDINGS.**






- KUBIK was born in 2010. The building has 3 floors, basement and roof
- Kubik has the experimental capabilities to realistically reproduce the real building operating conditions:
  - Constructive Solutions
  - Intelligent management of air conditioning and lighting systems
  - Supply from conventional and renewable energies (geothermal, solar and wind)
- Monitoring and control system that provides the necessary information for the development of I+D+i activities.
- KUBIK allows to develop and validate innovative products and systems to optimize energy efficiency in buildings, from its conceptualization to its implementation.

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# What is KUBIK?

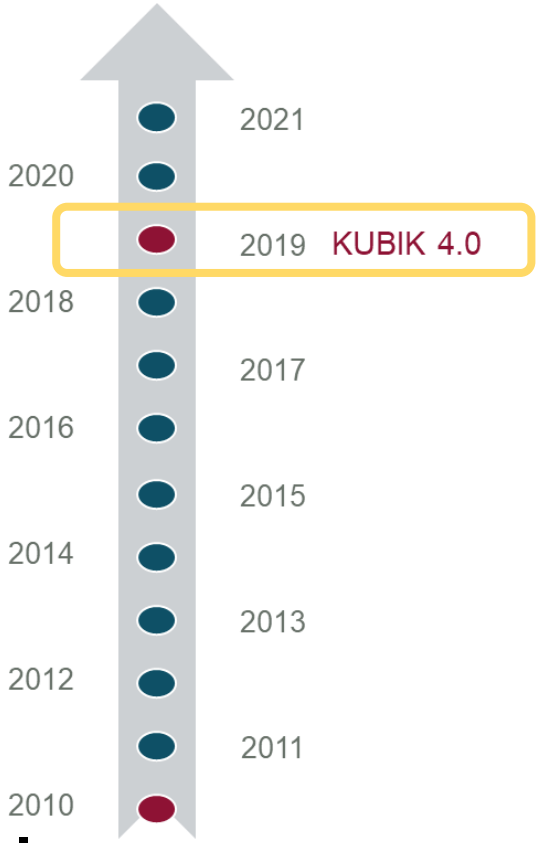
# What KUBIK has been transformed ?



KUBIK by tecnalia

**EXPERIMENTAL INFRASTRUCTURE FOR THE DEVELOPMENT OF NEW CONCEPTS, PRODUCTS AND SERVICES FOR THE IMPROVEMENT OF ENERGY EFFICIENCY, SAFETY, QUALITY OF LIFE AND INTERACTIVITY IN BUILDINGS**

DIGITAL TWIN




DIGITAL TWIN KUBIK is the first Building that has a complete **DYNAMIC AND VIRTUAL** model of the Building.

Real-time reflection of the status and evolution of any activity that occurs in the real building

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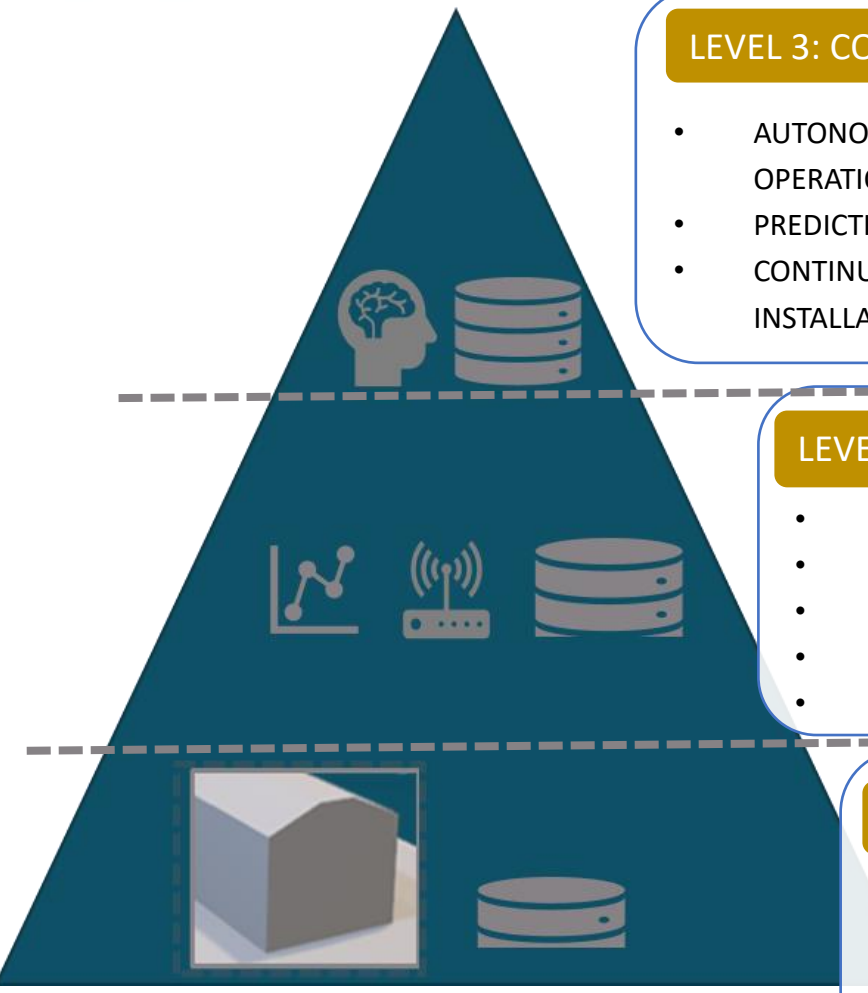
# Holistic Approach





