syn.ikia

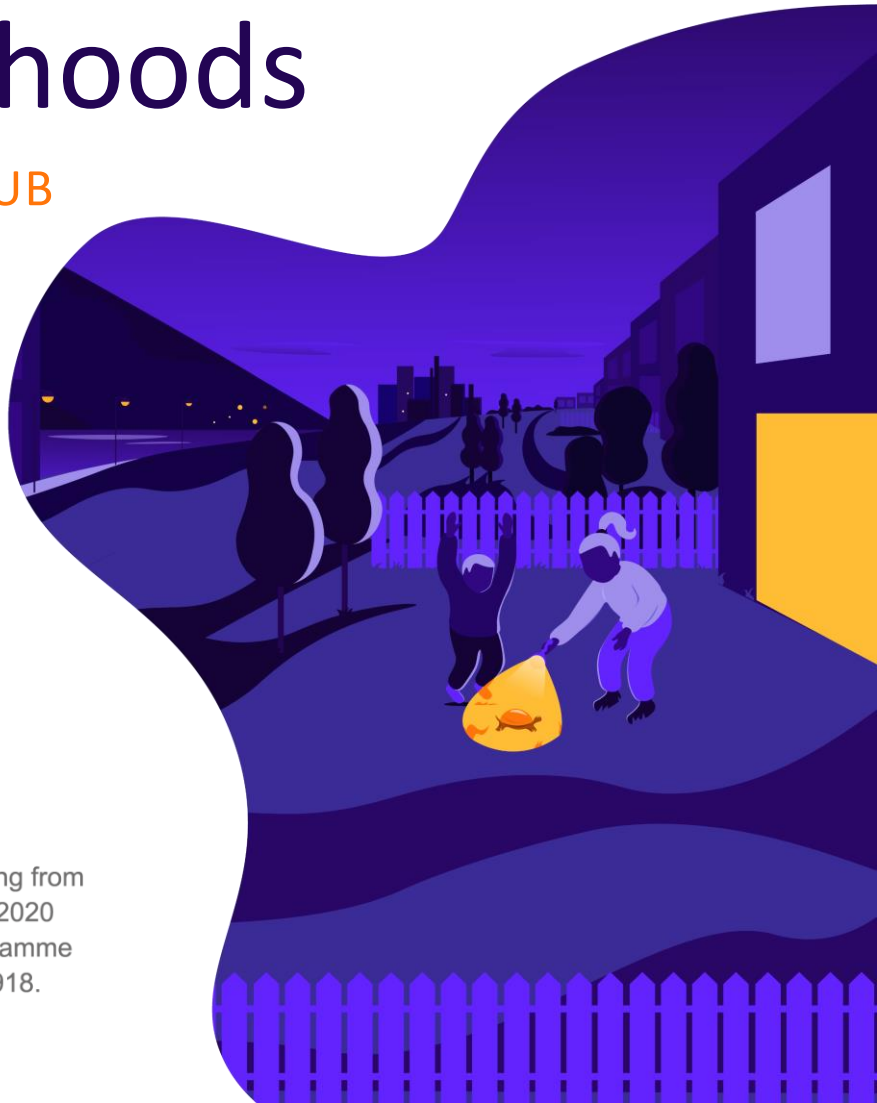
Sustainable plus energy neighbourhoods

# **WP3** - Technology Integration in Smart Managed Plus Energy Buildings & Neighbourhoods

## D3.3 SYN.IKIA CLOUD HUB

Balazs Emri - ENFOR

31.12.2023/M48



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# 1. Revision Log:

This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published work has been properly cited.

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# 2. Technical References

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| Deliverable (number) | D3.3 | | | |
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# 3. Executive Summary

This report is a short-written description of the deliverable 3.3, D3.3: Syn.ikia Cloud Hub.

The syn.ikia Cloud Hub serves as a pivotal component within the syn.ikia project, facilitating the seamless exchange of data and information between demonstration cases and research partners.

The following high-level functionalities are provided by the Cloud Hub:

1. **Real-time Monitoring:** The syn.ikia Cloud Hub monitors the actual behaviour of buildings, capturing insights into indoor climate, energy consumption, and system operation.
2. **Dynamic Control**: Visualizing the outputs of the implemented flexibility control algorithms from Work Package 4 (WP4), the cloud hub enables the effective control of buildings and neighbourhoods, optimizing their performance.
3. **Performance Evaluation:** The cloud hub facilitates the evaluation of demonstration projects by calculating Key Performance Indicators (KPIs) as outlined in Task 3.1 (T3.1). This evaluation process is integral to assessing project success and identifying areas for improvement.

