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MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE

ECTP INNOVATIVE BUILT ENVIRONMENT

PTEC

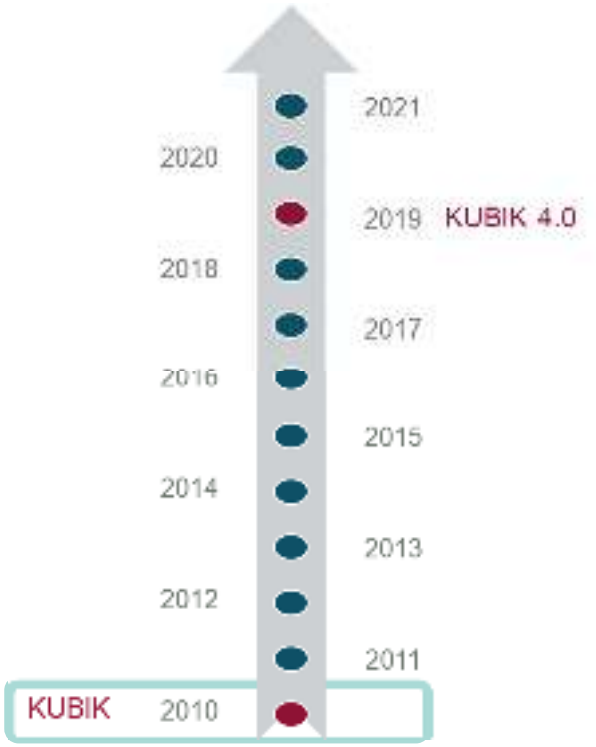
KUBIK 4.0 experience

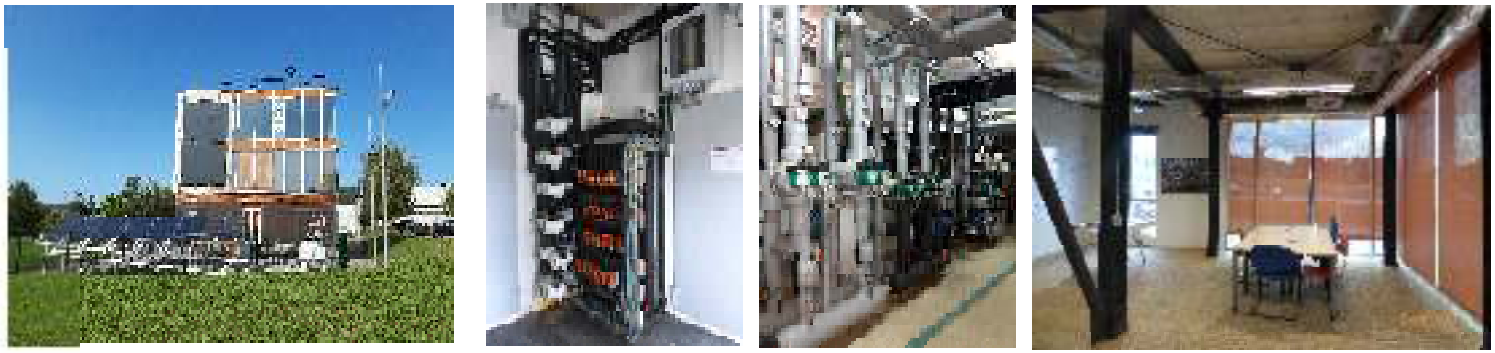
From BIM to Simulation Models

Madrid
03/12/2021

WHAT IS KUBIK?

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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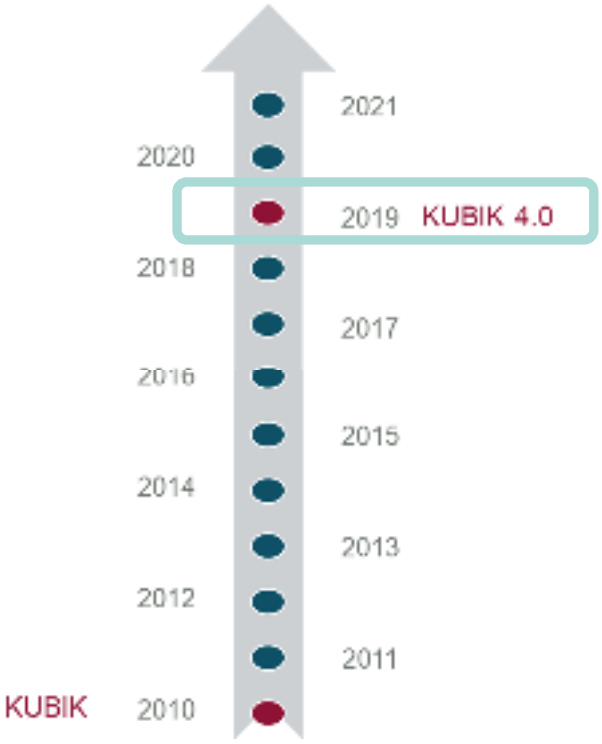
WHAT IS KUBIK?

