SYNERGY

This project has received funding from the **European Union's Horizon 2020 Research** and **Innovation programme** under Grant Agreement No **872734**

SUSTAINABLE PLACES 2022

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SYNERGY

Digitising and transforming European industry and services: digital innovation hubs and platforms

A Data-driven approach for asset maintenance and management in power systems

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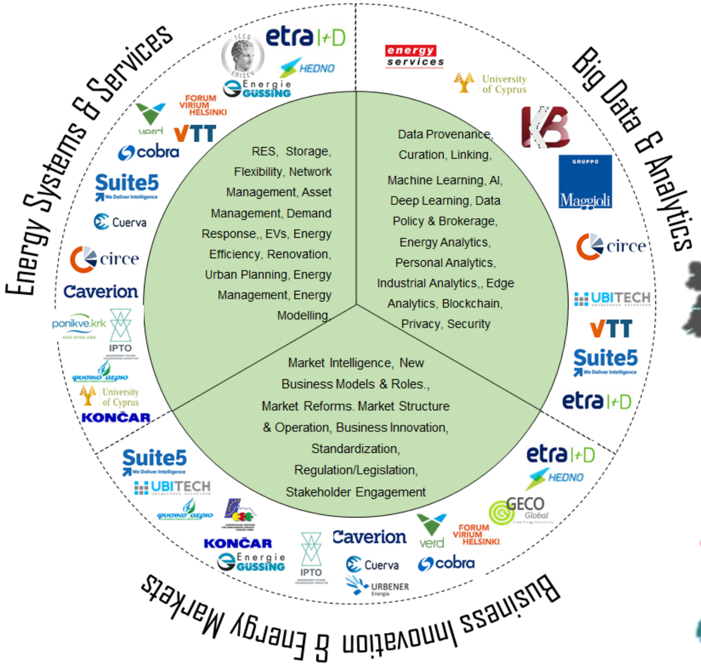
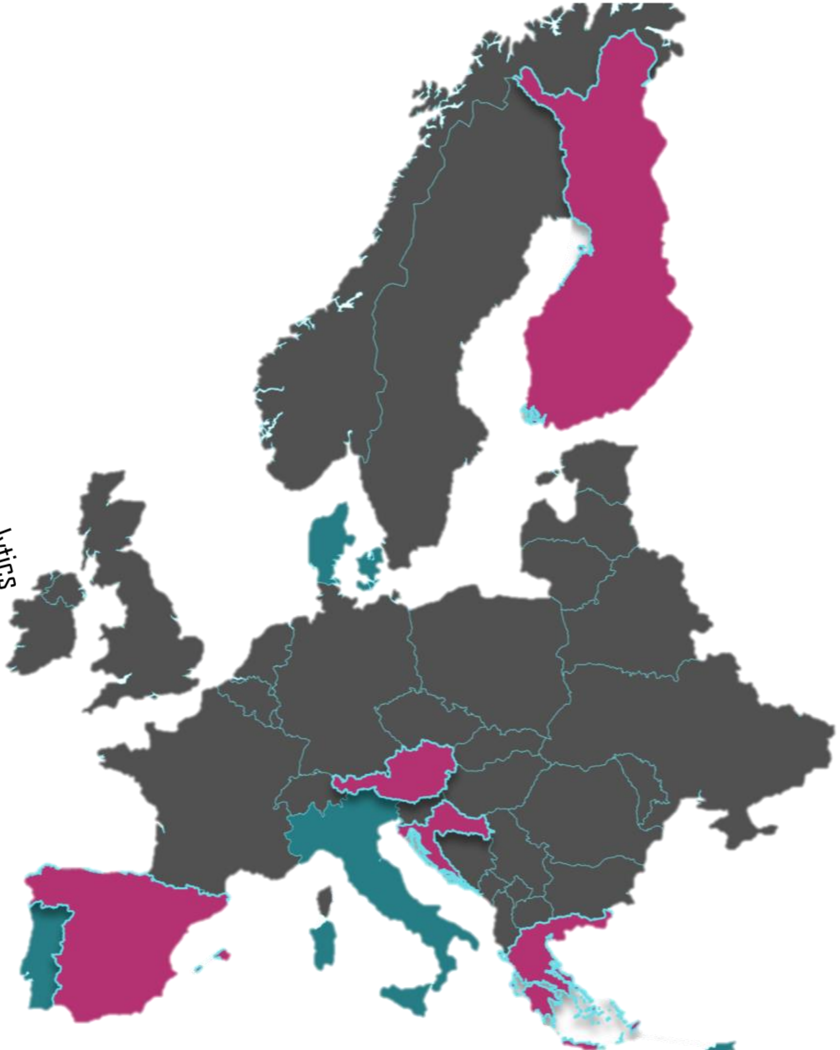
AGENDA

- Introduction to SYNERGY Project
  - Overview
  - Challenges
  - Broad Picture
  - Demo sites
  - Applications
- Network Asset Management Tool
  - Context
  - Architecture
  - Features
- Demonstration in real-life environment
  - Demo site description
  - Results of Service testing at demo site
- Conclusions

INTRODUCTION: SYNERGY overview

- Coordinator: ETRA I+D
- Consortium:24 partners from 9 EU countries
- Demonstration: 5 demos in 5 EU Member states
- Total budget: 12,8 M€
- Total funding: 9,9 M€
- Start date: 01/01/2020
- End date: 30/06/2023
- 42 Months
- IA, DT-ICT-11-2019, Big data solutions for energy



