iPredict. A predictive maintenance tool for heating, ventilation, and air conditioning (HVAC) equipment using artificial intelligence (AI)

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Summary

iPredict

- About me
- Eurecat
- Sphere project
- iPredict
- Architecture
- Italian Pilot (sensors & meters)
- Weather station
- iPredict daily tasks
- Initial results
- Conclusions

About me

iPredict

- Studies in Communications and Electronic **Engineering** in Spain and United Kingdom
- Worked in **Information Technology (IT)** in Spain, United Kingdom, France, Germany, Sweden and Australia
- **PhD** in **energy efficiency** and **simulations in buildings (Physics)** at the **University of Technology Sydney (UTS)** in Australia
- **Postdoctoral** position at **Fraunhofer USA – Center for Sustainable Energy Systems (CSE)** in Boston (USA)
- **Data Scientist** in **energy efficiency in buildings**
- **Researcher** at the **Applied Artificial Intelligence** Unit at **Eurecat**

Eurecat

iPredict

Applied research and technological development

- R&D&I units set up with the company
- R&D projects
- *Minimum viable product*

Advanced technology services

- Scientific and technological assessment
- Audits
- Testing and analysis
- Proofs of concept
- Approvals

Technology consultancy

- Innovation strategy and management
- Technology watch
- Trend analysis and feasibility studies
- Project management and funding

Specialised training

- Masters and postgraduate programmes
- Bespoke corporate training
- Continuous learning
- Soft and hard skills training

Value building

- Industrial and intellectual property protection and transfer
- Evaluation and support in building value from technological assets
- Advice and participation in setting up NTBFs
- Technological asset due diligence