WHAT KUBIK HAS BEEN TRASNFORMED ?

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

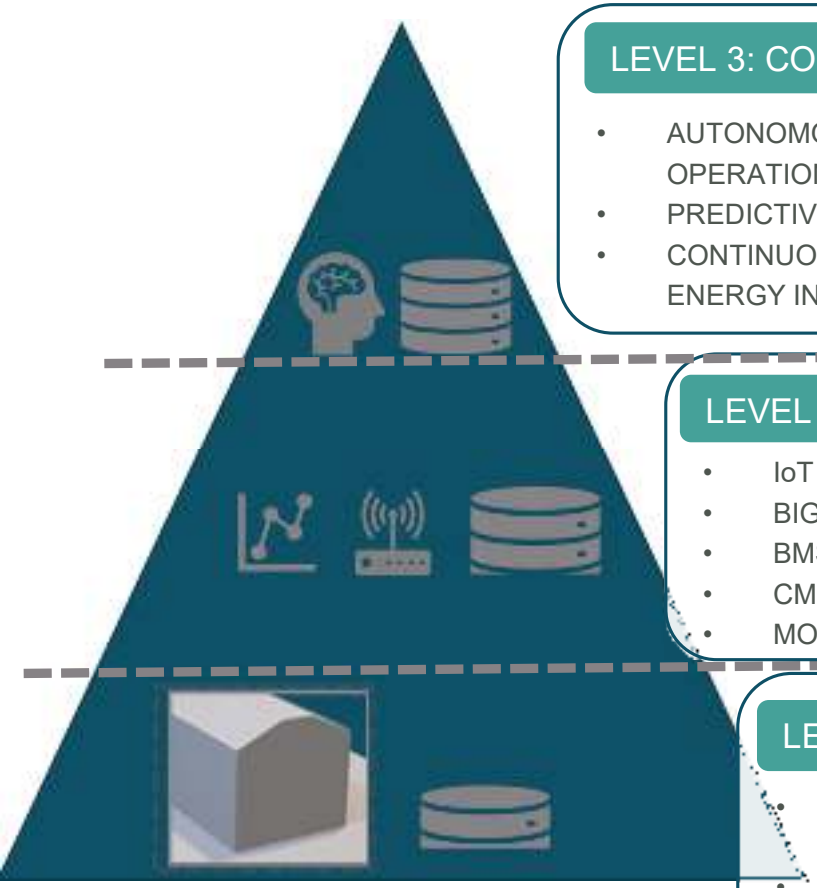


DIGITAL TWIN

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

HOLISTIC APPROACH



LEVEL 3: COGNITIVE BUILDING

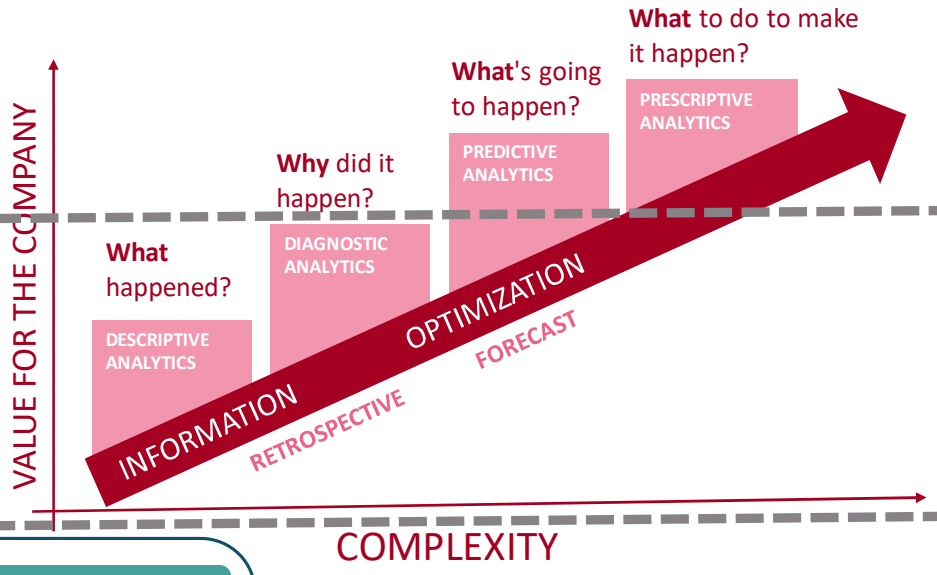
- AUTONOMOUS INTELLIGENT INTEGRAL OPERATION WITH AI (Machine Learning)
- PREDICTIVE MAINTENANCE
- CONTINUOUS OPTIMIZATION OF ENERGY INSTALLATIONS