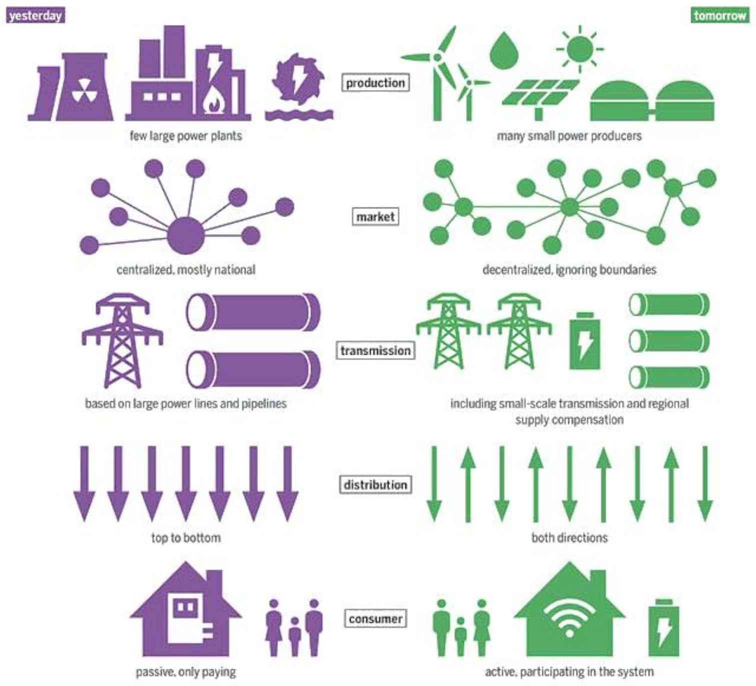


INTRODUCTION: The challenges

Operational/ Control Complexity

Access to distributed data

Data Sharing and Collective Intelligence



Electricity Data Value Chain Integration

Decentralization

Control at the edge

Increase of controllable assets

Digitalization

Huge Data volumes

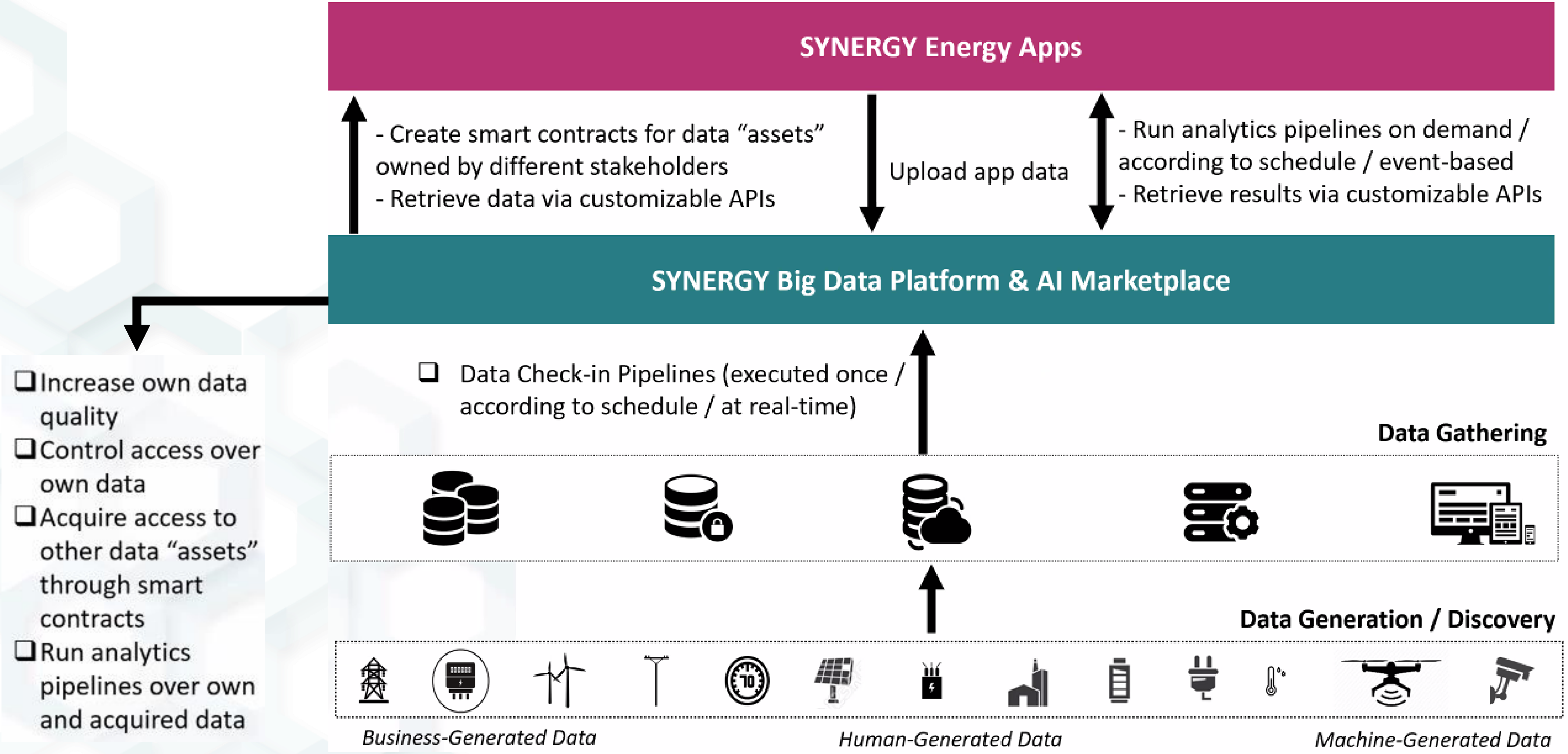
Mesh network of a wealth of Stakeholders