Knowledge sharing

- Promotion actions
- Knowledge sharing and transfer actions

Industrial Area

Sustainability Area

Biotechnology Area

Digital Area

+1700 private customers, of which **63%** are SME

675 employees, of which **250** new jobs in 7 years

125 Horizon 2020 projects

153 patents

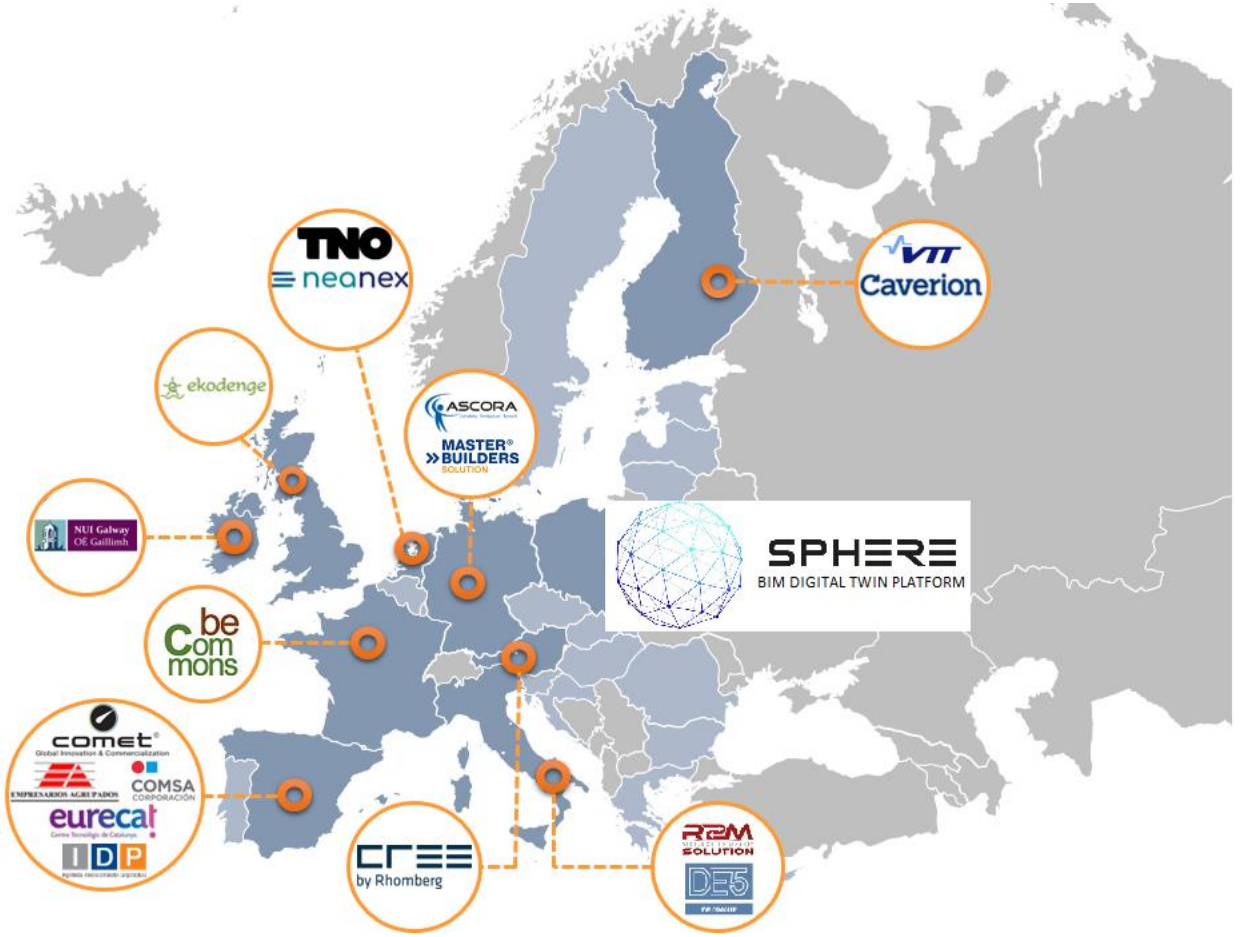
Sphere project

iPredict

- **Sphere** project is a **Horizon 2020 project funded by the European Commission**. https://sphere-project.eu/

- SPHERE project aims to provide a Building information modelling (BIM) based Digital Twin Platform