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



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LEVEL 1: DIGITAL BUILDING

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

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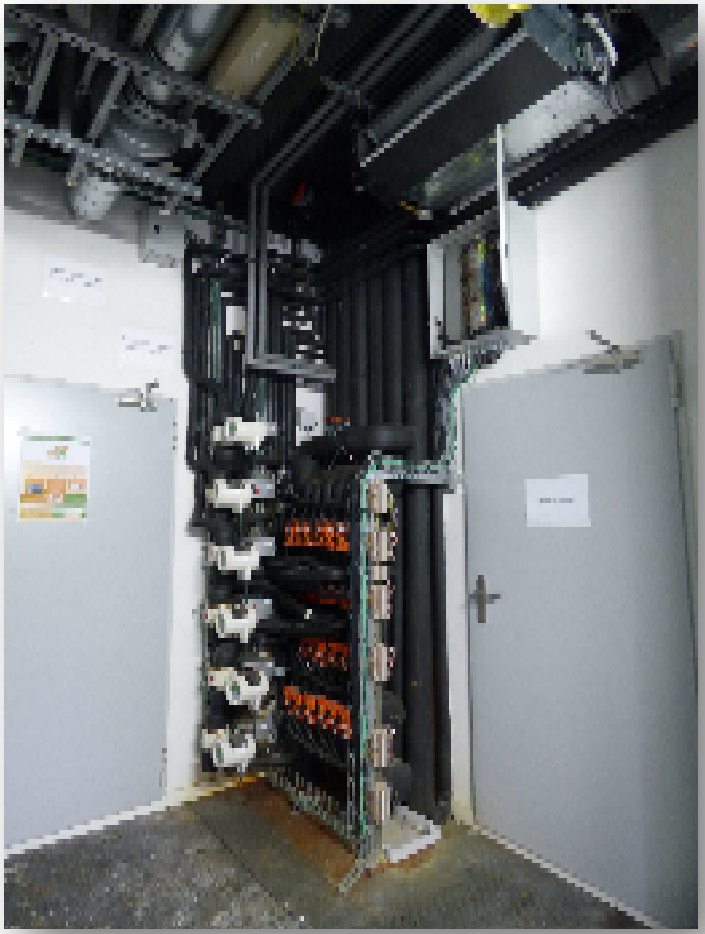
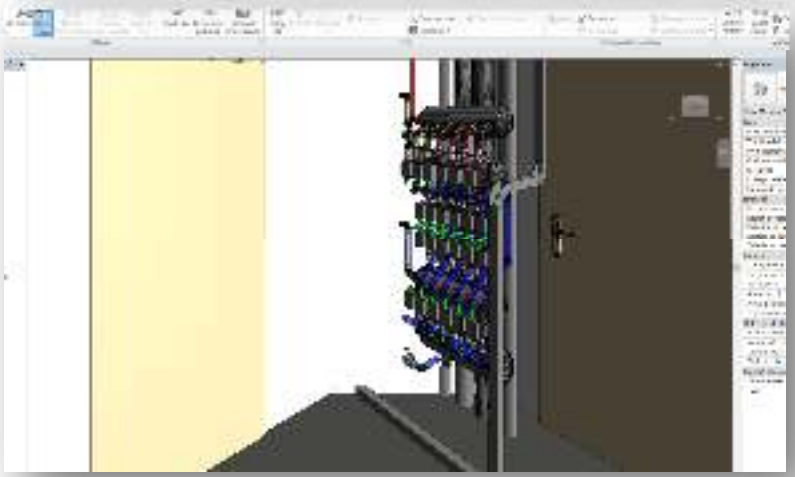
LEVEL 1: DIGITAL BUILDING