New Assets and DERs

New control variables and uncertainty

INTRODUCTION: Synergy broad picture

SYNERGY introduces a novel framework and reference architecture for a Big Energy Data Platform and AI Analytics Marketplace, together with big data-enabled applications to help the electricity value chain stakeholders



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INTRODUCTION: Synergy demo sites

- 5 **large-scale** demonstrators in 5 EU Member states,
  - Demonstrator #1 GREECE (MV grid, Smart buildings)
  - Demonstrator #2 SPAIN (RES, final users)
  - Demonstrator #3 AUSTRIA (MV/LV, prosumers, Smart homes)
  - Demonstrator #4 FINLAND (Smart buildings)
  - Demonstrator #5 CROATIA (RES)
- Different categories of actors and data sources,
- Various energy systems/assets,
- Heterogeneous climatic, demographic and cultural characteristics
- Replicability, scale-up and eventual market launch

INTRODUCTION: SYNERGY Applications

SO & RES Operators	Infrastructure sizing and grid planning	RES predictive maintenance	Flexibility-based network management	Asset Management Optimization
Retailers & Aggregators	Retailer portfolio analytics	Flexibility analytics and consumer-centric DR optimization	Personalized energy analytics	DR smart contract management
Building/District & Urban Management	Advanced renovation support	Urban energy monitoring & planning	Facility management monitoring & analytics	Real-time building energy performance and smart readiness certification

- 5 additional SYNERGY Apps developed through Open Call

Network Asset Management Tool: the context

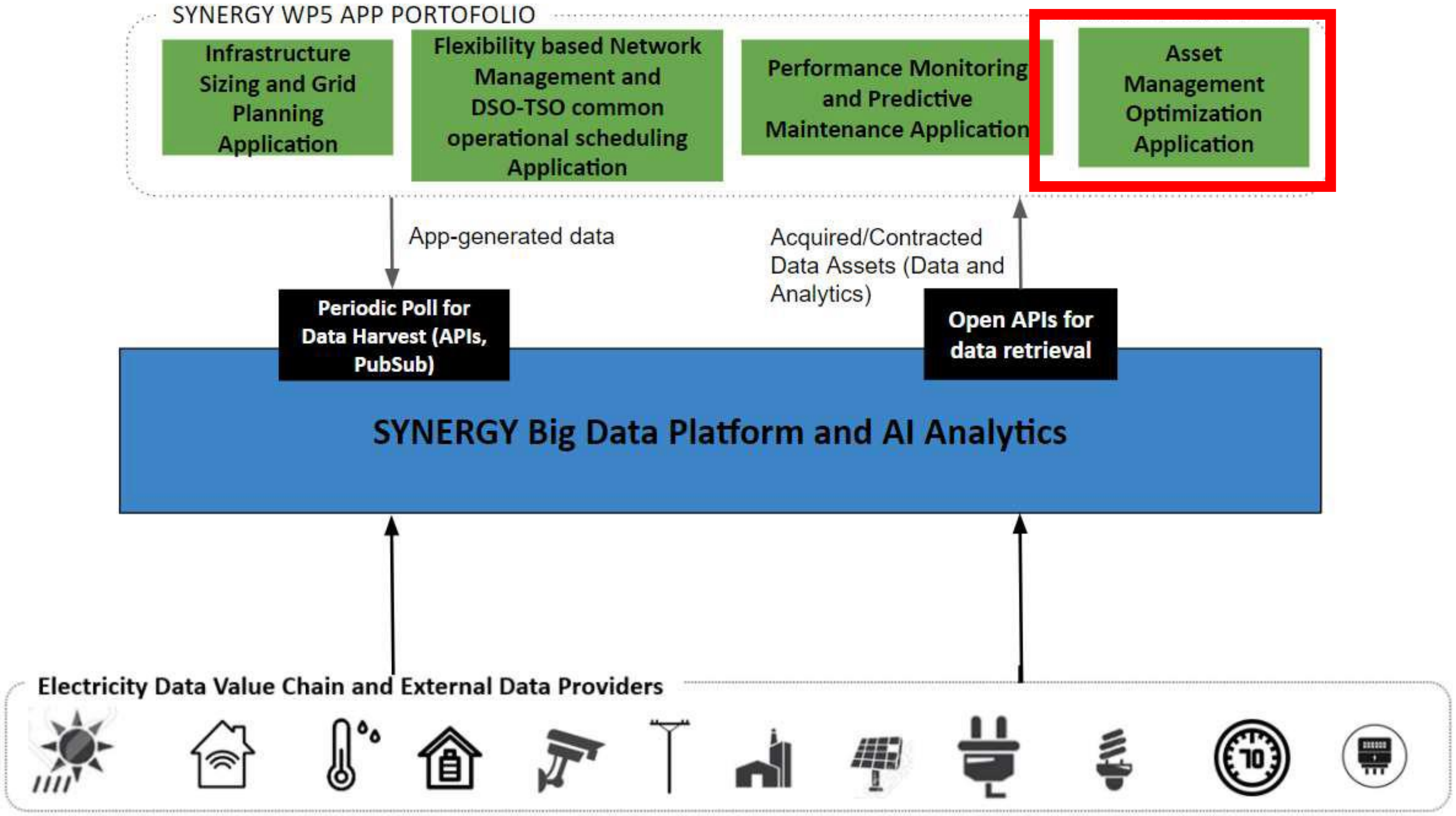
- Digitalization of traditional procedures is impacting energy industry
- Advanced monitoring and analysis process have been introduced in the daily operation at control centres and field infrastructures