## LEVEL 3: COGNITIVE BUILDING

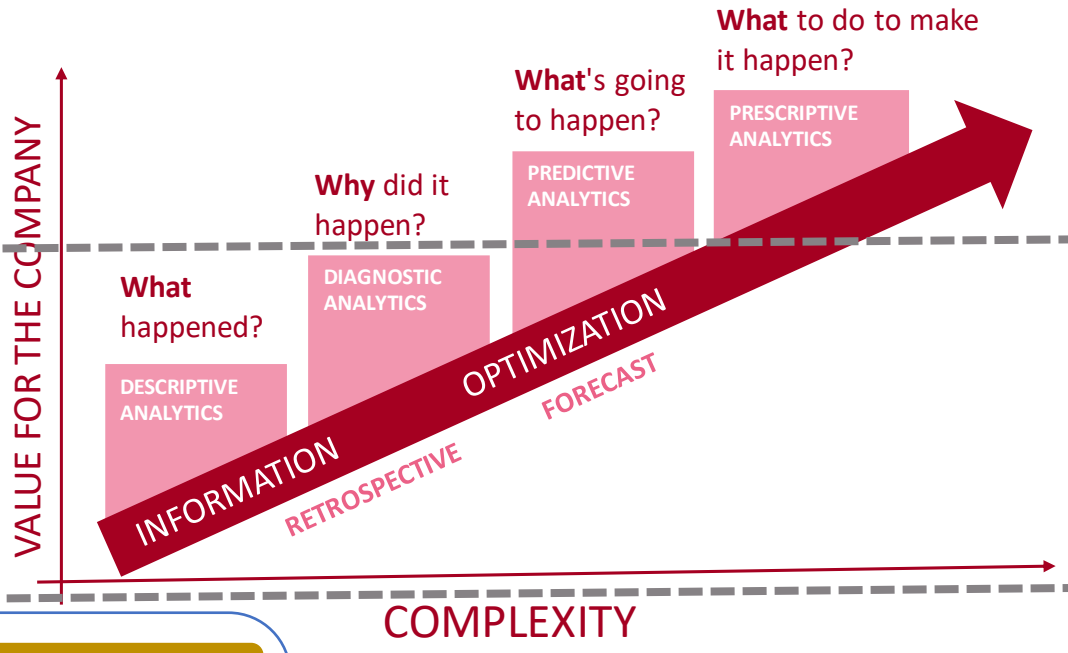
- AUTONOMOUS INTELLIGENT INTEGRAL OPERATION WITH AI (Machine Learning)
- PREDICTIVE MAINTENANCE
- CONTINUOUS OPTIMIZATION OF ENERGY INSTALLATIONS

## LEVEL 2: ANALYTICAL BUILDING

- IoT
- BIG DATA
- BMS
- CMMS
- MODELLING

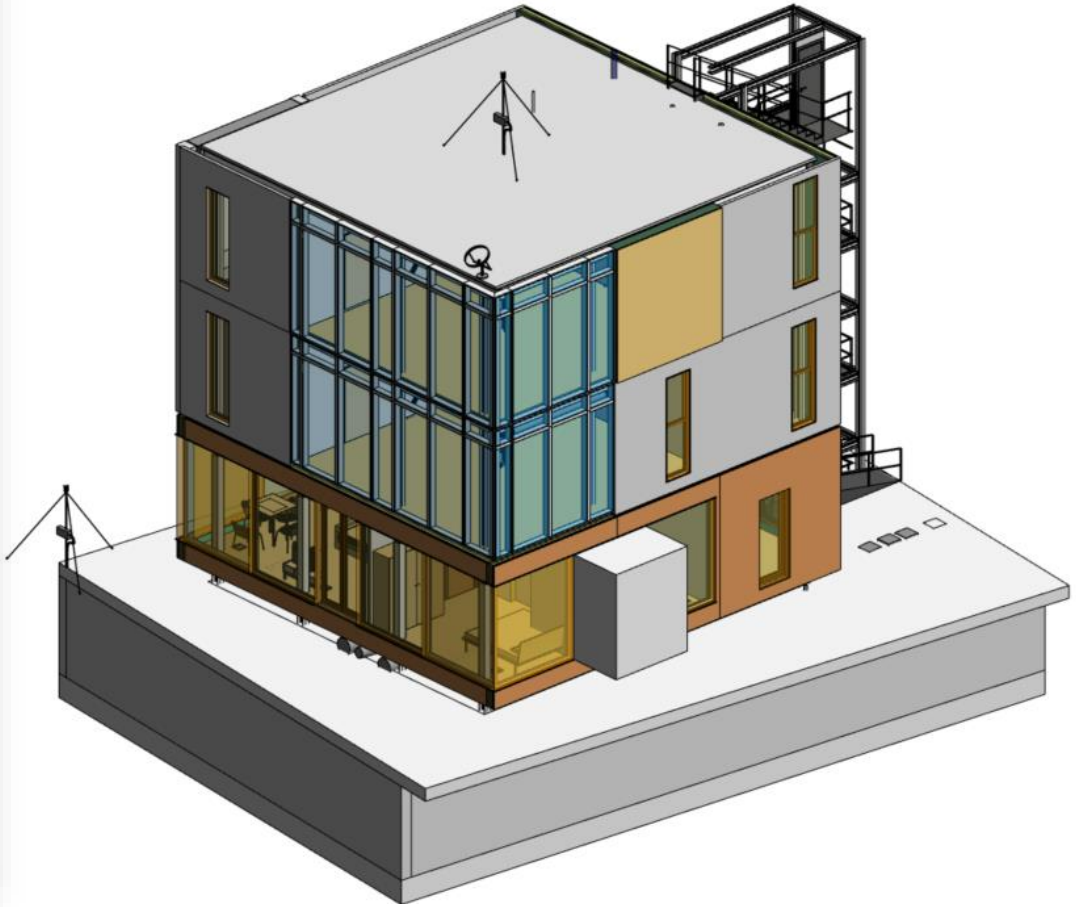
## LEVEL 1: DIGITAL BUILDING

- INTUITIVE ITERATION WITH 3D MODEL (BIM) AND STATIC INFORMATION VISUALIZATION
- AR / VR
- PLATFORM FOR PROCESS MANAGEMENT AND DOCUMENTAL MANAGEMENT