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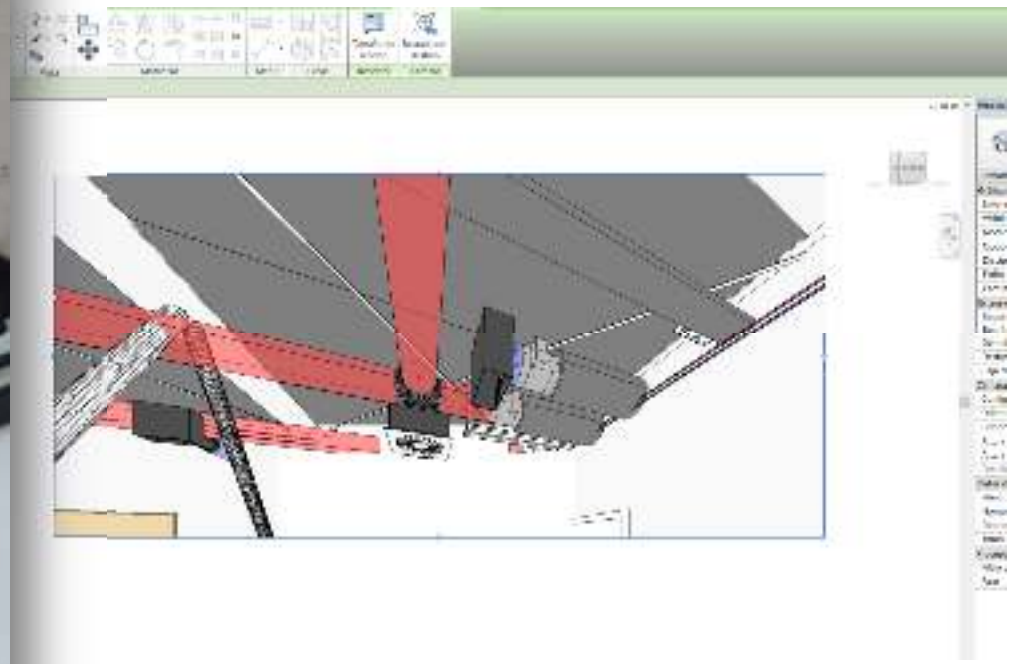
LEVEL 1: DIGITAL BUILDING