- Many solutions are still not mature enough for the market or real-life deployment
- TSOs & DSOs still rely on traditional means, therefore preventive and corrective maintenance routines still prevail

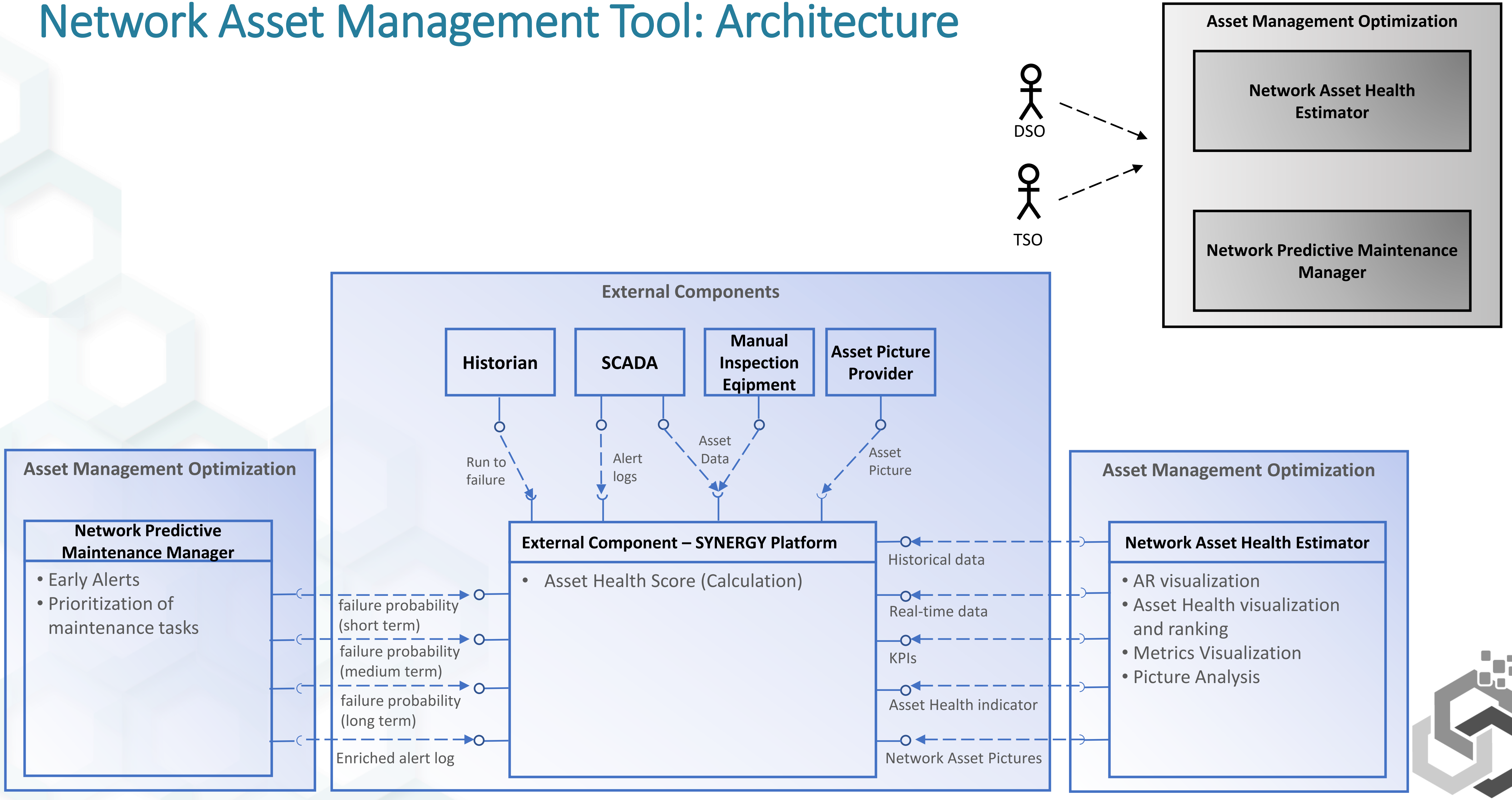
- Exploiting the potential of SYNERGY platform as one stop shop" of electric data single poi
- A novel digital tool for critical asset monitoring (transformers, power lines, etc.) based on AI, IP and AR

Network Asset Management Tool: Architecture

The application supplies the DSOs’ and TSOs’ maintenance operators with a variety of tools that facilitate maintenance management