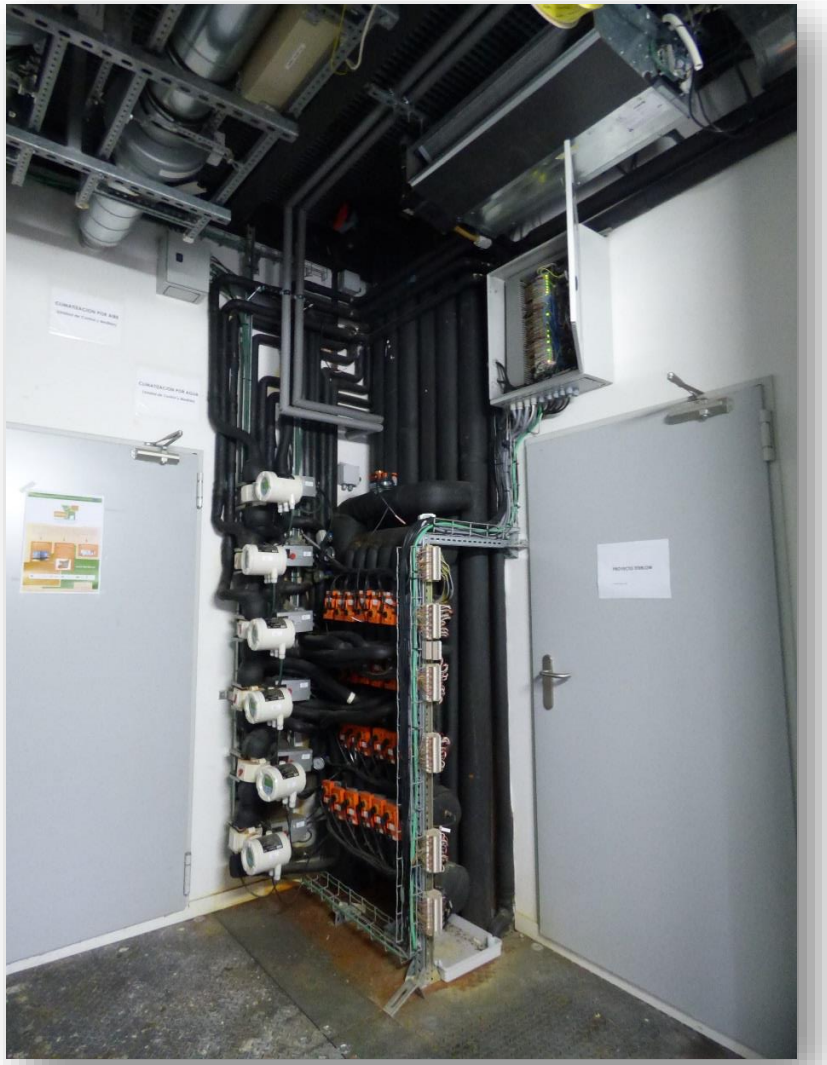
# LEVEL 1: Digital Building

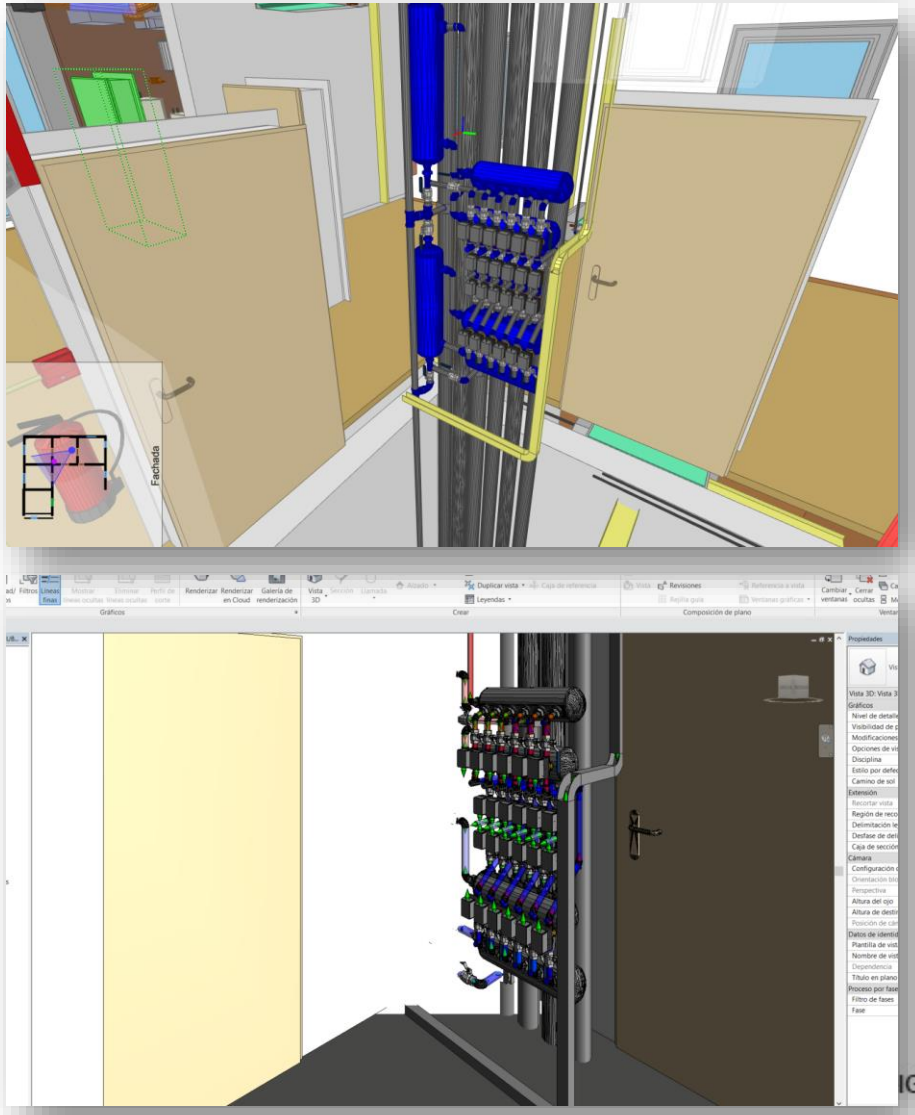
INTUITIVE ITERATION WITH 3D MODEL (BIM) AND STATIC INFORMATION VISUALIZATION



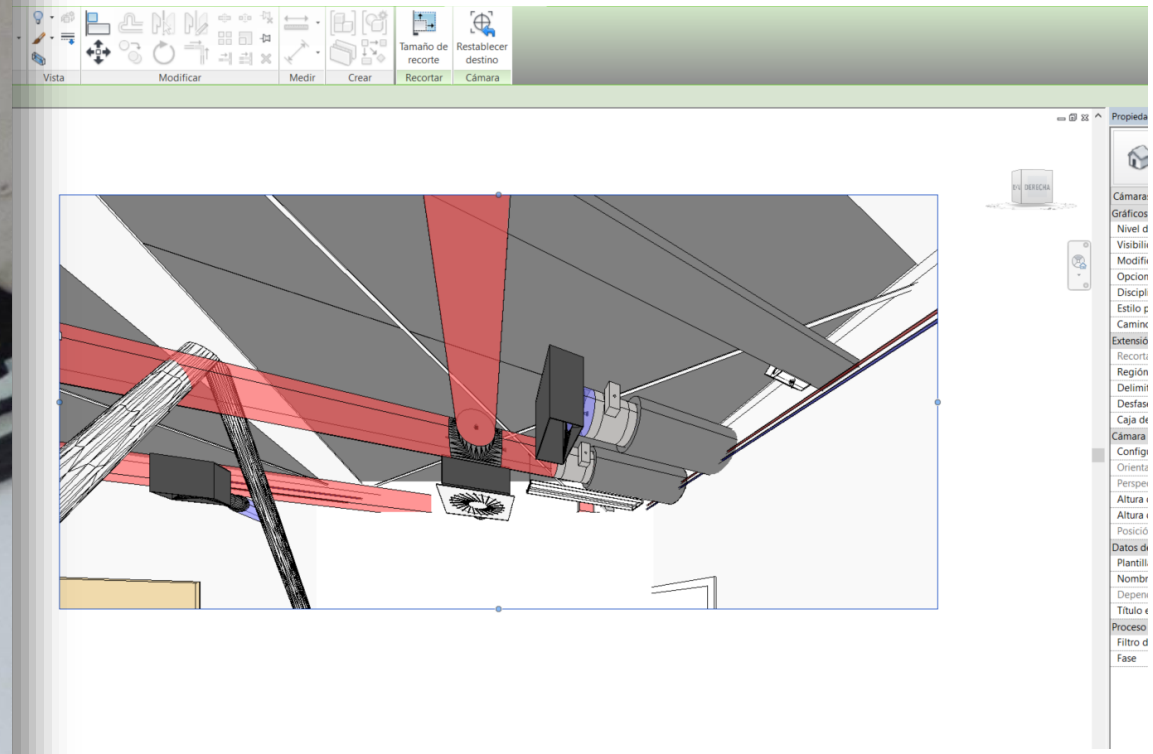
# LEVEL 1: Digital Building





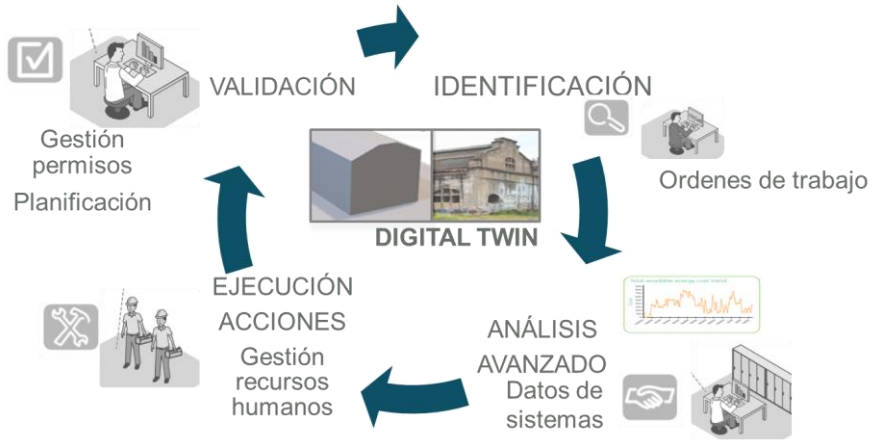


# LEVEL 1: Digital Building

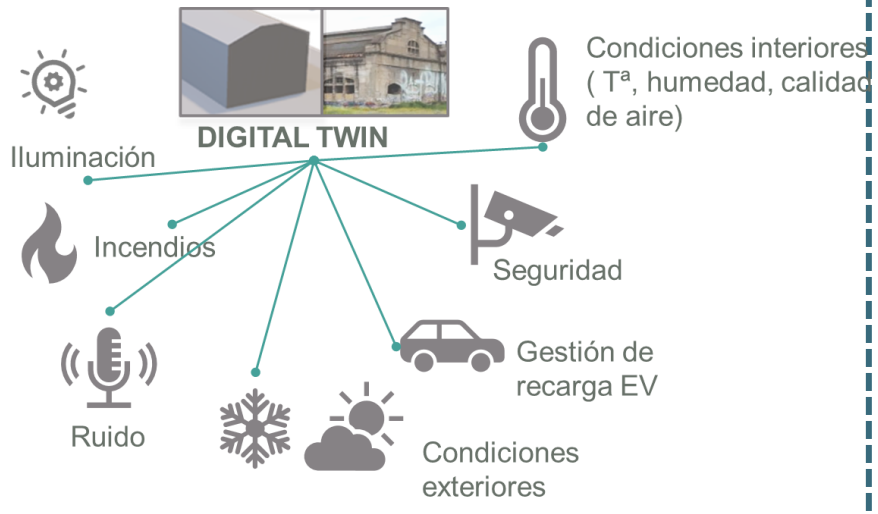


# LEVEL 2: Analytical Building

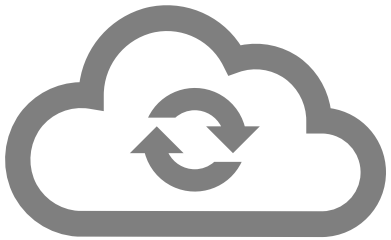




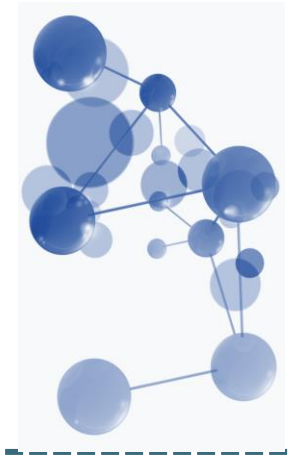

## GMMS CONNECTION




## BMS CONNECTION



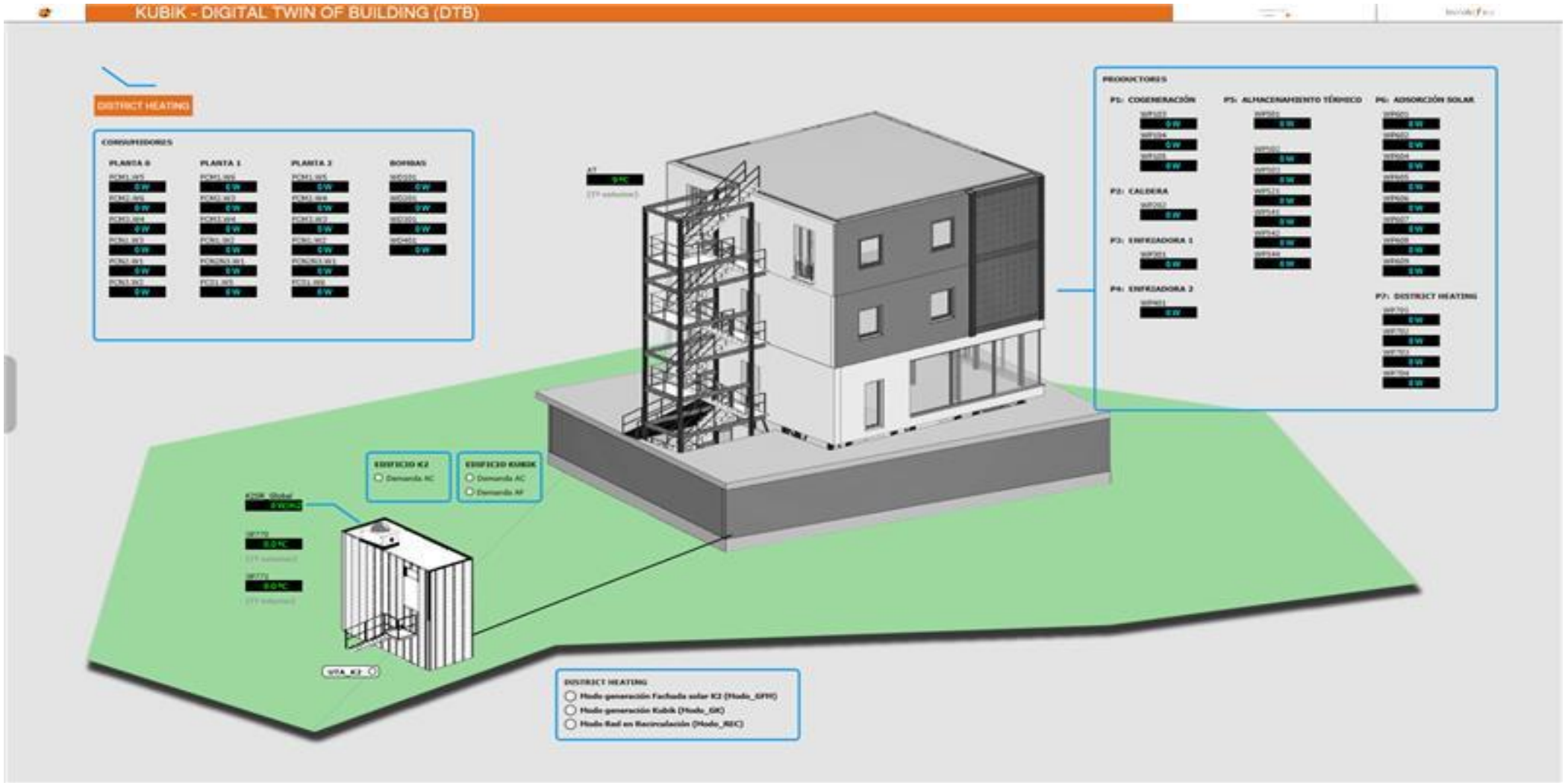
## IoT



## MODELING

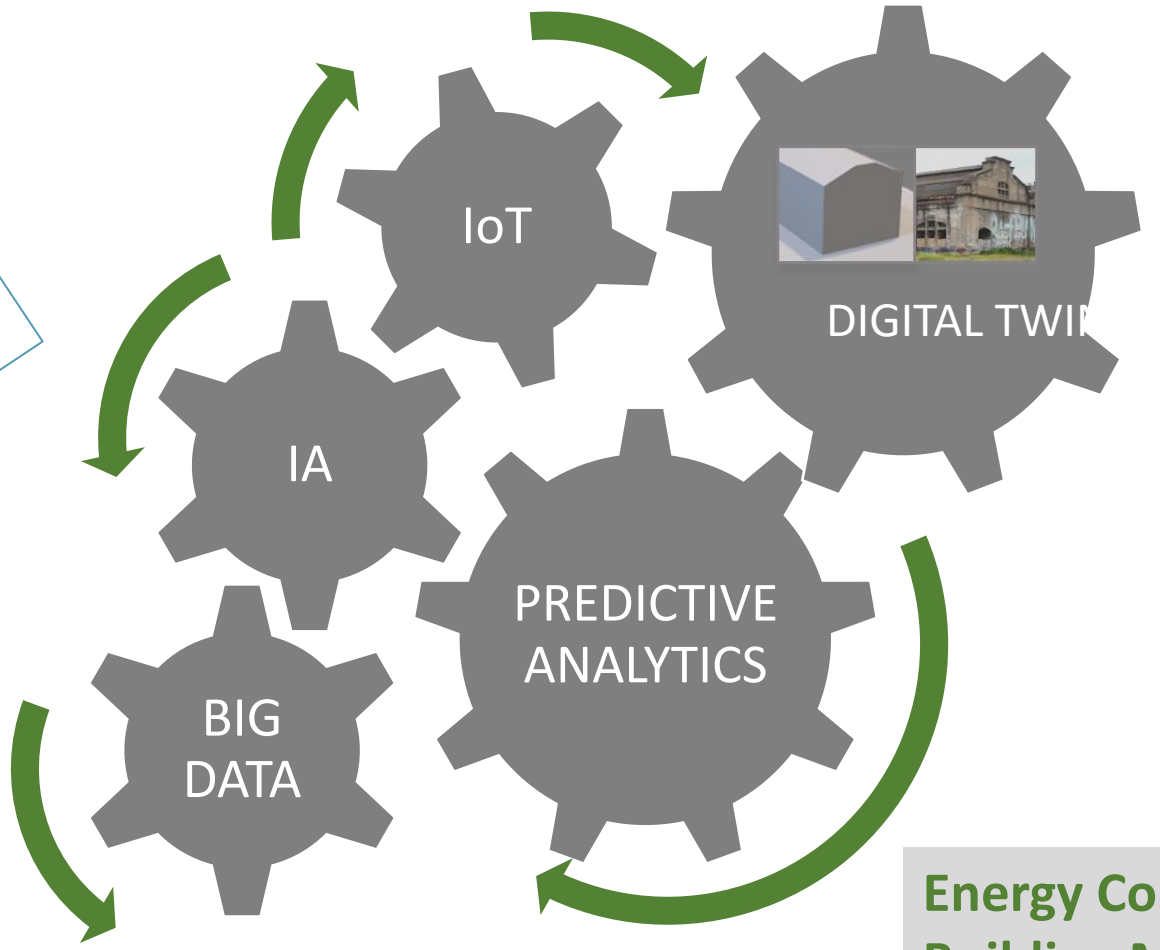