to **optimise the building lifecycle, reduce costs**, and **improve energy efficiency** in residential and office **buildings**

- Consortium is composed by **17 partners** from **9** different **EU countries**, consisting of multi-purpose SME technology leaders as well as software tool providers and expert researchers



iPredict

iPredict is one of the software technologies in the **Sphere** project. The scope is the **use**, **operation** and **maintenance** of the building.

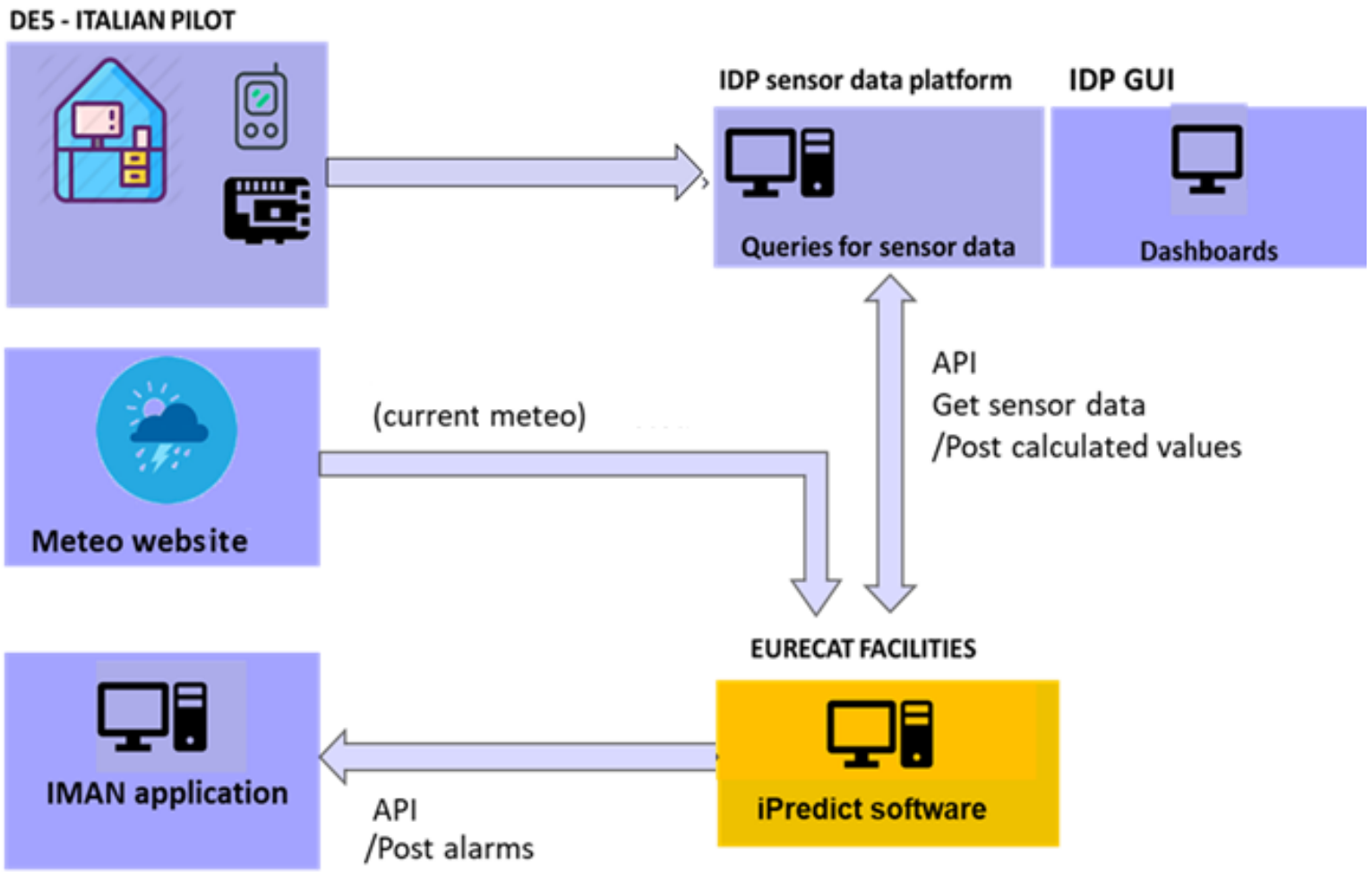
What is the purpose/**goal** for **iPredict**?