The report details the overview, implementation and achieved progress of the Cloud Hub components:

1. **Webservice:** This is the tool used for data transfer between the demonstration sites and the Cloud Hub. It is a secure route where data travels back and forth, ensuring a smooth flow of information.
2. **Data Storage**: A centralized data server where all the uploaded data is archived in an easily (if authorized) accessible way. Each demo site gets its own space, making it easy to retrieve and use the data for analysis.
3. **Computational Environment:** A customizable workspace where the research partners can process the data stored in the Data Storage. It is hosted by ENFOR and provides the tools needed for developing custom code and analysis.
4. **Visualization Interface**: A user-friendly web application that displays performance metrics such as KPIs in a way that's easy to understand, compare and evaluate for each demo.

The default data flow in case of the KPI computation follows these steps:

1. The measurement data from the Building Monitoring System of a demo is uploaded from the **Edge Computer** of the demo site to the Cloud Hub, using the **Webservice**.
2. The uploaded data lands on the **Data Storage**. From the **Data Storage** it can be accessed from the **Computational Environment**, where further analysis, such as KPI computation can be executed on this data.
3. The result of the KPI computation is uploaded back to the **Data Storage** from where it can be downloaded by using the **Webservice** or can be visualized on the **Visualization Interface**, for example as bar charts.

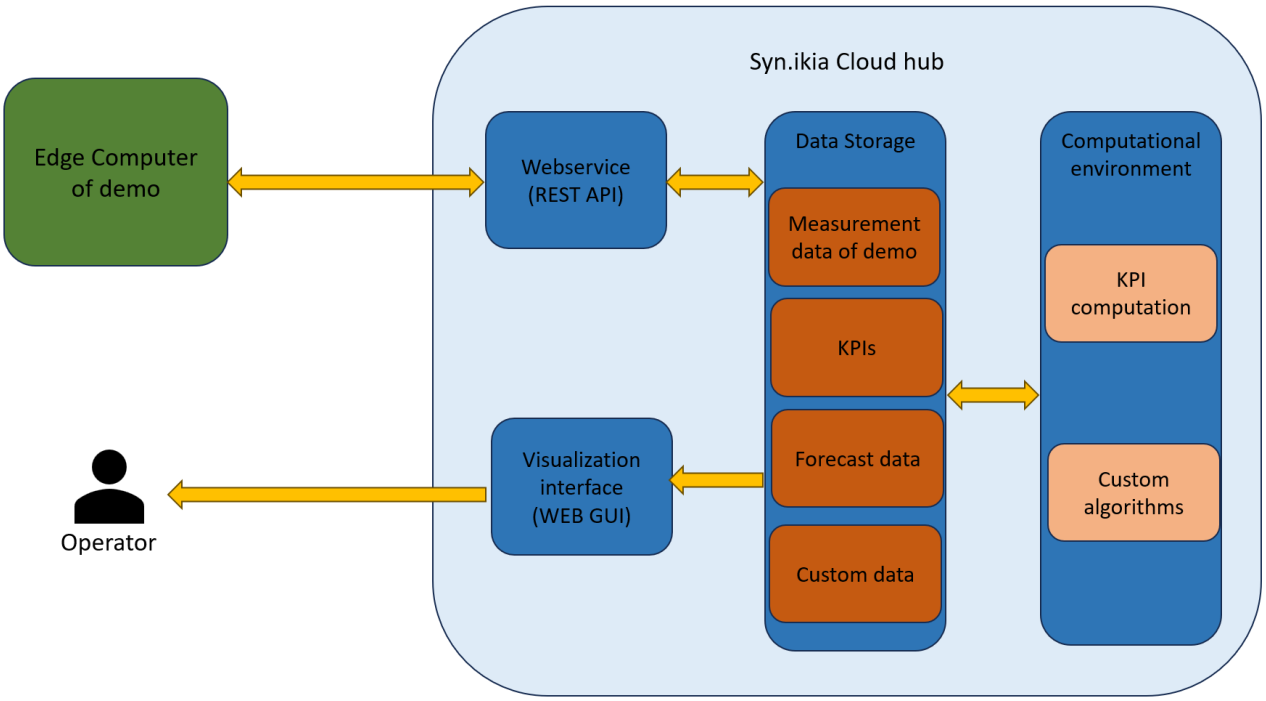


*Figure 1 Architecture of the syn.ikia Cloud Hub*

Note that the report will be supplemented and completed when the monitored data for the four demo projects is available, new edition is expected to be submitted at the last semester of syn.ikia project.