Network Asset Management Tool: Architecture

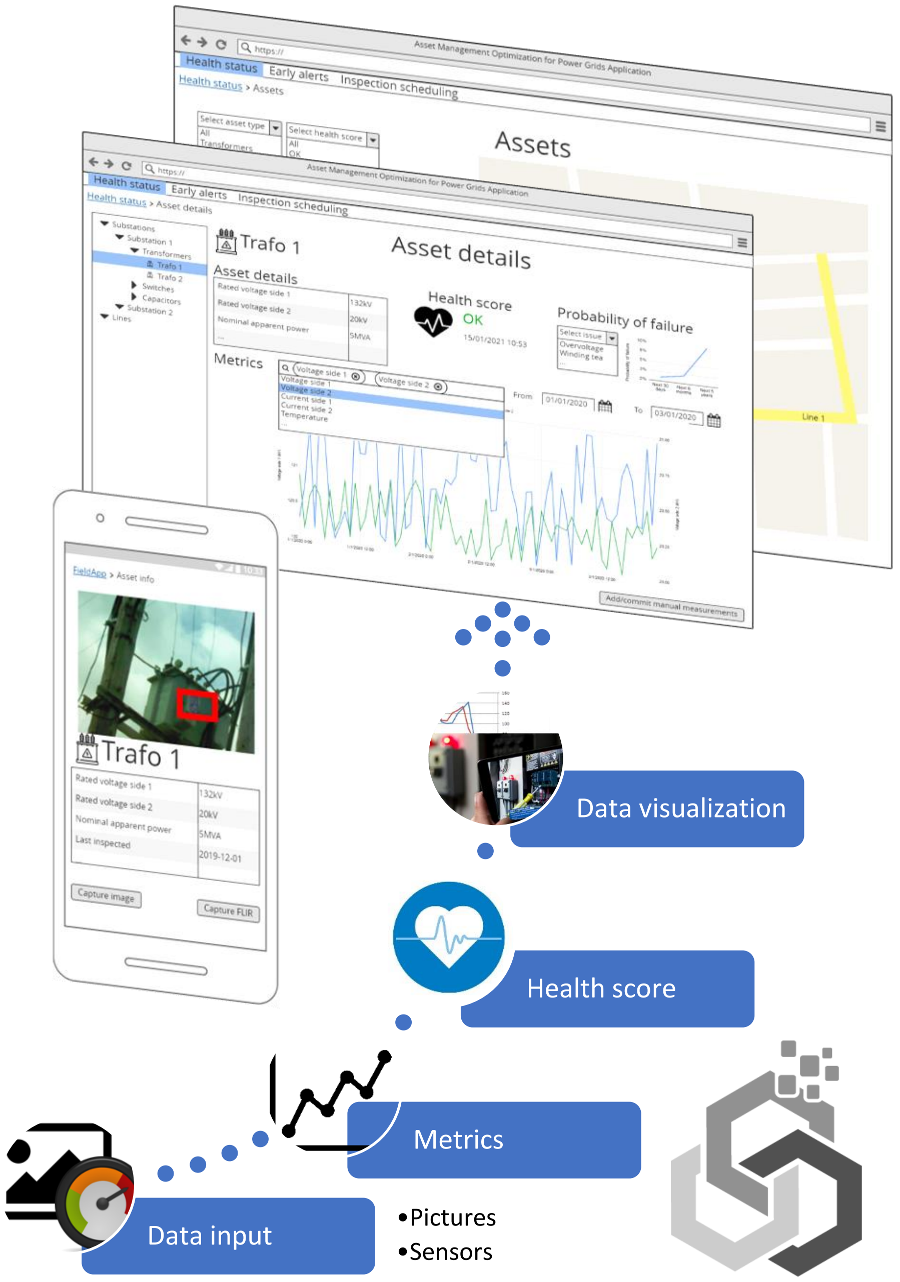


Network Asset Management Tool: Functionalities

1. *Network Asset Health Estimator*

- It uses measures from assets to train models able to provide a health score based on the last set of measures available
- It uses remote or manually fed inputs (measures from field), pictures can be processed to generate additional information about the assets as well

- Three types of analytics to provide the expected results:
    - ***Picture analysis*** extracts information out of the available pictures
    - ***Classification models*** provide a health score based on the latest available set of measures.
    - ***Regression Models*** predicts next asset's failure in days
- These analyses provide as a final result **a health indicator** for each asset under maintenance.



Network Asset Management Tool: Functionalities

1. *Network Asset Health Estimator*

Feature	Description
Picture Based Indicators	A pretrained neural network has been used to solve this problem. The neural network is called YOLO (You-Only-Look-Once) and it has been previously trained to detect 3 classes: Persons, Fire and Smoke. This new system has been deployed in a fast API and it has been served using a dockerized container.
Metrics Visualization	Metrics calculation and graph visualizations for all available metrics, this component provides appropriate graph visualizations to support the maintenance operator work.
Asset Health Score Calculation	Probability scores of occurrence of failures: A custom deep neural network has been used to solve this problem. It consists of an input layer, two hidden layers where the first one is a LSTM (Long-Short Term Memory) layer with 100 neurons and a dropout with 0.2 threshold and the other has the same architecture but with 50 neurons. Finally, it has an output layer with 2 neurons (number of classes: error before 30 cycles and error after 30 cycles), with a categorical-crossentropy as a loss function and a softmax activation function. The optimized used for the training has been the Adam optimizer.
Asset Health Score Calculation Regression	A high-level health score will be provided, allowing the maintenance operator to rank the assets accordingly and use this information in the maintenance scheduling A custom deep neural network has been used to solve this problem. It consists of an input layer, two hidden layers where the first one is a LSTM (Long-Short Term Memory) layer with 100 neurons and a dropout with 0.2 threshold and the other has the same architecture but with 50 neurons. Finally, it has an output layer with 1 neuron, with a MSE as a loss function and a linear activation function. Adam optimizer has been used for the training.
AR System	Presentation of results by means of a mobile AR visualization system: Augmented Reality visualization of the information managed by this component, explored in order to provide maintenance operators with novel means of accessing information, which will enhance their user experience

Network Asset Management Tool : Functionalities

2. *Network Predictive Maintenance Manager*

- analyse a variety of data sources, including metrics from Network Component Health Estimator, with the objective of complementing Maintenance Management Systems with estimations of the probability to failure of a single network assets in different time frames
- use of different models for failure prediction at different time ranges, which will be specialized for relevant combinations of asset and failure type
- analyse historical alert logs from the DSO and TSO systems to find out correlations among those alerts, which can be used to trigger early alerts signalling potential cascade effects in the network under analysis
- The component gives back probability failure in short (days), medium (months) and long term (years)

Network Asset Management Tool: Functionalities

2. Network Predictive Maintenance Manager

Feature	Description
Prioritization of maintenance tasks	different metrics available for each asset brought together with the technical maintenance specifications to assign relative maintenance priorities to each of the network assets under maintenance
Event Correlations (early alerts)	A correlation matrix of all occurrences between each alert will be used to calculate the probability to occur an alert given a previous one. The data will be analysed by the process to obtain all possible pair of events, but the process will be improved in the future to allow it to manage more than one previous alert to predict the new one.