# LEVEL 2: Analytical Building





# LEVEL 3: Cognitive Building

**Owner**
**Operator**
**Manager**




**SMART BUILDING MANAGEMENT SYSTEM OF OPERATION AND MAINTENANCE WITH CONTINUOUS OPTIMIZATION (O&M)**

**Energy Consumption - 40 %**
**Building Maintenance - 20 %**

# LEVEL 3: Cognitive Building



## DIGITAL TWIN: ADVANCED SERVICES. **Digital Twin overview.**

- The Digital Twin of TECNALIA is deployed as an additional layer on top of the SCADA/BEMS system of the buildings to supervise, without human intervention, the operation and maintenance of all the systems.
- This DT incorporates an **energy management optimization service** and a **predictive maintenance service**.
- The energy management optimization service based on a **Model Predictive control approach** provides continuous commissioning and flexible load (thermal and electric) management optimization functionalities to minimize energy consumption and maximize Distributed Energy Resources coverage.
- Functionalities of the the predictive maintenance service:
  - Diagnosis: Detection and classification of the most relevant failure types for each equipment.
  - Anomaly detection: Detection of faulty operation created by unclassified faults.
  - Automatic labelling algorithms to generate incremental diagnosis capabilities.
  - Prognosis: Prediction of the remaining useful life (to optimize maintenance interventions)