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# 4. Roles and Responsibilities

| Name | Role | Responsibility |
|---|---|---|
| ENFOR | Task 3.3 leader, coordinator of deliverable contents, contributor | Implementation of the syn.ikia Cloud Hub |
| TNO | Contributor | Research partner of the Dutch demo case, providing data collected from the Dutch demo |
| IREC | Contributor | Research partner of the Spanish demo case, providing data collected from the Spanish demo |
| NTNU | Contributor | Research partner of the Norwegian demo case, providing data collected from the Norwegian demo |
| ABUD | Contributor | Research partner of the Austrian demo case, providing data collected from the Austrian demo |

# 5. Introduction

ENFOR is a company focused on energy forecasting and optimization. The usual workflow of providing a forecast follows these steps:

1. Get general information about the project of the customer (e.g. GPS coordinates, parameters of the buildings/power plants)
2. Get historical data of energy consumption information from the customer (e.g. the power consumption of a building over the last year)
3. Collect weather forecast inputs of the region
4. Set up initial forecasting using the inputs of point 1, 2 and 3
5. Set up continuous transfer of the energy consumption data, in the agreed format
6. Set up continuous transfer of the forecasts to the customer, in the agreed format
7. Calibrate the forecasting algorithms using the most actual energy consumption data

As the forecasts are calibrated by inputs from the customers and the outputs of the forecasts are to be provided for the clients in a predefined format, ENFOR has to be equipped to manage this kind of data flow.

In the energy sector, the ways of transferring data are dependent on the standards the customers use, so when a customer requests a forecast from ENFOR, the format of their input data has to be converted into a standardized format which the software solutions of ENFOR can process. The same logic applies to the output of the forecasts, as well as to the way of transferring the inputs and outputs between the parties.

The requirements of the syn.ikia Cloud Hub overlap with the requirements the infrastructure of ENFOR has to cover in terms of the data flow. Each demo site can be considered as a customer, providing its data in a custom, demo specific format. This data has to be transferred to the syn.ikia Cloud Hub, in a formatted way so it can be processed later.

One of the main goals of the syn.ikia Cloud Hub is to provide an environment where the performance of the demo sites can be evaluated and compared using KPIs. To achieve this, a good understanding of the differences between the data of each demo is required. This requires the collaboration and assistance of research partners, enabling the transformation of data uploaded from demonstration sites into inputs for the Key Performance Indicators (KPIs) subsequently employed in the evaluation process.

Another main goal of the syn.ikia Cloud Hub is to act as a place where the research partners can have access to the uploaded data and perform analysis on them. This is satisfied by providing user access to one of the servers hosted by ENFOR, having access to the data in the Data Storage.

The last function the syn.ikia Cloud Hub has to fulfil is to make the data downloadable and browsable for authorized users. For this reason, the data transfer is set up in two directions: the user can not just upload data but can also fetch data from the cloud hub using the same webservice. For browsing the data, a web based graphical interface, the Visualization Interface is used which can be opened up from any web browser.

The goal of this deliverable is to detail these aspects of the syn.ikia Cloud Hub and give a brief progress report of the implementation of each element.

# 6. Webservice

This section describes the Webservice component of the syn.ikia Cloud Hub, responsible for transferring data from the Edge Computers into the Cloud Hub.

## Overview

The Webservice of the syn.ikia Cloud Hub is a REST API implemented by ENFOR, serving as the transfer protocol between the demo sites and the Data Storage of the Cloud Hub. The REST API, which stands for Representational State Transfer Application Programming Interface, is a set of rules and conventions for building and interacting with web services. In the context of syn.ikia it is used as the tool transferring data from the Edge Computers (e.g. from an Excel sheet) to the Cloud Hub in a way that it can be later processed by the applications of the research partners and ENFOR.

The Webservice can be used for uploading or downloading data to/from the Cloud Hub, by executing REST API calls on predefined endpoints (URLs).

Ideally the operator of the edge computers located at the demo site is responsible for implementing a scheduled execution of these REST API calls, continuously feeding data to the Cloud Hub.

Practically, as a functionally equivalent solution and as a proof of concept, collected historical data can be shared periodically with ENFOR and ENFOR can upload this data executing the same REST API calls.

## Implementation

The Webservice is implemented by ENFOR and hosted on the Data Server of ENFOR. The data server of ENFOR is accessible by the name: host0.enfor.dk after username password authentication. As a security measure, access is only granted for users whose IP address has been whitelisted on the firewall of the data server. For availability, ENFOR has a redundant server setup behind host0.enfor.dk. This means that in case there is a hardware failure on the server hosting the webservice, another, identical server takes over the tasks of the failed server.

The Webservice, as mentioned is a REST API over HTTPS, with username password authentication. Each demo site has their own username/password pair configured. The endpoint the users have to execute their REST APIs on is: *https://host0.enfor.dk/web-service/<CLIENT_ID>/*, where CLIENT_ID is unique for every client and provided by ENFOR.