LEVEL 2: ANALYTICAL BUILDING

GMMS CONNECTION

BMS CONNECTION

IoT

MODELING

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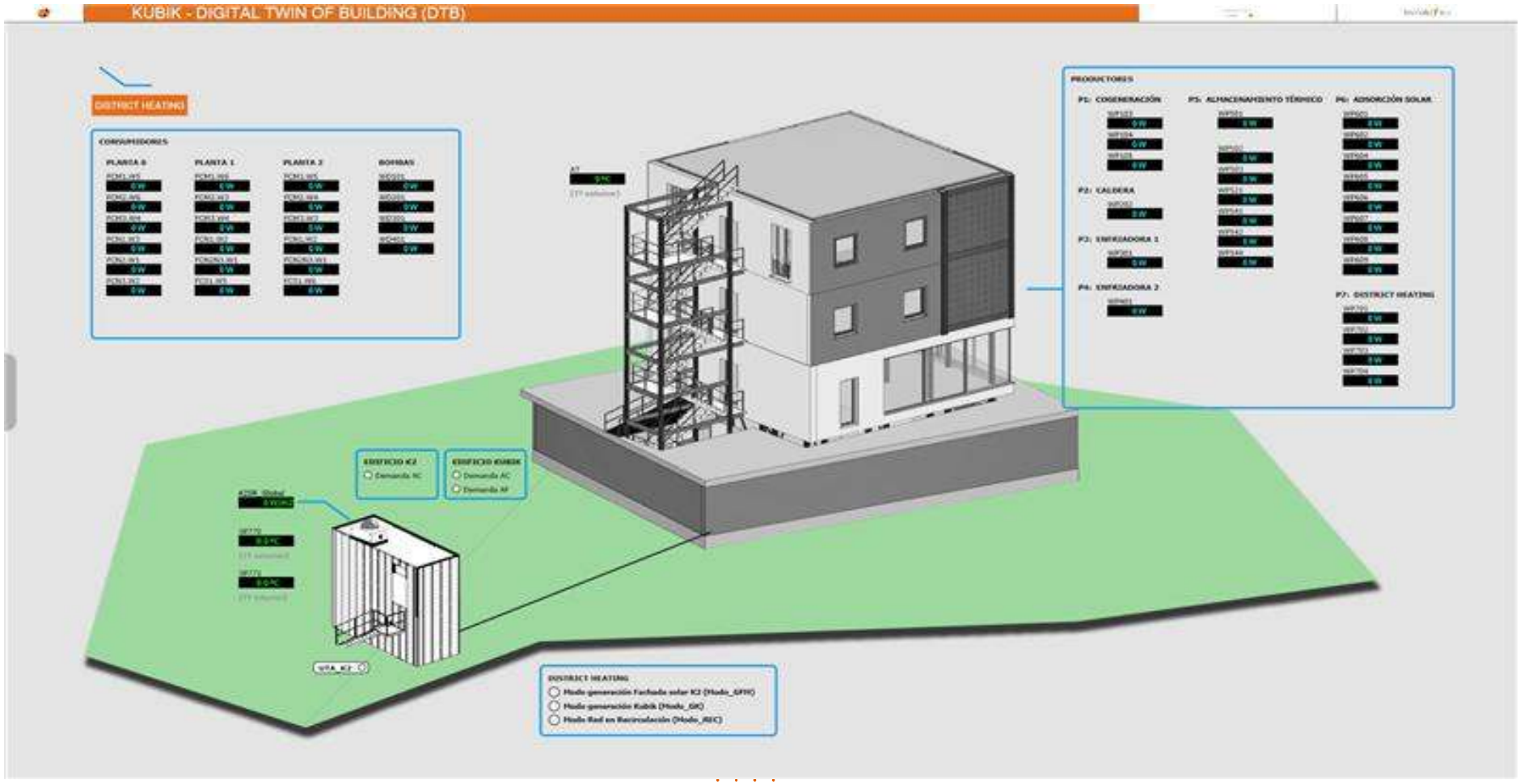
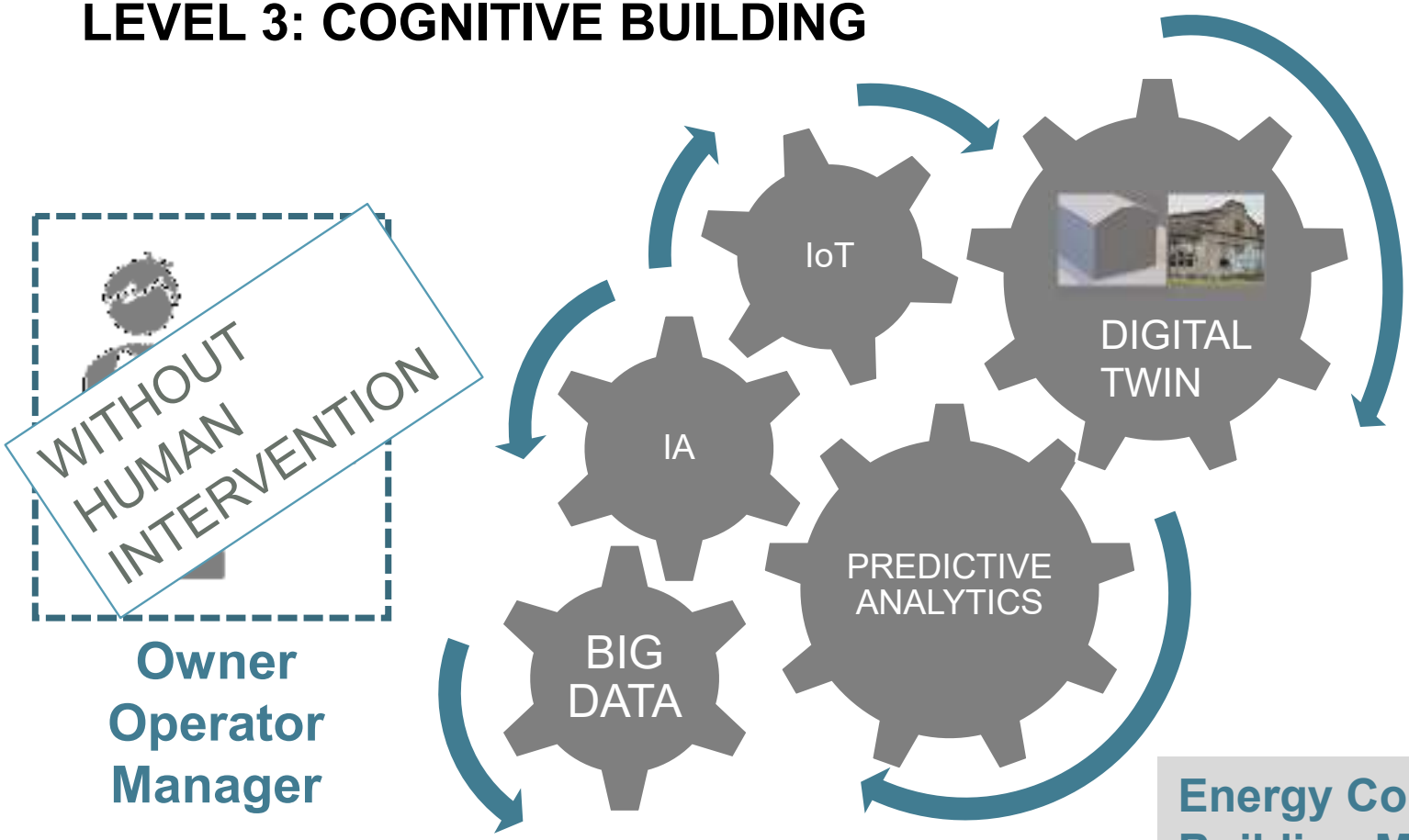
LEVEL 2: ANALYTICAL BUILDING