- Enable **predictive maintenance** of **HVAC equipment** using **real time data** and **machine learning** algorithms
- **Reduce** downtimes, **loss of comfort** and/or **loss of efficiency**

How does **[iPredict]** achieve these goals?

- **Create a data-driven model using data** from **sensors** (temperatures, humidity, setpoints, operation status/mode), **weather data** and electricity and thermal **energy consumption**
- **Predict energy consumption** using historical data
- **Detect abnormal energy consumption** in **heating** and **cooling systems**
- **Send notifications** to **facility managers** through a Computerized **Maintenance** Management System (**CMMS**)/ SPHERE platform

Architecture

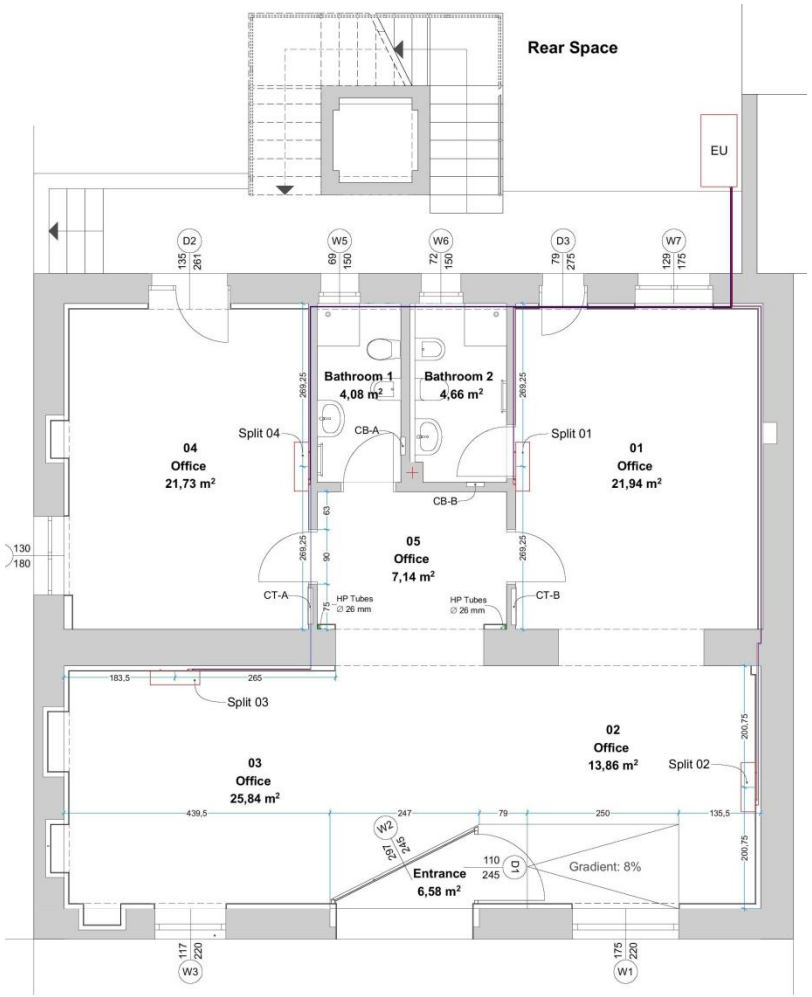


Italian pilot

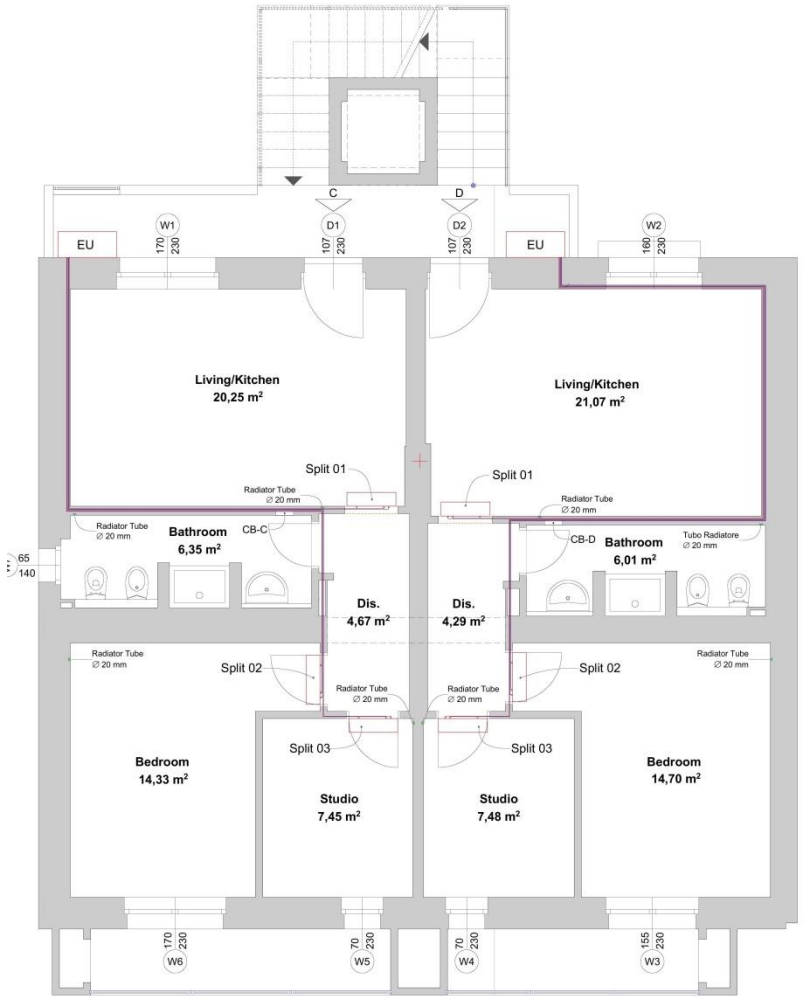
3-story building in Italy, an office on the ground floor and two apartments in each floor