### Upload data

For measurement data upload, the REST API handles the following json format:

- list of measurement data:
  - name
  - area
  - type
  - unit
  - values – list:
    - t - epoch second end time in , UTC
      - example: 1570701600 which is 2019.10.10 12:00:00 UTC
    - v - float value

Example data:


```
[
  {
    "name":"Electricity_used",
    "area":"Spain",
    "type":"Power",
    "unit":"kW",
    "values":[
      {
        "t":1570701600,
        "v":15.678
      },
      {
        "t":1570703400,
        "v":17.2
      }
    ]
  },
  {
    "name":"PV_produced",
    "area":"Spain",
    "type":"Power",
    "unit":"kW",
    "values":[
      {
        "t":1570701600,
        "v":20.00
      },
      {
        "t":1570703400,
        "v":20.00
      }
    ]
  }
]
```


Curl example:


```
curl -X POST -H "Content-Type: application/json" -u <CLIENT_ID>:<CLIENT_PASS> https://host0.enfor.dk/web-service/<CLIENT_ID>/upload -d '[{"name":"Electricity_used","area":"Spain","type":"Power","unit":"kW","values":[{"t":1570701600,"v":15.678},{"t":1570703400,"v":17.2}]},{"name":"PV_produced","area":"Spain","type":"Power","unit":"kW","values":[{"t":1570701600,"v":20},{"t":1570703400,"v":20}]}]'
```

**Download data**

Endpoint:

https://host0.enfor.dk/web-service/<CLIENT_ID>/json?varName=<NAME>[&ptime=<EPOCH_SECOND>]

- CLIENT_ID is unique for every client and provided by ENFOR
- varName=<NAME>, the name of the value to be downloaded
- ptime=<EPOCH_SECOND> date of the value to be downloaded. Optional, by default the latest value is downloaded

For data download ENFOR provides the following json format:

- An object of variable:
    - varName – same as requested
    - ptime – same as requested
    - value – list of values:
        - t - epoch second end time of requested varName instance
        - v - float value of varName of requested varName instance

## Progress

The implementation of the REST API is completed and the Webservice is continuously running on host0.enfor.dk.

The setup of the continuous upload from edge computers towards the syn.ikia cloud hub is not yet implemented on any of the demo sites.

As a proof of concept, data of the Dutch demo has been supplied to ENFOR and ENFOR has uploaded the measurement data of the Dutch demo site using the REST API. The same is applicable in case of the Spanish demo, where the data set of a one-year long simulation has been uploaded.

The solution of ENFOR for uploading via the REST API can be easily reused on the edge computers once those systems become online.

# 7. Data Storage

This section describes the Data Storage component of the syn.ikia Cloud Hub, responsible for storing the data in a way that it is easy to access for all parties working with it.

## Overview

The Data Storage is located on the data server of ENFOR. The same redundancy and firewall whitelisting is applied here as in case of the Webservice to provide security and availability. Each syn.ikia demo site has their own storage space allocated on the Data Storage.

The data stored in the Data Storage is accessible can be downloaded to the edge computers or further processed in the Computational Environment.

## Implementation

The location of the Data Storage is not publicly available, as this element of the syn.ikia Cloud Hub only acts as an internal storage where data can be uploaded to and fetched from. Having separate users for each demo site ensures that the data is separated by each demo site and can be fetched also like that.

To fetch data from the Data Storage, the Webservice can be used, or in special cases, such as the KPI computations (detailed below) the data can be directly accessed and used as inputs for the algorithms. For direct access SFTP, or Secure File Transfer Protocol which is a network protocol used for secure and encrypted file transfers between computers can be used between the Data Storage and the Computational Environment to transfer data.

The format of each file conforms to the JSON format described by the REST API, making it easy to read in by software. JSON (JavaScript Object Notation) is a lightweight data interchange format that is easy for humans to read and write, and easy for machines to parse and generate. It is often used to transmit data between a server and a web application as an alternative to XML. The JSON format's simplicity, readability, and compatibility with various programming languages make it a popular choice for representing and exchanging structured data. Its design makes it easy for both humans and scripts to work with, facilitating data exchange and interoperability in a wide range of applications.

**Sensitivity of the data**

As certain subsets of the data stored in the syn.ikia cloud hub can be considered as personal data, the parties having access to the data have agreed upon the following:

1. In case of the inputs needed for the energy related KPIs, only aggregated data will be transferred to the Cloud Hub
2. In case of the inputs needed for the Indoor Environmental Quality KPIs, the data will be transferred to the cloud hub after pseudonymisation
3. In case the above 2 strategies do not comply with the regulations of any demo, a Data Management Agreement will be signed between ENFOR and the parties using the data

## Progress

The Data Storage is up and operational. The output of each successful REST API call, such as the uploaded Dutch and Spanish demo data is available in the Data Storage for further usage.

The direct access from the Computational Environment is also set up and is used while computing the KPIs of the Dutch and Spanish demos.

Currently only energy related, building level aggregated consumption data is uploaded to the Cloud Hub, as the signing of the Data Management Agreements is in progress to share sensitive data such as the inputs of the Indoor Environment Quality KPIs.