# LEVEL 3: Cognitive Building



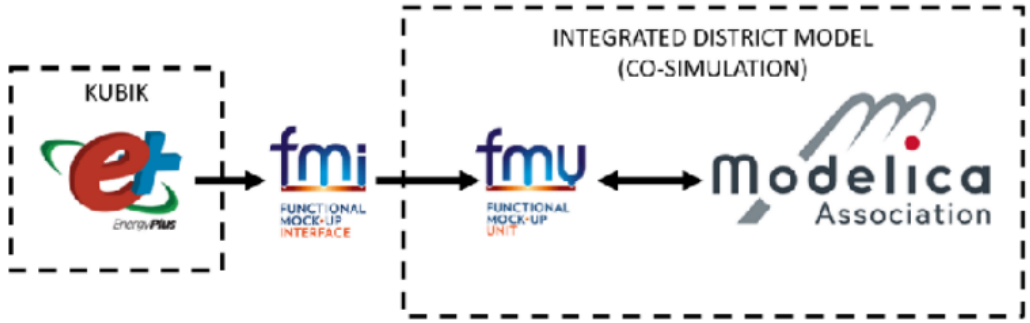
## PREDICTIVE MAINTENCE SERVICE. Development of predictive maintenance functionalities

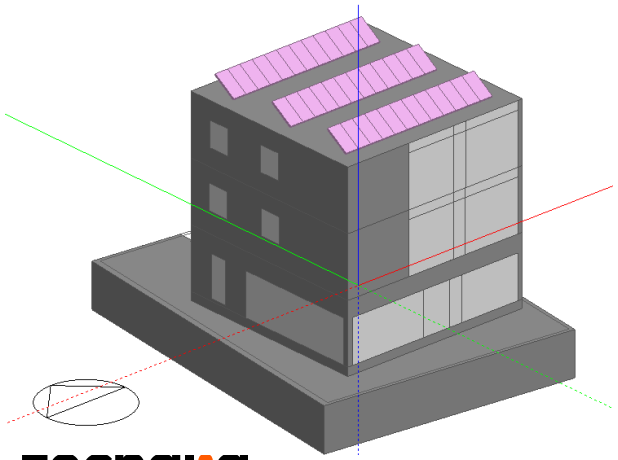
- Limitations of physics based models:
  - A comprehensive knowledge of the physic domain is necessary (expert knowledge).
  - Applicable only to relatively simple equipment due to their complexity and the high development effort.
- Limitations of data driven models:
  - Data scarcity particularly in relation to equipment faulty operation and labelled data.
  - Limitations of unsupervised ML methods to provide diagnosis functionalities when the number of considered fault types is not small (in relation to supervised ML algorithms).
  - Reinforcement Learning not feasible due to equipment damage risk during the agent training stage.
- **Alternative. Hybrid Models (physics informed/constrained models)**
  - Predictive maintenance metamodels (anomaly detection, diagnosis and prognosis) developed through the combined use of energy performance physics based models (Modelica) and machine learning techniques (supervised for diagnosis and unsupervised for anomaly detection).

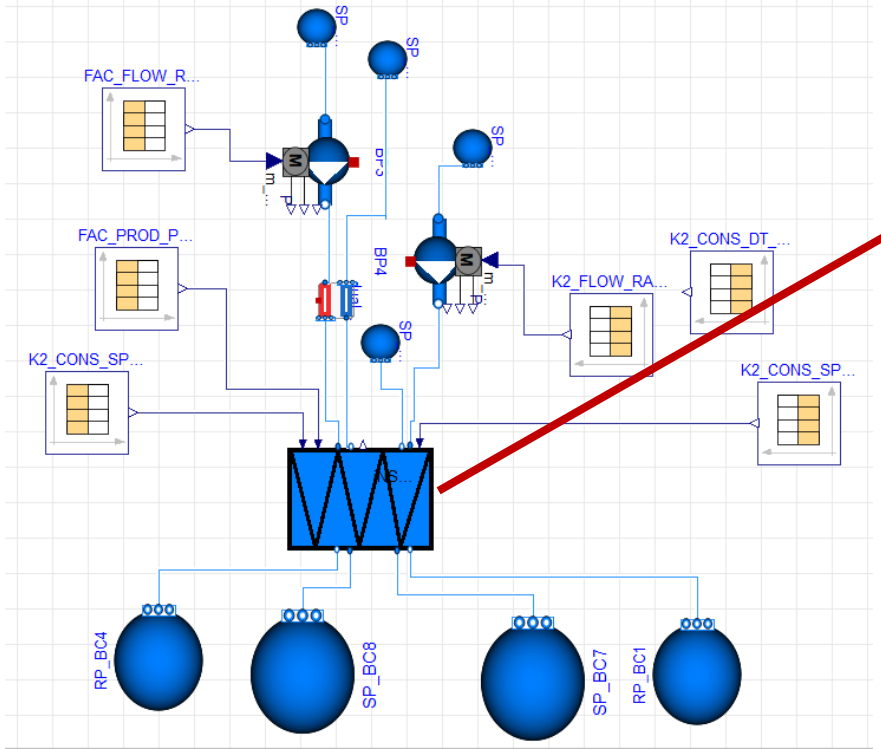
# LEVEL 3: Cognitive Building

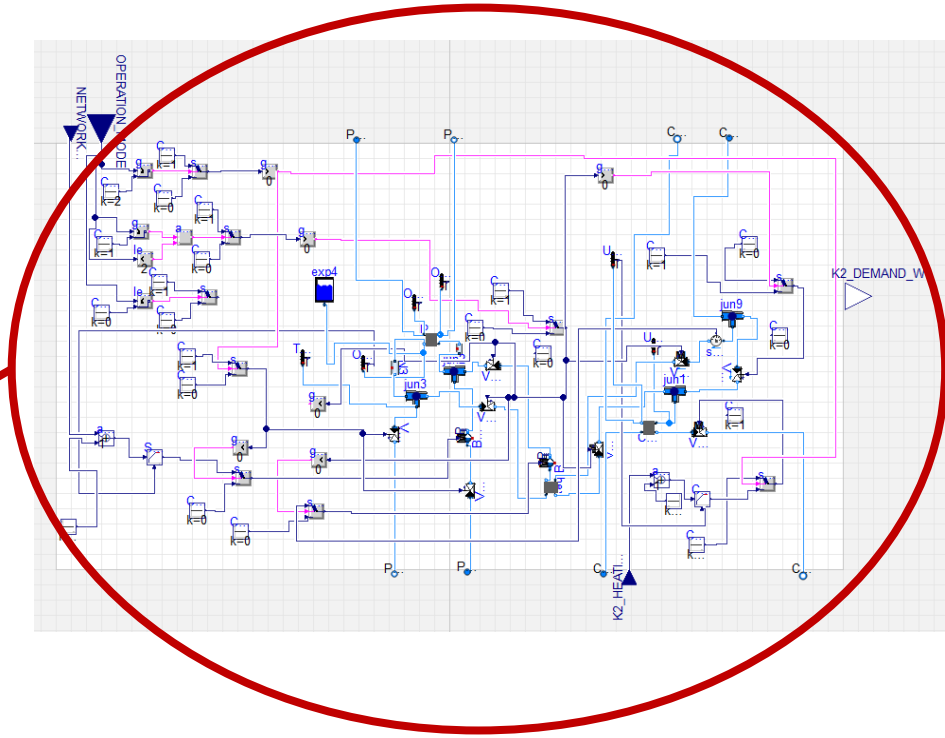
## PREDICTIVE MAINTENCE SERVICE

### PREDICTIVE MAINTENANCE METAMODEL DEVELOPMENT PROCESS



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# LEVEL 3: Cognitive Building