Floor plans

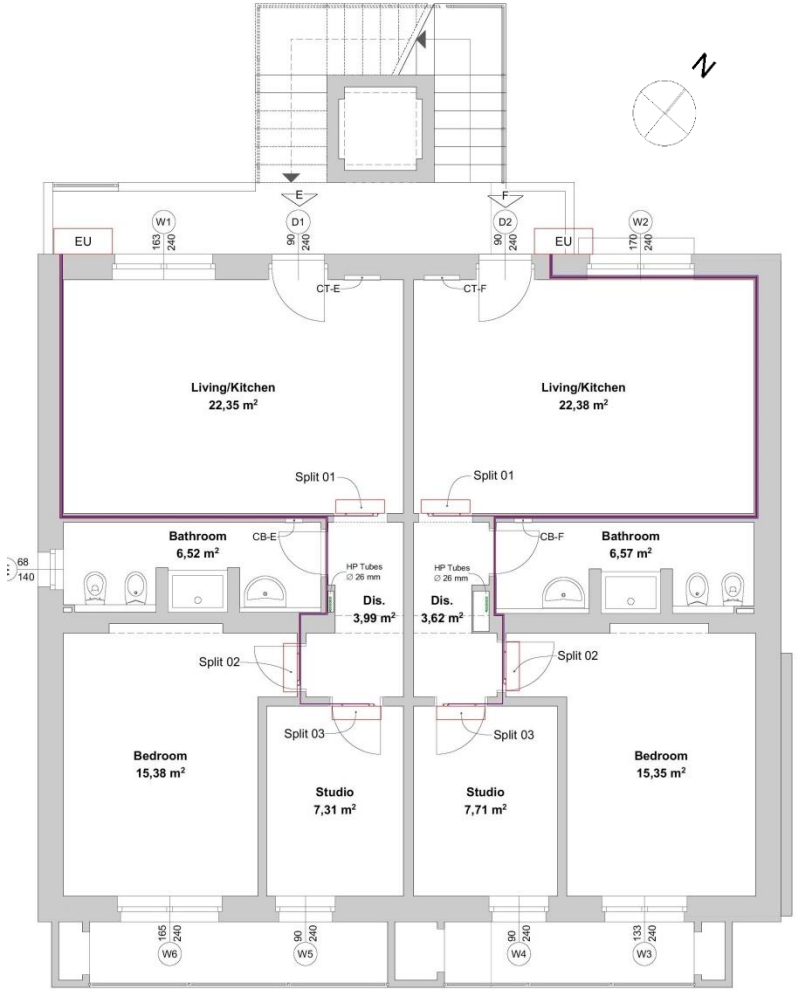
iPredict



P0 - Ground Floor



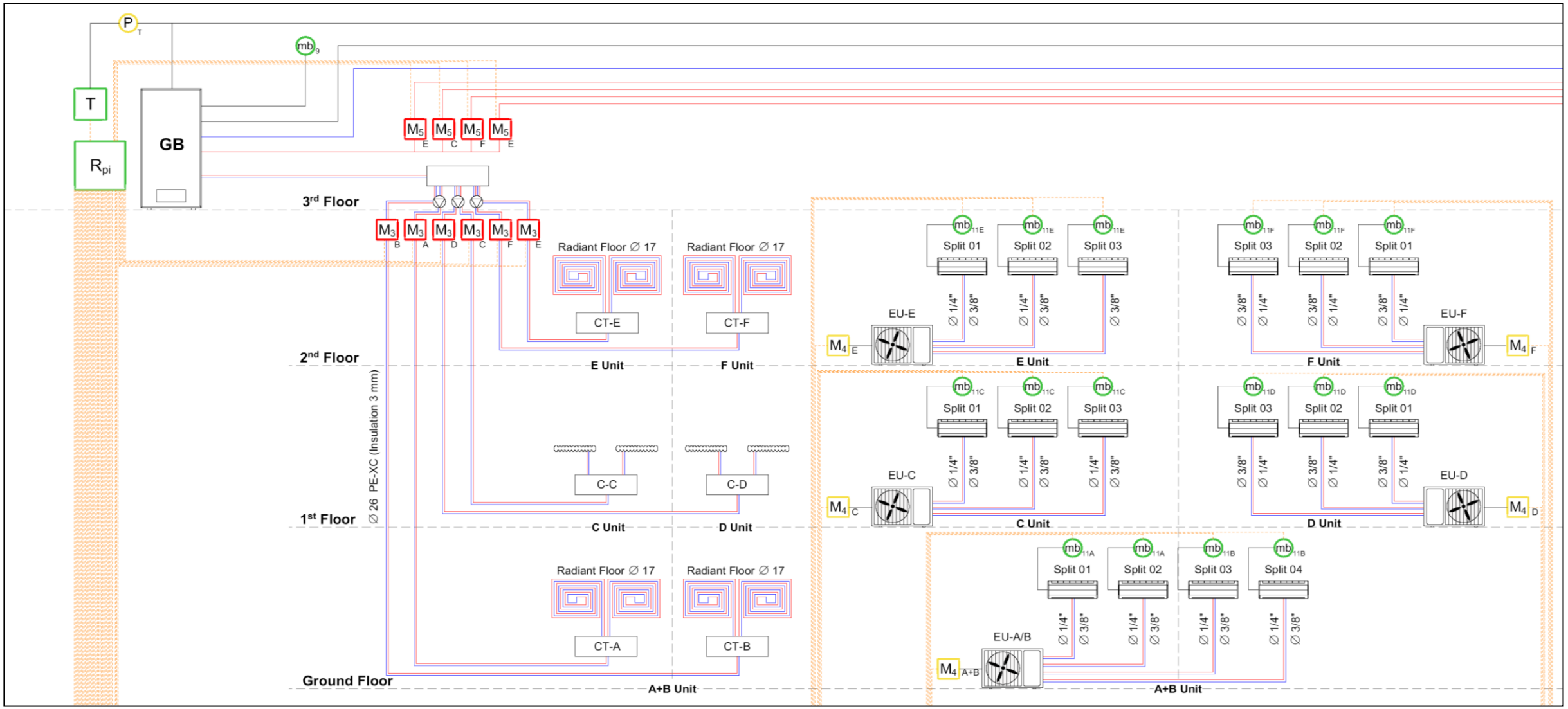
P1 - 1st Floor



P2 - 2nd Floor

HVAC general layout

iPredict



Sensors & meters

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Outdoor Temperature sensor

Variables: Temperature in ºCelsius
Where: Installed outside the building
Total: 1

Thermal Energy meter (Kamstrup)

Variables: Thermal Energy Consumption kWh-th
Where: Installed on the pipes (Supply & Return heating water circuit), 4 for radiant floor heating in the ground floor and 2nd floor & 2 for radiators in the 1st floor
Total: 6

Electric Energy meter (Circutor)

Variables: Electrical HVAC Consumption kWh-el
Where: Installed in the outdoor unit main electric supply
Total: 5

Temperature and relative humidity sensor

Variables: Temperature in ºCelsius and relative humidity (%)
Where: Installed inside each room in each apartment (2x3x4), and 2x4 in the office
Total: 32

Variables in indoor HVAC units

Variables: Indoor temperature, Setpoint temperature, Operation Status (ON/OFF) and Operation Mode Cool/Dry/Fan/Auto/Heat
Where: Installed inside each split in each apartment on 1st Floor (4x3x2) and 4x4 in the office
Total: 40

Weather station

iPredict

WEATHER UNDERGROUND

Elev 21 m, 42.04 °N, 14.74 °E

san salvo sud 3 - ISANSA11

Station Summary

Online(updated 28 seconds ago)