# 8. Computational Environment

This section describes the Computational Environment component of the syn.ikia Cloud Hub, the workspace where any kind of custom algorithm can be run on the data stored in the Cloud Hub.

## Overview

The syn.ikia Cloud Hub offers the possibility to set up a user for any research partner. Each user can run their custom code and has access to the data stored on the data storage of the hub. In case the output of the algorithms matches the format required by the ENFOR GUI, then the output can be visualized on the visualization interfaces (web GUI).

As the computational environment is hosted by ENFOR, the development tools, the hardware needs (such as CPU, memory or disk space) can be customized based on the needs of the user.

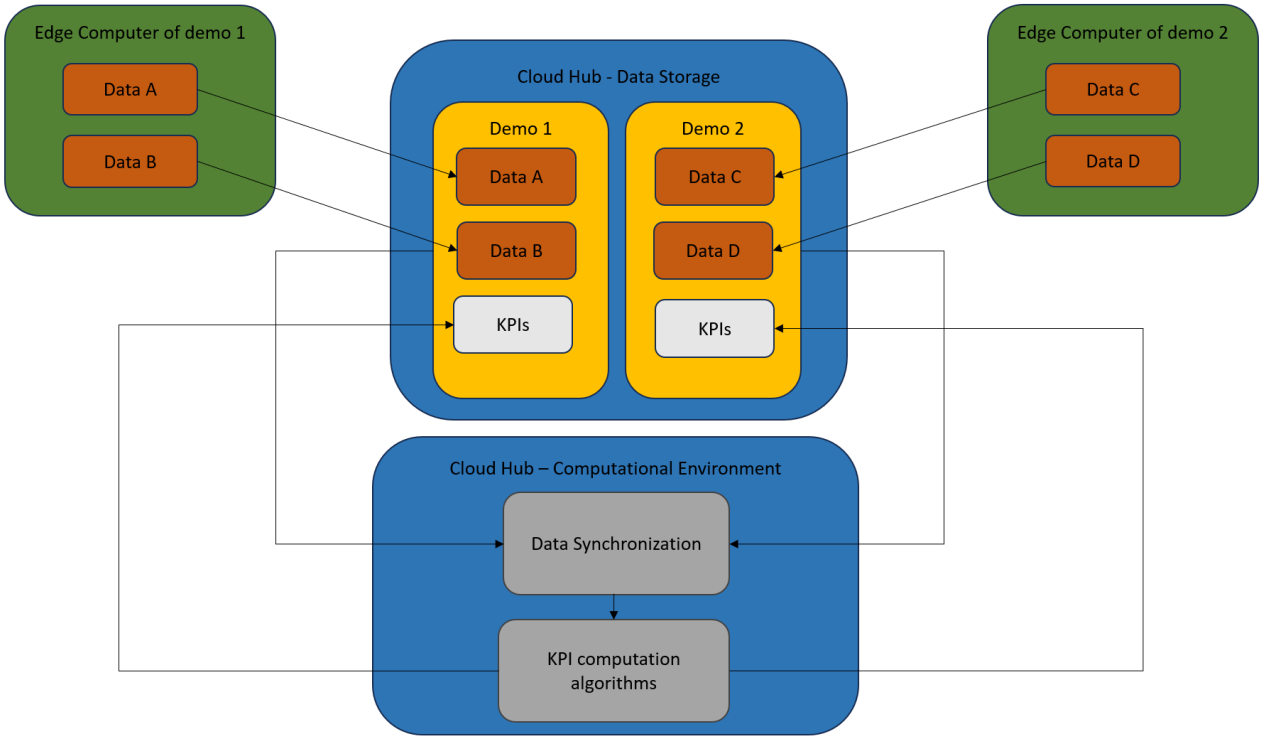


*Figure 2Architecture of Computational Environment*

## Implementation

### Environment

The Computational Environment is served by one of the servers of ENFOR. Users dedicated for executing different custom applications (e.g. the KPI calculations) are set up on this host, along with development tools such as Python, R, C++, code editors and their dependencies. The access of the Computational Environment is following the same principles as the Webservice and the Data Storage (username/password and IP whitelisting).

As described in the section of Data Storage, the users of the Computational Environment have access to the data stored on the Data Storage. As the data from the edge computers are expected to be continuously updated with the latest measurement values, the users of the Computational Environment have to periodically

synchronize data from each demo site. To achieve this, the task scheduler of the Linux system, called crontab can be utilized. In the crontab a user can define a task and a period when it should be executed. For example, every 5 minutes the data of the Spanish demo can be downloaded to the Computational Environment and the KPI computation algorithms can be executed based on the latest downloaded input data.