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 %

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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)

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LEVEL 3: COGNITIVE BUILDING

PREDICTIVE MAINTENCE SERVICE. Development of predictive maintenenance 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).

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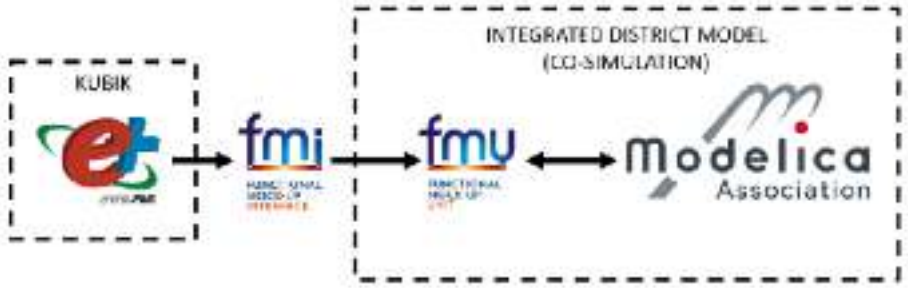
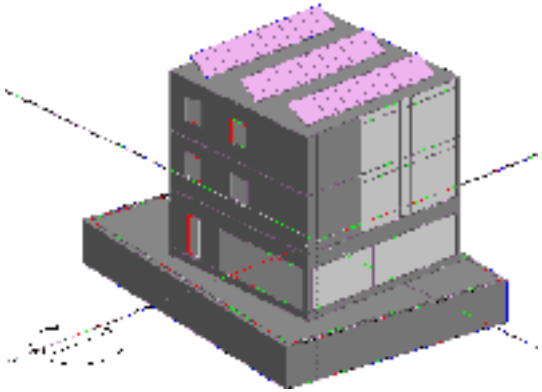
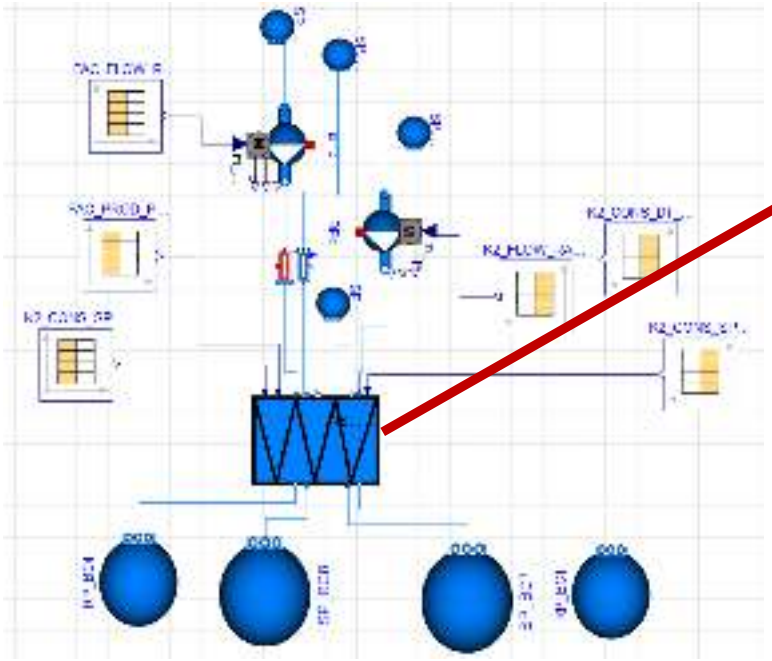
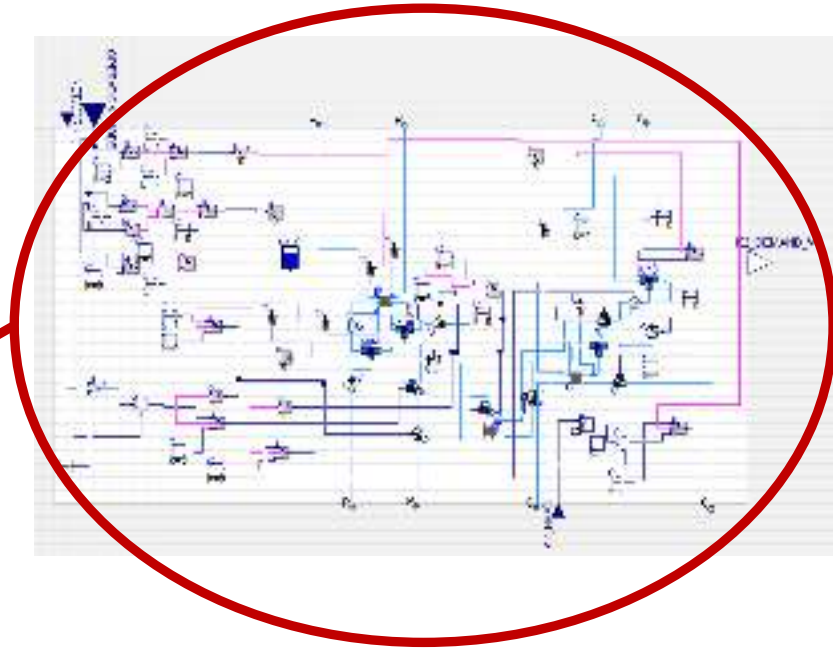
LEVEL 3: COGNITIVE BUILDING. PREDICTIVE MAINTENCE SERVICE.