CURRENT CONDITIONS

28.0 °C

Feels Like 28.0 °

SW

WIND & GUST
2.9 / 3.5 km/h

DEWPOINT	PRECIP RATE	PRESSURE
20.1 ° C	0.00 mm/hr	1,007.11 hPa
HUMIDITY	**PRECIP ACCUM**	**UV**
62 %	0.00 mm	3

MAP

TEMPERATURE

CURRENT 28°

DEWPOINT
20.1 °C

HUMIDITY
61 %

WIND

4.0

WIND FROM
SSE

GUST
5.5 km/h

PRESSURE

CURRENT
1,006.94 HPa

PRECIPITATION

PRECIP RATE
0.00 mm/hr

PRECIP TOTAL
0.00 mm

UV

CURRENT UV
4

UV RISK

SOLAR RADIATION

CURRENT
415.90 watts/m²

Graph | Table

July 25, 2022

Time	Temperature	Dew Point	Humidity	Wind	Speed	Gust	Pressure	Precip. Rate.	Precip. Accum.	UV	Solar
12:04 AM	27.0 °C	16.3 °C	52 %	West	3.4 km/h	4.4 km/h	1,012.53 hPa	0.00 mm	0.00 mm	0	0 w/m²
12:09 AM	27.1 °C	16.4 °C	52 %	West	3.2 km/h	4.1 km/h	1,012.43 hPa	0.00 mm	0.00 mm	0	0 w/m²
12:14 AM	27.3 °C	16.4 °C	52 %	WSW	2.3 km/h	3.0 km/h	1,012.33 hPa	0.00 mm	0.00 mm	0	0 w/m²
12:19 AM	26.8 °C	16.6 °C	54 %	WSW	4.0 km/h	5.2 km/h	1,012.33 hPa	0.00 mm	0.00 mm	0	0 w/m²
12:24 AM	26.0 °C	16.4 °C	55 %	SW	2.6 km/h	3.6 km/h	1,012.43 hPa	0.00 mm	0.00 mm	0	0 w/m²
12:29 AM	25.8 °C	16.4 °C	56 %	WSW	2.4 km/h	3.0 km/h	1,012.33 hPa	0.00 mm	0.00 mm	0	0 w/m²
12:34 AM	25.7 °C	16.2 °C	56 %	SW	2.4 km/h	2.7 km/h	1,012.33 hPa	0.00 mm	0.00 mm	0	0 w/m²
12:39 AM	25.4 °C	16.3 °C	57 %	SW	3.2 km/h	3.5 km/h	1,012.43 hPa	0.00 mm	0.00 mm	0	0 w/m²

iPredict daily tasks

iPredict

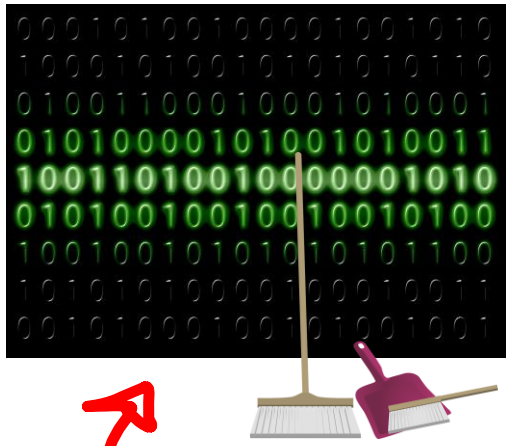
Daily

Azure IoT Hub

1. Download data from the platform

```
\\Sphere\\JSON\\GetJSON_2022-08-21\\00OTS01_00_R-2022-08-21.json -> <Response [200]>
\\Sphere\\JSON\\GetJSON_2022-08-21\\00MMD01_IT_R-2022-08-21.json -> <Response [200]>
\\Sphere\\JSON\\GetJSON_2022-08-21\\00MMD01_RH_R-2022-08-21.json -> <Response [200]>
\\Sphere\\JSON\\GetJSON_2022-08-21\\00MMD02_IT_R-2022-08-21.json -> <Response [200]>
\\Sphere\\JSON\\GetJSON_2022-08-21\\00MMD02_RH_R-2022-08-21.json -> <Response [200]>
\\Sphere\\JSON\\GetJSON_2022-08-21\\00MMD03_IT_R-2022-08-21.json -> <Response [200]>
\\Sphere\\JSON\\GetJSON_2022-08-21\\00MMD03_RH_R-2022-08-21.json -> <Response [200]>
\\Sphere\\JSON\\GetJSON_2022-08-21\\00MMD04_IT_R-2022-08-21.json -> <Response [200]>
\\Sphere\\JSON\\GetJSON_2022-08-21\\00MMD04_RH_R-2022-08-21.json -> <Response [200]>
\\Sphere\\JSON\\GetJSON_2022-08-21\\00EEM01_00_R-2022-08-21.json -> <Response [200]>
\\Sphere\\JSON\\GetJSON_2022-08-21\\00MMC01_IT_R-2022-08-21.json -> <Response [200]>
\\Sphere\\JSON\\GetJSON_2022-08-21\\00MMC01_SP_R-2022-08-21.json -> <Response [200]>
```

2. Clean data



3. Upload clean data to the platform


```
{
  "tag": "11MMD01_IT",
  "clientId": 1,
  "records": [
    {
      "recordTime": "2022-08-21T00:00:00.000",
      "value": 28.4
    },
    {
      "recordTime": "2022-08-21T00:05:00.000",
      "value": 28.4
    },
    {
      "recordTime": "2022-08-21T00:10:00.000",
      "value": 28.4
    },
    {
      "recordTime": "2022-08-21T00:15:00.000",
      "value": 28.4
    },
    {
      "recordTime": "2022-08-21T00:20:00.000",
      "value": 28.4
    },
    {
      "recordTime": "2022-08-21T00:25:00.000",
      "value": 28.4
    },
```

Daily

4. Run the prediction algorithm with existing model and clean data (4+1) to predict electric & thermal energy

	EMR01_00	EME01_00	EMD01_00	TEC01_00	TMR01_00	TME01_00	TMD01_00	DateTime
Office	11.34	11.35	-0.1	NaN	NaN	NaN	NaN	2022-08-21
Alfa	0.82	1.03	-25.5	NaN	NaN	NaN	NaN	2022-08-21
Bravo	2.96	3.2	-7.9	NaN	NaN	NaN	NaN	2022-08-21
Charlie	0.32	0.2	37.5	NaN	NaN	NaN		
Delta	1.46	1.19	18.5	NaN	NaN	NaN		