Network Asset Management Tool : Pre-processing

- V and I measures of each transformer from SCADA, have been used as an input to be analyzed and obtain the final results.
- This data is obtained as a time series and resampled to 30’ granularity.
- Once the data has been obtained and resampled, it has been merged by the date with a dataset which contains the event failures.
- A new column called “Time Window” has been created on the dataset, which contains when the current row will fail in the time series (It is calculated looking for the next failure, counting the number of registers between the row and the failure and normalizing these cycles to days).
- An integer id has been assigned to each time window since the neural networks only allow numerical values.

cycles	timeWindowFailure	voltage	current
1102	0	20.654375	30.654375
1101	0	20.612865	30.612865
1100	0	20.725184	30.725184
1099	0	20.693441	30.693441
1098	0	20.859478	30.859478

Preprocessed dataset

Network Asset Management: Deep Learning Techniques and development

- Recurrent neural networks (RNN) are the state of the art algorithm for sequential data. It is the first algorithm that remembers its input, due to an internal memory, which makes it perfectly suited for machine learning problems that involve sequential data.
- To solve our problem, the Long short-term memory network (LSTMs) has been used, which belongs to RNN family and extends it memory.
- The LSTMs enable RNNs to remember inputs over a long period of time. This is because LSTMs contain information in a memory, much like the memory of a computer. The LSTM can read, write and delete information from its memory.
- This memory can be seen as a gated cell, with gated meaning the cell decides whether or not to store or delete information based on the importance it assigns to the information.
- In an LSTM there are 3 gates: input, forget and output gate. These gates determine whether or not let new input in (input gate), delete information because it isn't important (forget gate), or let it impact the output at the current timestep (output gate).

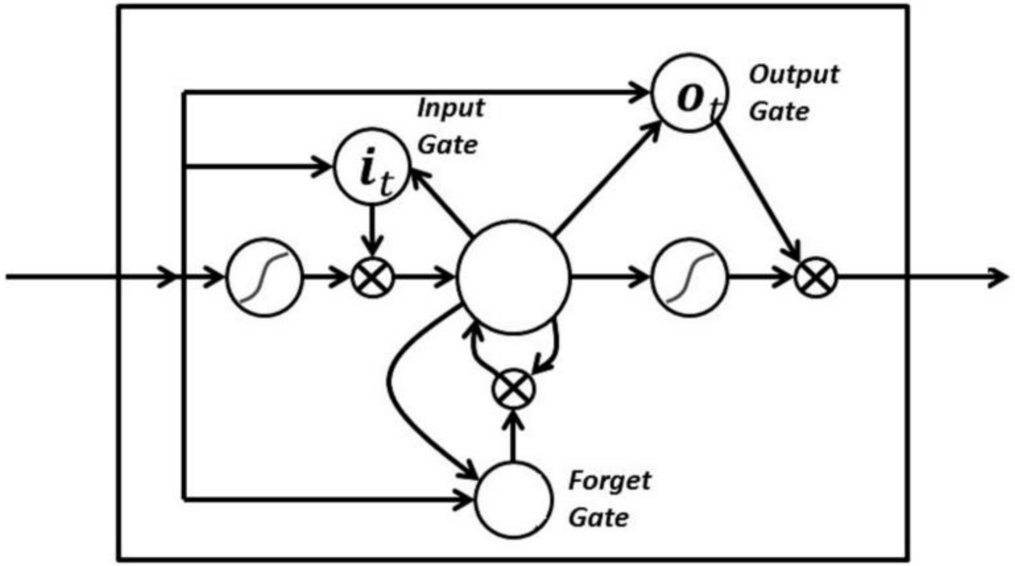
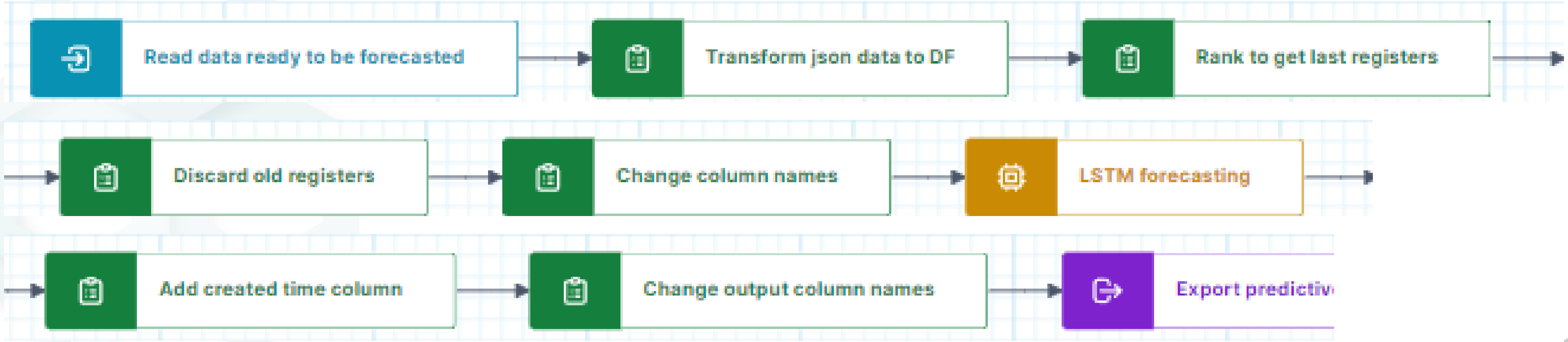


Illustration of a RNN with its three gates

Network Asset Management Tool : Workflow and Algorithm

- A training workflow has been created on the SYNERGY platform, which is being re-trained weekly by a scheduled task also defined in the platform. The data used for the trainings is also allocated in the platform and daily updated by TSOs and DSOs.
- Another forecast workflow has been created, which uses the output model created on the training stage and calculates predictive maintenance for each asset in the data. It is calculating each hour the probability of failure in the next defined time windows. It is scheduled using the task scheduler that the platform serves.
- The outputs are stored in a result dataset, which is retrieved by the User Interface, to display the results to the final application users.