In case a research partner requests a user in the Cloud Hub, a user can be set up for them, (e.g. synikia-dtu). The hardware requirements of the software run by a user in terms of CPU usage, Memory consumption and Hard Disk space has to be defined in order to set up a user.

**KPI calculations**

As part of Task 3.3 ENFOR is responsible for computation of the KPIs using the equations detailed in Deliverable 3.1. To make this possible, each research partner has to provide an interpretation of their data set so the data they provide can be somewhat standardized and used as inputs for KPI calculations.

To demonstrate the workflow, this is how the interpretation of the Spanish simulated data happened.

1. IREC, the research partner of the Spanish demo provided simulated data for the timeframe of one year of power consumption and production in kW, with 15 minutes resolution
2. To interpret the data, IREC also provided a description of the data and equations to process the data as inputs, resulting in a list of intermediate indicators and usage of these in the final KPI computations of Deliverable 3.1
3. ENFOR formatted the received data so it can be uploaded by the REST API under the space of the Spanish demo in the Data Storage
4. ENFOR implemented the fetching of the data from the Data Storage to the Computational Environment
5. ENFOR implemented the computations described in point 2, using the uploaded data as input to provide the Energy KPIs as output
6. ENFOR set up the visualization of this data on the Visualization Interface

In case of the Dutch demo, the step 2 was omitted and the logic of the Spanish demo has been applied on the Dutch demo inputs. As this has been implemented recently, further evaluation and polishing of the interpretation might be needed, because each demo has their own specific custom set of data and their interpretation can differ.

## Progress

To perform the KPI calculations, a user has been set up in the Computational Environment. The data synchronization between this user and the Data Storage has been set up, so the data available for the demo sites in the Data Storage is accessible by this user. The KPI computation for the Dutch and Spanish demo is implemented.

No other user has been requested to be set up in the computational environment, but in case it happens, reusing the setup of the synikia-global user is a simple task.

# 9. Visualization Interface

This section describes the Visualization Interface component of the syn.ikia Cloud Hub, responsible for visualizing the data stored in the Cloud Hub.

## Overview

The Visualization Interface is a tool designed to provide a comprehensive view of Key Performance Indicators (KPIs) for various demo sites. Developed by ENFOR, this web application offers a customizable graphical interface accessible from any internet browser.

To ensure secure access, the system requires IP whitelisting on the ENFOR firewall and a simple username-password pair. This security measure safeguards sensitive data, ensuring that only authorized personnel can explore and analyse the performance metrics.

The primary objective of the visualization interface is to present KPIs from multiple demo sites side by side, enabling users to effortlessly evaluate and compare their performance. By offering a graphical representation of data, the interface simplifies the process of deriving insights and making informed decisions.

Similar to the Computational Environment, where data synchronization and KPI generation are executed periodically, the visualization interface ensures users always have access to the latest outputs. It reads the generated outputs at regular intervals, guaranteeing real-time insights into the performance of each demo site.

## Implementation

The web interface can be reached at the address: https://host0.enfor.dk/synikia-global/ and the users synikia-spain, synikia-austria, synikia-netherlands and synikia-norway are configured for login.

The web interface is hosted on host58 but the https traffic for this host is proxied over the host0 ENFOR server, to maintain the same whitelist restrictions as in case of the other elements of the Cloud Hub.

The front end of the web interface is implemented in JavaScript and the back end, providing the data in a formatted way so it can be visualized on the front-end is written in R..