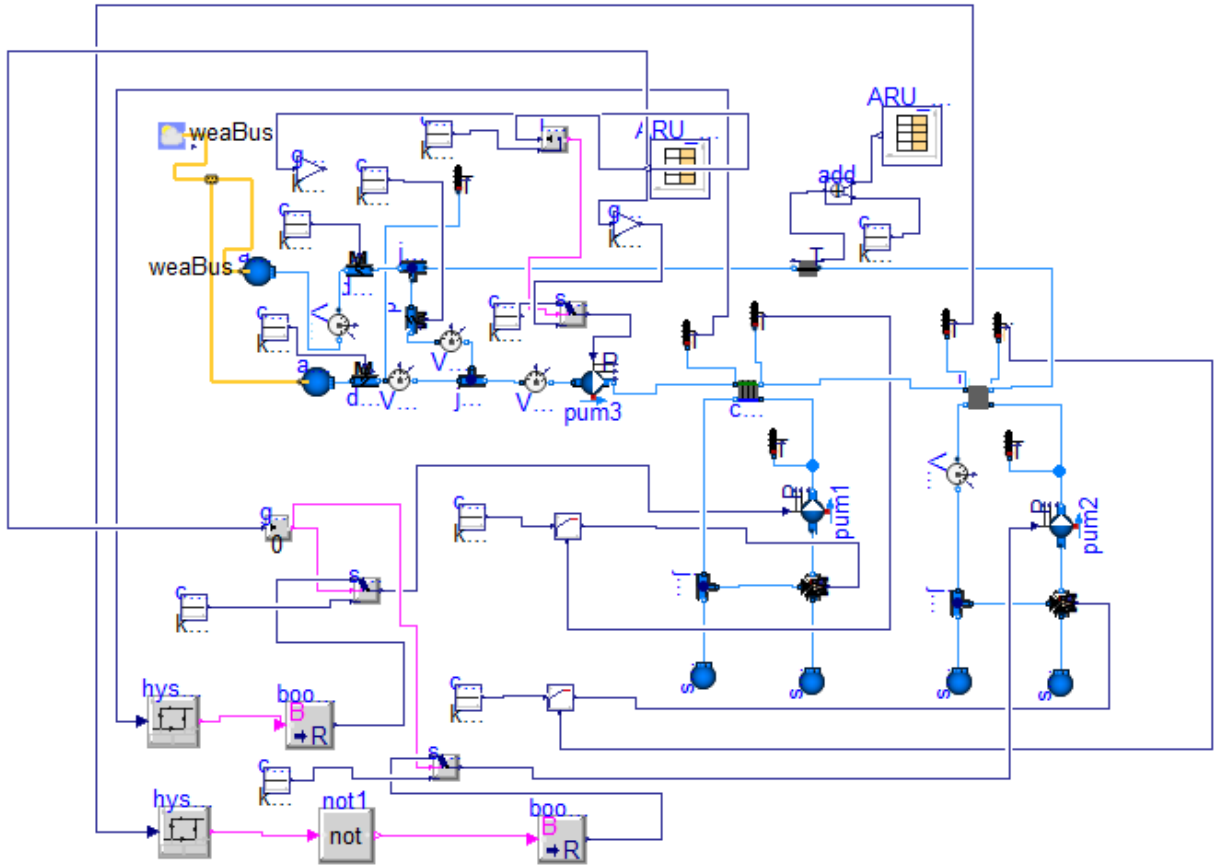
## PREDICTIVE MAINTENCE SERVICE. Predictive Maintenance metamodel development process

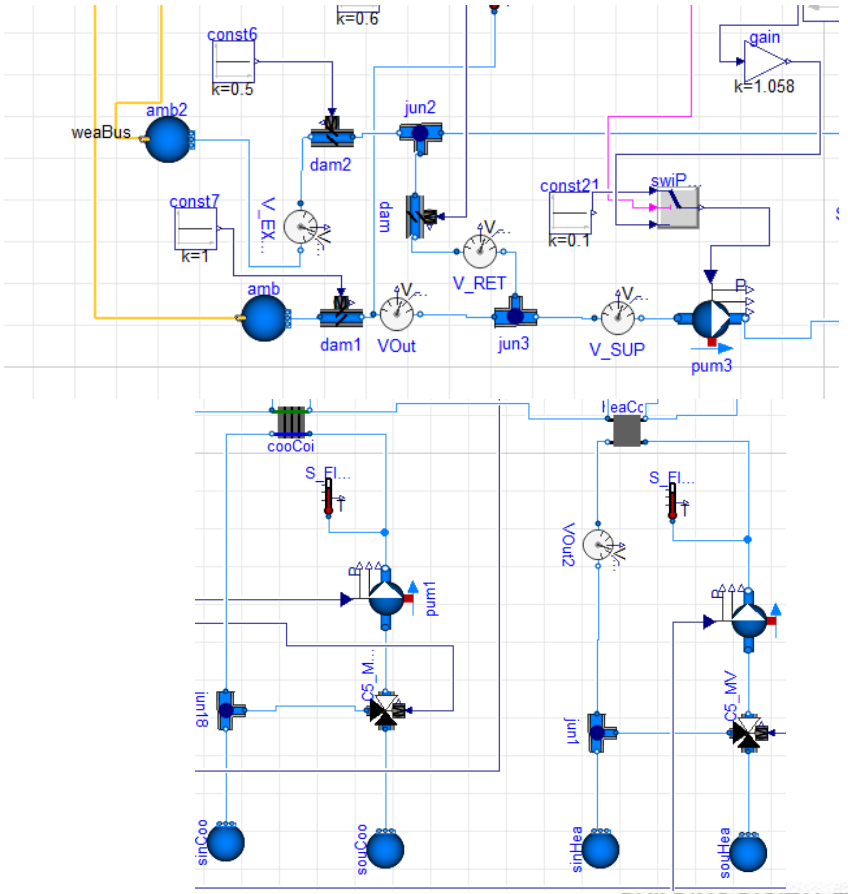
- Definition of the Modelica models of the evaluated equipment/system.
- Identification of the faults relevant to each equipment type (including different severity levels).
- Definition and simulation of dedicated simulation sets to address all the relevant fault types to produce the synthetic data required to generate the predictive maintenance metamodels.
- Feature engineering (feature selection or feature extraction) to optimize the feature space relevant for each equipment (dimensionality reduction through unsupervised methods, PCA, etc).
- Selection of the most suitable machine learning algorithm for each equipment and functionalities.
    - Diagnosis: Support vector machine, different architectures of ANNs (shallow and deep), ensembles of more simple methods.
    - Anomaly detection: One class SVM, etc.
- Ongoing development of predictive maintenance functionalities for Air Handling Units, heat pumps and chillers, boilers and building thermal substations for DH systems