Forecast workflow implemented on SYNERGY platform

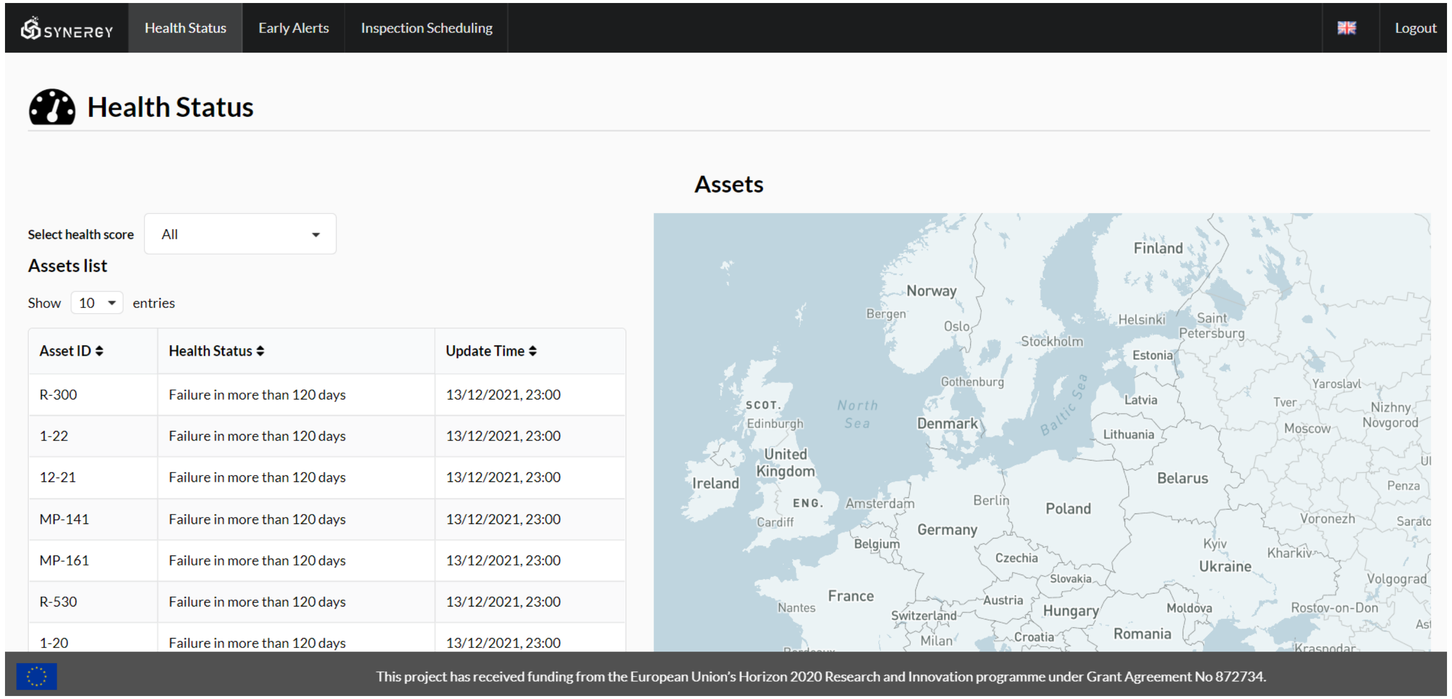
Demo Site Description

- Greek Distribution Network demo site:
  - MV line (1-21): 46 MV/LV Substations, 12 MV consumers and their own Substations, 4 major RES producers (PV stations) connected at LV and LV users.
  - AMI: telemetering centers, remotely collecting meter readings from MV customers and RES producers, and from major LV customers (> 55 kVA) including PV plants.
  - SCADA-DMS: supervision of the HV/MV substations, critical data: event, fault alarms and metering data
  - GIS: MV/LV Network Topology and Equipment Status
  - Databases: Failure and Maintenance Databases

Related Data Assets
AMI & Smart Metering Data of MV and LV users
Metering Data
SCADA Data (events & P, Q, V, I)
RES Data of MV and LV producers
GIS Data
Outage Data (time, Substation, Cause, Description..)
Transformer Data (Visual and IR images)

Results of Service testing at demo site

- 3 years of historical data to train the models
- SoH - failure probability in:
  - 30 days
  - 60 days
  - 90 days
  - 120 days
  - or >120 days
- Probability Ranking:
  - scheduling inspections
- Web application UI
  - georeferenced assets' locations
- Automatic and manual measures and images acquisition