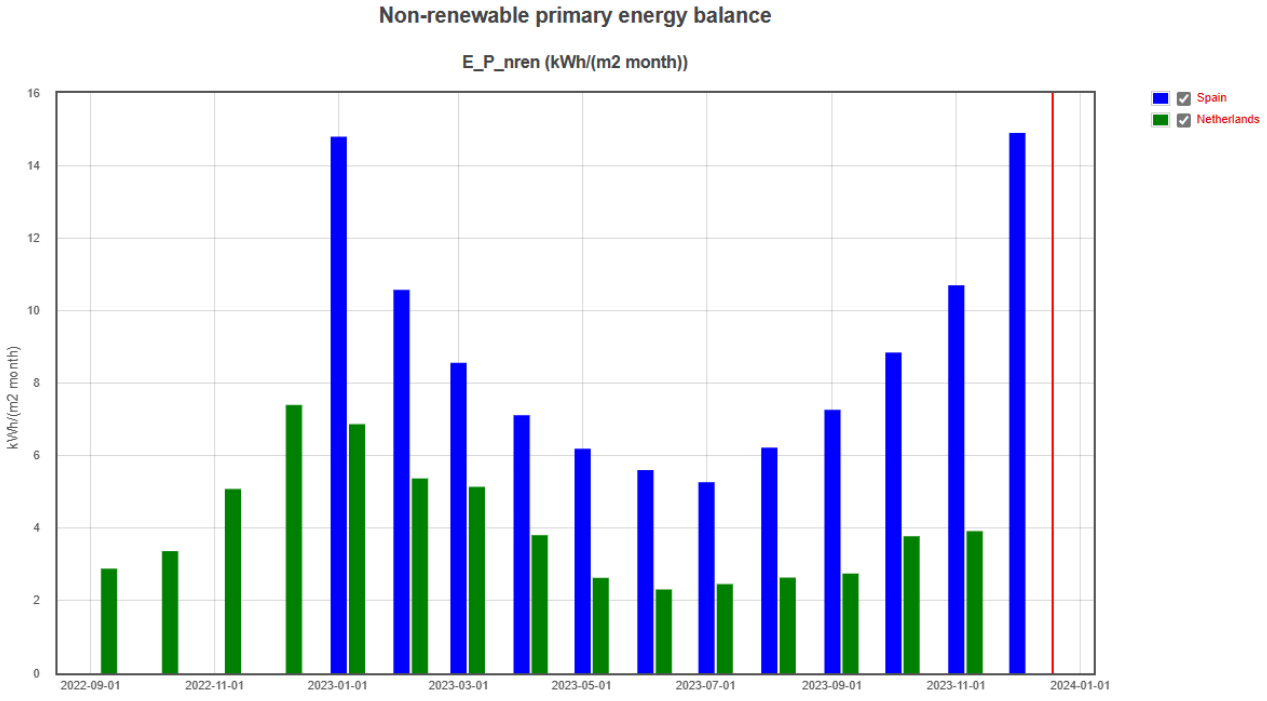


*Figure 3 KPI visualization (Non-renewable primary energy balance)*

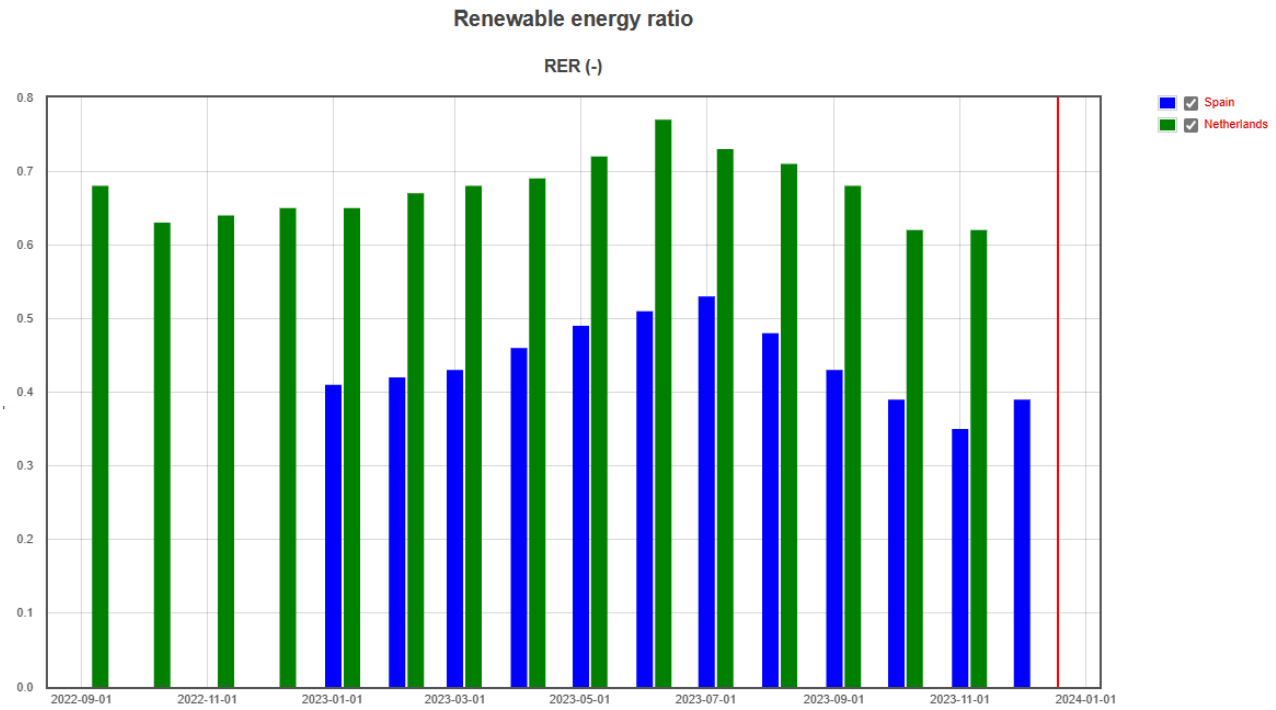


*Figure 4 KPI Visualization (Renewable energy ratio)*

### Progress

The visualization interface is up and running. Further features such as different visualization methods can be requested. Currently only the Spanish and Dutch demo energy KPIs are visualized as a proof of concept, using bar charts with monthly aggregation.