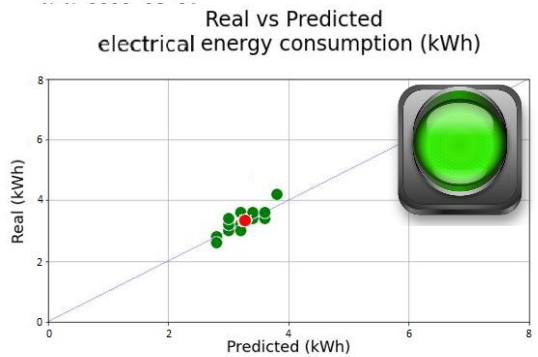
5. Calculate deviation between real and predicted energy consumption

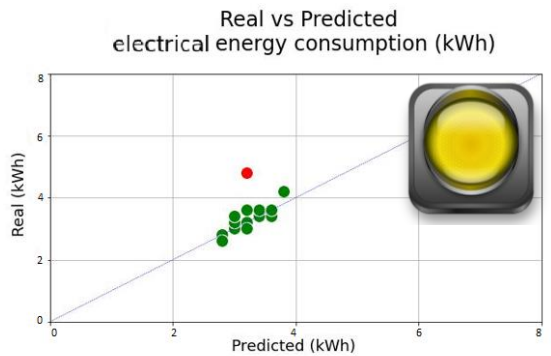
Electric Meter (Real)

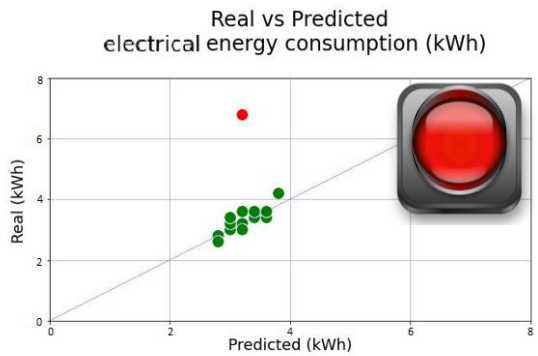
Electric Meter (Estimated)

Electric Meter (Deviation)

EMR01_00	EME01_00	EMD01_00	TEC01_00	TMR01_00	TME01_00	TMD01_00	DateTime
1.46	1.19	18.5	NaN	NaN	NaN	NaN	2022-08-21







Daily

6. Send the results to the SPHERE ecosystem

To the platform

Azure IoT Hub

Time series for daily values:

Electrical consumption: real, predicted, deviation

Thermal consumption: real, predicted, deviation

```
{
  "tag": "DEEMD01_00",
  "clientId": 1,
  "records": [
    {
      "recordTime": "2022-08-21T00:00:00.000",
      "value": 18.5
    }
  ]
}
```

To IMAN (CMMS)

Notification:

Severity

Consumption values

```
{
  "type": "request",
  "reset": "False",
  "requestOtherMaintenance": {
        "idCodGeographical": 3,
        "install": 41,
        "priority": 3,
        "description": "Real electricity consumption: 1.46kWh //
        Predicted electricity consumption: 1.19kWh              //
        Deviation: 18.5%",
        "date": 1661032800000
```

To Facility Manager

Predicted Energy Consumption vs Real Energy Consumption

iPredictEUT@gmail.com

Para Jose Luis Castro Aguilar

Responder | Responder a todos | Reenviar

Good morning,

- The predicted electricity consumption has been 1.19 kWh and the real electricity consumption has been 1.46 kWh for apartment Delta on 2022-08-21.

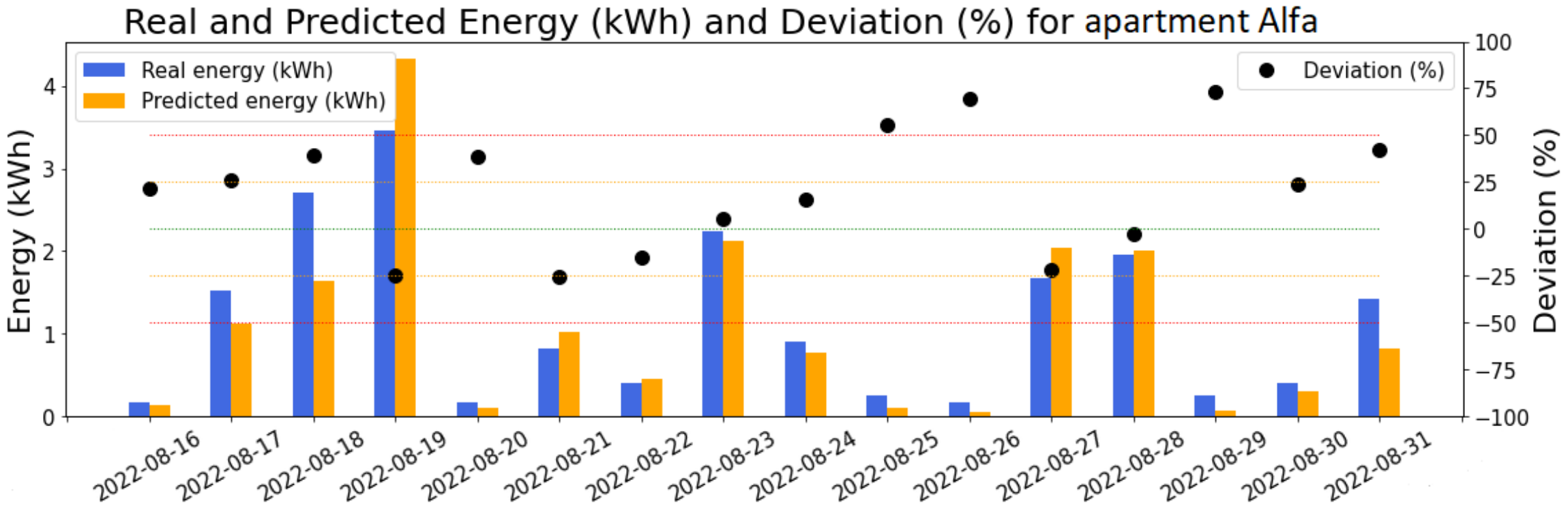
Please, consider that the real electricity consumption has been 18.5 % more than the predicted electricity consumption.