Results of Service testing at demo site

Current Measurements

Measurement type	Value	Updated Time
Voltage	20.93 V	12/31/2021, 11:49 PM

View pictures

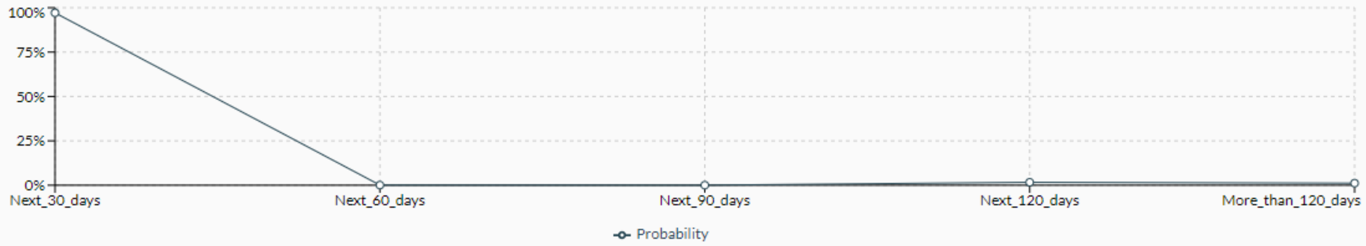
Health score

Failure in next 30 days

8/9/2022, 9:20

Commit manual pictures | Add/commit manual measurements

Probability of failure



Current Measurements

Measurement type	Value	Updated Time
Voltage	20.85 V	1/1/2022, 12:29 AM

View pictures

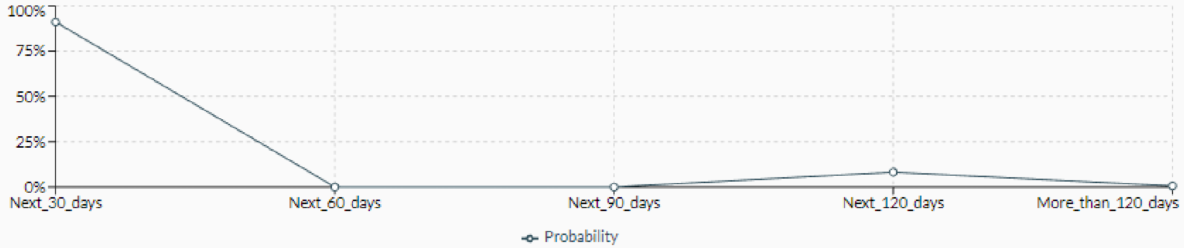
Health score

Failure in next 30 days

9/7/2022, 3:34 PM

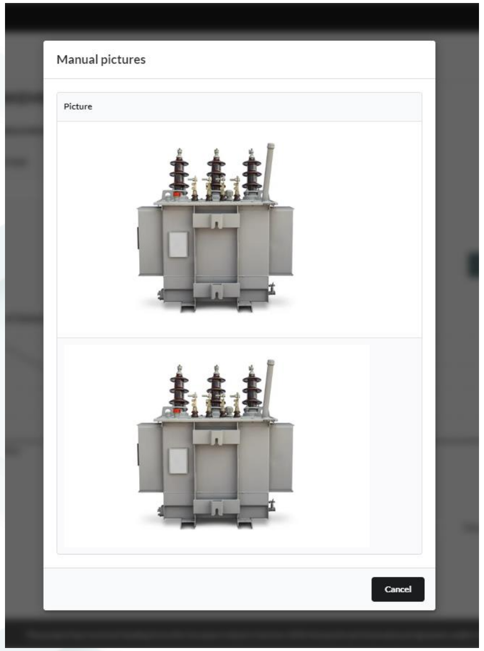
Commit manual pictures | Add/commit manual measurements

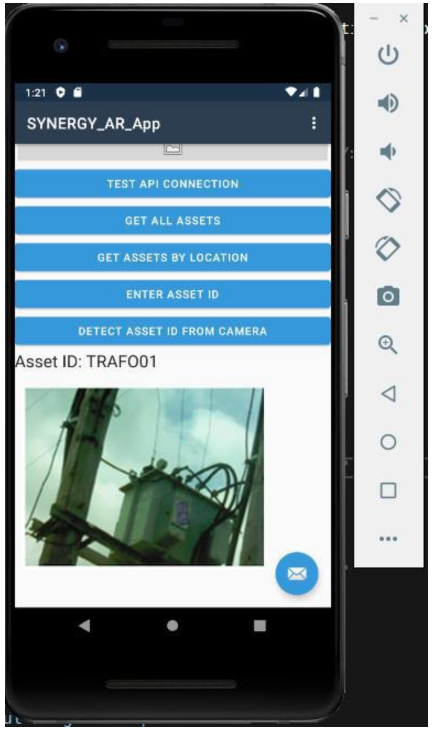
Probability of failure



Results of Service testing at demo site

- The tool calculates the hourly probability of failure for each transformer and lines
- On an initial sample of 67 assets identified by the demo owner, 2 of them have resulted with a probable failure within the upcoming 30 days (97% and 91%)
- These 2 assets (power transformers) have been also identified by demo owner in a grid portion where failures use to occur due to stress conditions on the grid
- No failures in overhead lines neither early alerts detected so far





Network Asset Management Tool: Benefits and Innovations

- Exploiting the various data analytics available through the integration with SYNERGY platform to create test scenarios and improve network planning
- Supporting the transition to an automated coordination and interaction between the distribution and transmission network operators, where they would be in a position to optimally manage congestions and unbalances and operate their networks using the available flexibility
- Supporting the transition from a conservative planning for a long future period to a more flexible predictive planning, that reports network performance, grid status awareness of the near future (next weeks and next months) and uses flexible capacity instead of traditional expansion investments
- Feeding into DSOs and TSOs high-value information to manage their assets and networks, to optimize green power exchanges/ trading (retailers) or improve short-term operational scheduling
- Supporting DSOs and TSOs to transition from preventive-based to predictive-based maintenance

THANK YOU

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