# LEVEL 3: Cognitive Building

## PREDICTIVE MAINTENCE SERVICE

**Anomaly detection and diagnosis metamodels for AHUs.**



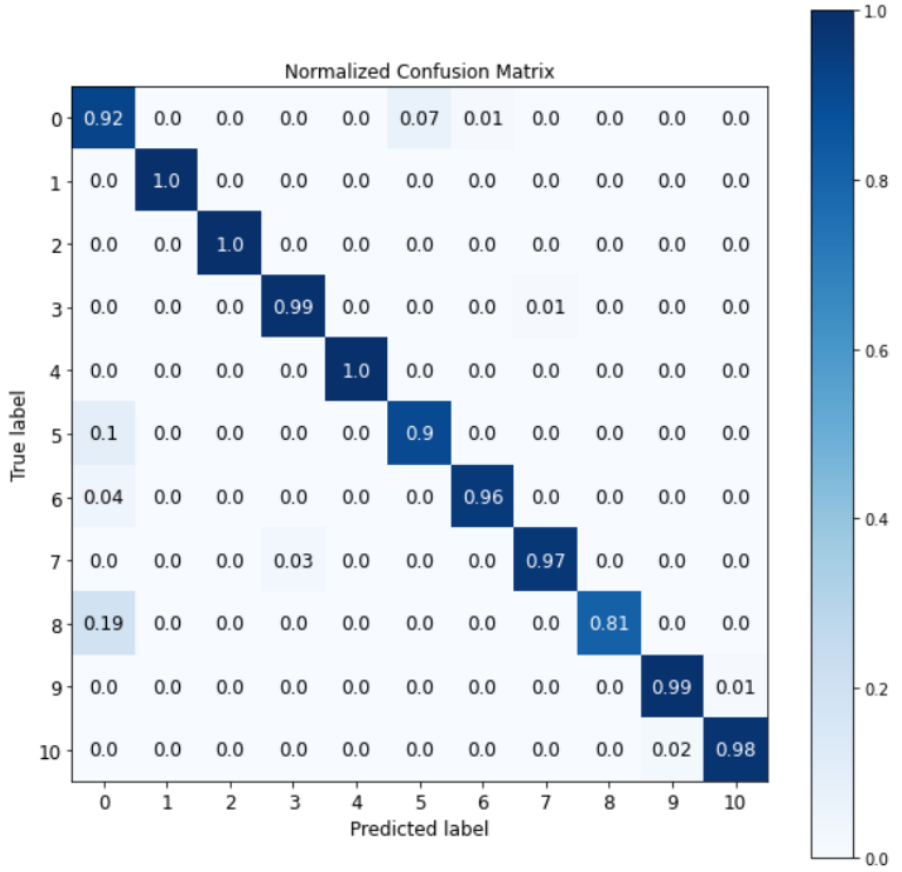



# LEVEL 3: Cognitive Building

PREDICTIVE MAINTENCE SERVICE

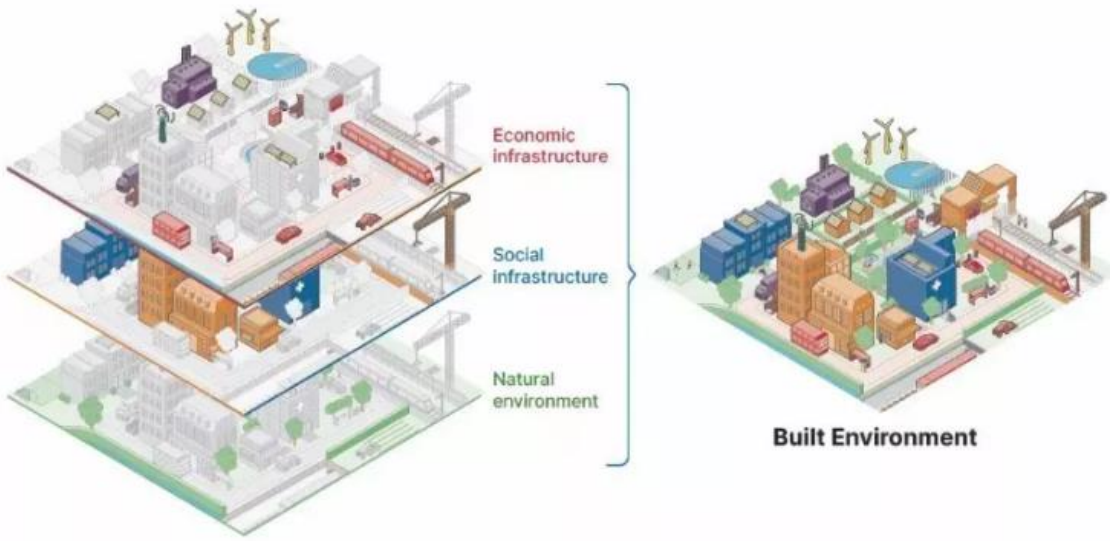
## Anomaly detection and diagnosis metamodels for AHUs

- Evaluated fault types
  - Fouling on heating/cooling coils
  - Simultaneous operation of heating cooling coils
  - Fouling on heat recovery heat exchangers
  - Failures on the inlet/exhaust/recirculation dampers (control failure, loss of air tightness, stuck dampers, etc).
  - Failures in the control valves of the heating/cooling coils (control failure, leakage, actuator stuck position, etc).
  - Dirty filters
  - Ventilator efficiency loss.
  - Other faults (anomaly detection)



# What is an Urban Digital Twin?






Our built environment is an interconnected system of systems.

Image: Cambridge Centre for Smart Infrastructure & Construction

*A **Digital Twin** is a virtual replica of the main **elements of the city and its critical infrastructure**, connected to databases and sensors. This **model of the city and its processes** makes it possible to analyze, model, simulate and predict scenarios or develop hypotheses to support **better decision-making processes in urban planning and in the management** of infrastructures and public services, in multiple domains and in an integrated way.*

## Smart City digital Twins - a hybrid ecosystem, physical and digital, of the city through the concept of digital twin.

# Urban Digital Twin Roadmap



Level 5

Level 1

- Interaction Real-Virtual
- Algorithms & Simulation
- Dynamic Data (IoT)
- Semantic 3D Model
- 3D Model

Modeling the City and its processes (Digital Twin):

- Based on a 5 layered-model
- Allowing

…To better understand
…To interact
…To simulate
…To predict

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# Thank you!!

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