Kind regards,

iPredict

Initial results

- Real and predicted energy consumption (kWh) and deviation (%) from August 16th to August 31st
- Algorithm trained from August 1st until the day before of the prediction



Initial results

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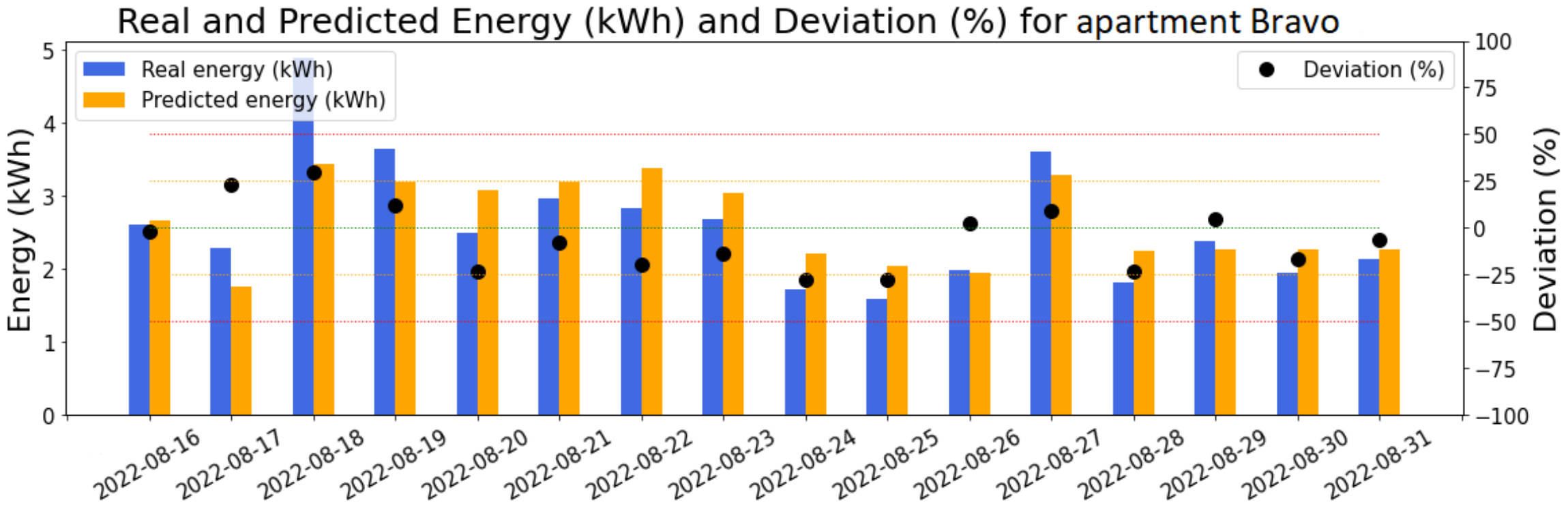

Conclusions

iPredict

- After stakeholder interviews performed in **Sphere**, a **predictive maintenance tool** is a desired functionality for a Building Digital Twin
- The tool follows a **data-driven** approach and uses **machine learning algorithms** to **predict energy consumption**
- **Detecting abnormal consumption** due to **malfunction/operation** in **HVAC** can **save energy** and **reduce CO_2 emissions**
- If **deviation/real energy consumption** is **higher than predicted** an **alert/notifications** is **sent automatically** to the **Facility Manager** and IMAN **maintenance tool**
- Data-driven models are becoming important due to the increased availability of data and progress in internet of things (IoT) sensors and machine learning algorithms
- Initial results during August showed better predictions in the apartment they used HVAC more often
- Next steps are to improve accuracy of energy predictions with:
  - More days and weeks of sensors and meters data to train the algorithm
  - Better selection of the variables that are most relevant among the available sensor data
  - Better selection of machine learning algorithm for this case

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Thank you for your attention

SPHERE
BIM DIGITAL TWIN ENVIRONMENT

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