PREDICTIVE MAINTENANCE METAMODEL DEVELOPMENT PROCESS







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

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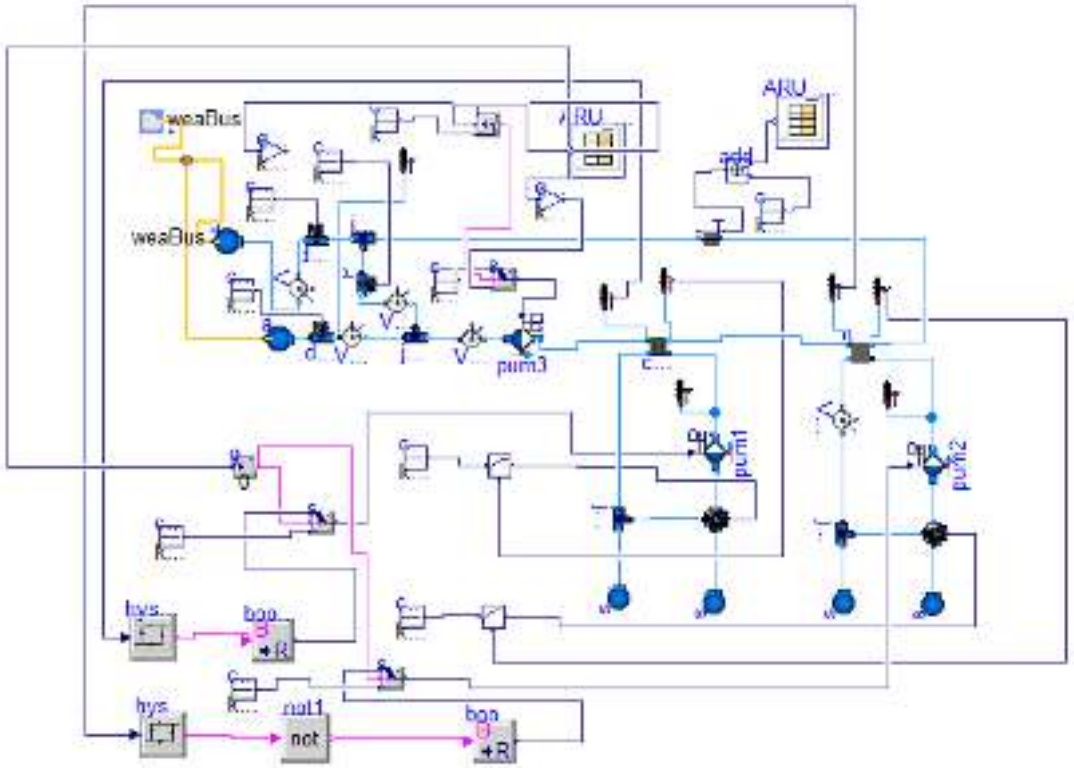
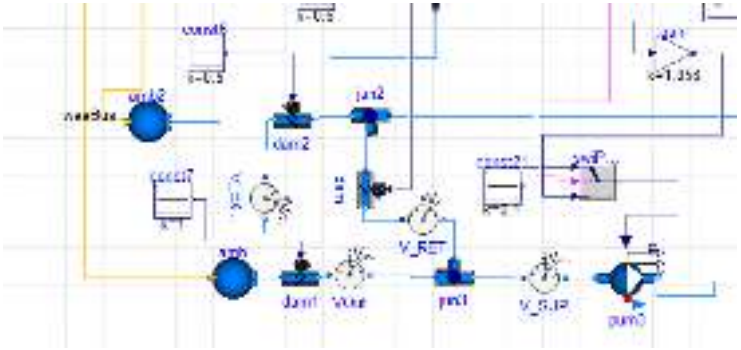
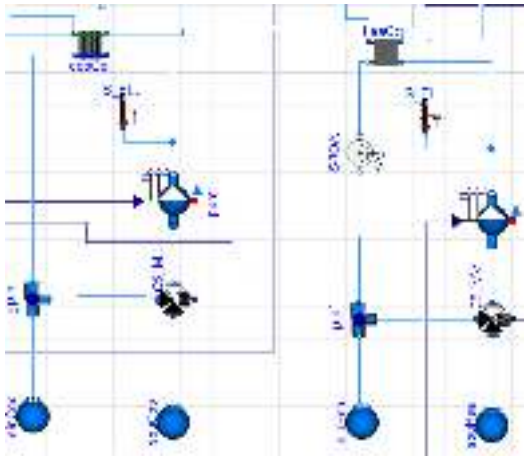
LEVEL 3: COGNITIVE BUILDING. PREDICTIVE MAINTENCE SERVICE.