Further visualization methods can be implemented relatively easily during the lifetime of the Cloud Hub.

# 10. Outlook

As the availability of the edge computer and the measurement data and its interpretation are clearly the bottleneck in case of the completeness of the syn.ikia Cloud Hub, the decision was to create one working chain of the data flow for the demo of Netherlands and then use the Spanish simulated data for comparison.

In case of the Dutch demo case the data is available on site, it is uploaded to the cloud hub by using the REST API and using this data the algorithms in the computational environment are producing the outputs of the energy related KPIs which are visualized on the web GUI.

Based on this we can conclude that the framework is ready and the concept is proven working. Once the blocking issues around the availability of the data get resolved, the same framework can be utilized in case of the other demo cases also.


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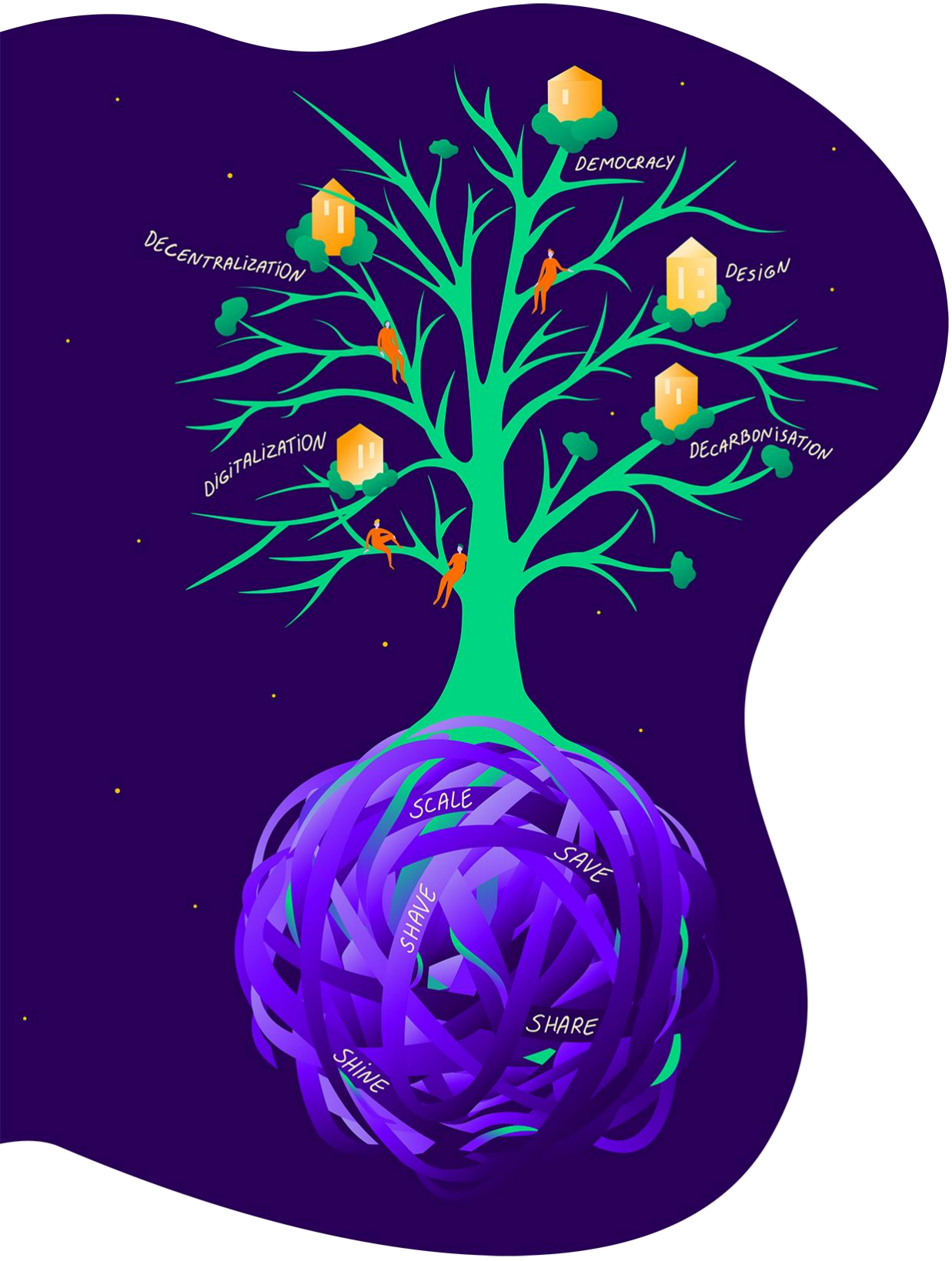
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