Anomaly detection and diagnosis metamodels for AHUs.



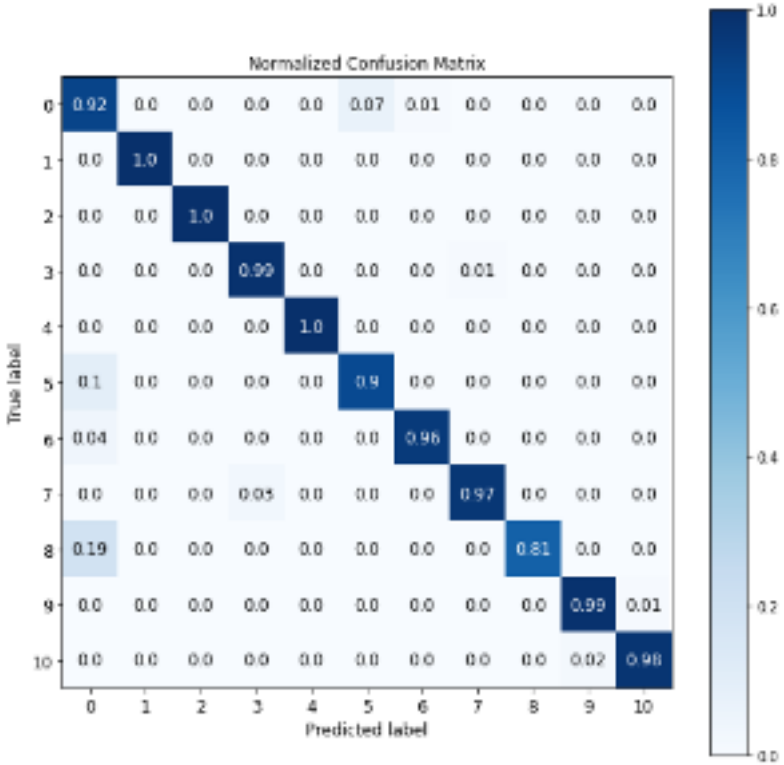




LEVEL 3: COGNITIVE BUILDING. PREDICTIVE MAINTENCE SERVICE.

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)



LEVEL 3: COGNITIVE BUILDING. PREDICTIVE MAINTENCE SERVICE.

Ongoing activities

- Improvement of prognosis metamodels.
- Evolution from models developed for specific equipment instances to generic models developed for equipment types.
  - Air/water heat pump with alternative compressors
  - Air/water heat pump with scroll compressors
  - Etc.

Next

Expand decision-making algorithms for more use cases