EEnvest

*Risk reduction for Building Energy Efficiency investments*

# EEnvest platform

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n. 833112

# Document Information

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# 1 Introduction – Background Knowledge

## 1.1 PURPOSE OF THIS DOCUMENT

This document is intended to briefly describe the work done towards the implementation of the EEnvest Platform Final Prototype as web platform. The document starts with an introduction to the EEnvest platform scope, the user roles, platform architecture and requirements specifications identified in previous deliverables, and then describes the features implemented to fulfil these requirements and testing processes.

## 1.2 SCOPE OF THE EENVEST PLATFORM DEVELOPMENT

EEnvest web platform act as Search & Match app to bridge the gap between building owners, interested in seeking for financing to upgrade their buildings performance, and investors that are willing to push the investment to generate profits and other impacts. In parallel, the platform mainstreams building energy efficiency investments by facilitating access and benchmarking of risk profiles, financial performance and sustainability impacts of the specific investment in a clear and standardized way. While the focus is on commercial office buildings, the implemented solutions are modular, generalized and scalable, then suitable for replication to extensive risk databases and models, different asset types and locations across EU. Finally, a blockchain validation mechanism ensures the validity of the data in the platform, allowing the investors to trust the exchanged information, avoiding need for 3rd party data brokers or risk of data tampering on the platform.

The development of the platform is intended to reach the levels of a Minimum Viable Product (MVP)[1], and in parallel to enable engagement of stakeholders as early adopters during and beyond the project end, to identify the improvements required to develop a Commercially Viable Product and promote later exploitation.

A MVP is a fully functional working prototype, which has core features to effectively deploy the product, and to develop a working prototype of a professional but user friendly platform that de-risks energy efficiency investments in buildings and brings together investors and building owners. A MVP is typically deployed as a product to a subset of possible customers, such as early adopters who are thought to be more tolerant, more likely to give feedback, and able to grasp a product vision from an early prototype or marketing information. This strategy targets avoiding building products that customers/stakeholders do not want and seek to maximize information about the customer/stakeholder with the least resource spent. The platform concept and early versions have been shared with internal and external stakeholders since M18 of the project and has been refined based on their needs. As discussed in use cases and architecture report, which is the requirements specification of the platform, the ideal User Interface for the EEnvest stakeholders was designed in an interactive prototype accessible by the link below.

https://framer.com/share/EEnvest-Investor-Portal--eRF1MR6z8RYegJS8Xy6Y/qZY150PS5?fullscreen=1 (see figure 1, figure 2 below)

Using the method of slicing in Agile software development, it was agreed during the architecture design and specification phase that the MVP delivered by the end of EEnvest to include the key features below that were found absolutely necessary to allow the platform to operate for early adopters:

- Ability for building owner to create a project and enter relevant data required for calculations
- Mechanism to calculate EEnvest risks and KPIs
- Map View of projects
- Comparison and benchmarking to allow spotting the “ideal” investment

[1] https://en.wikipedia.org/wiki/Minimum_viable_product

- Ability to download a full report and a blockchain verified report
- Interoperability features (APIs)

In paragraph 4, a roadmap of commercialisation is presented to inform the exploitation strategy beyond the duration of the EEnvest programme.

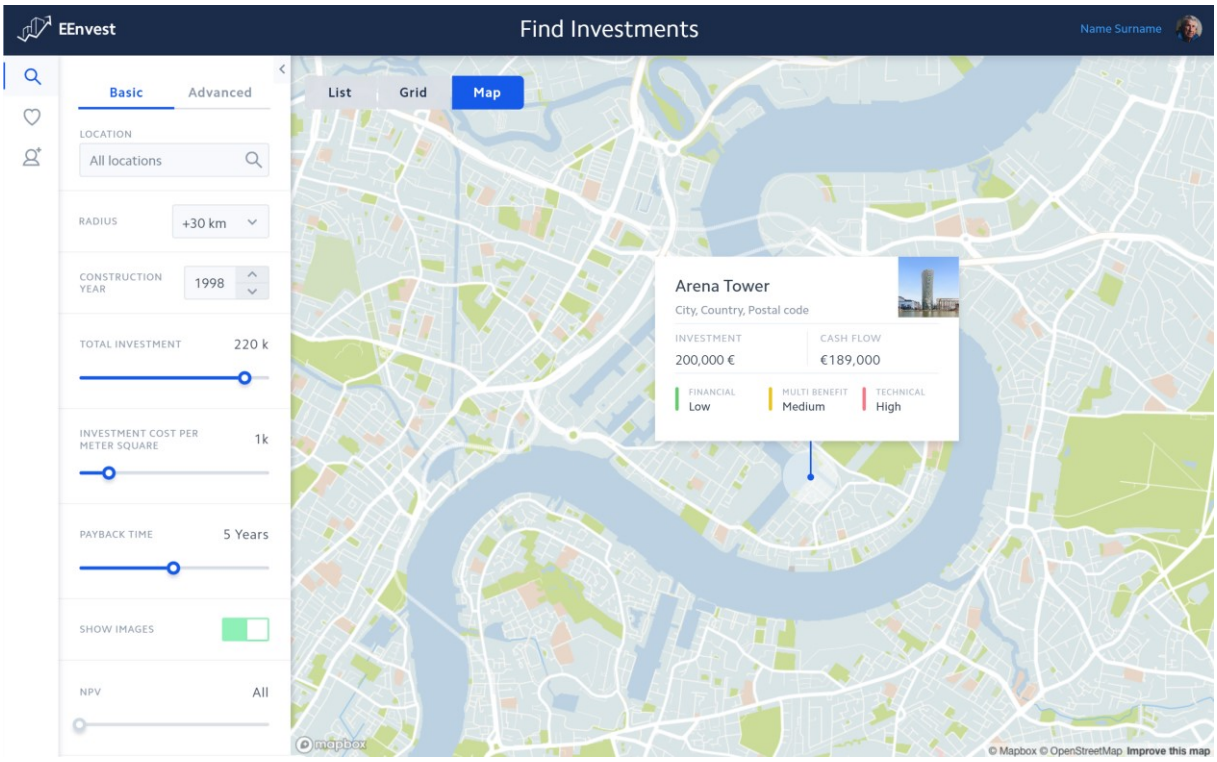



**Figure 1: Map view in EEnvest interactive prototype**

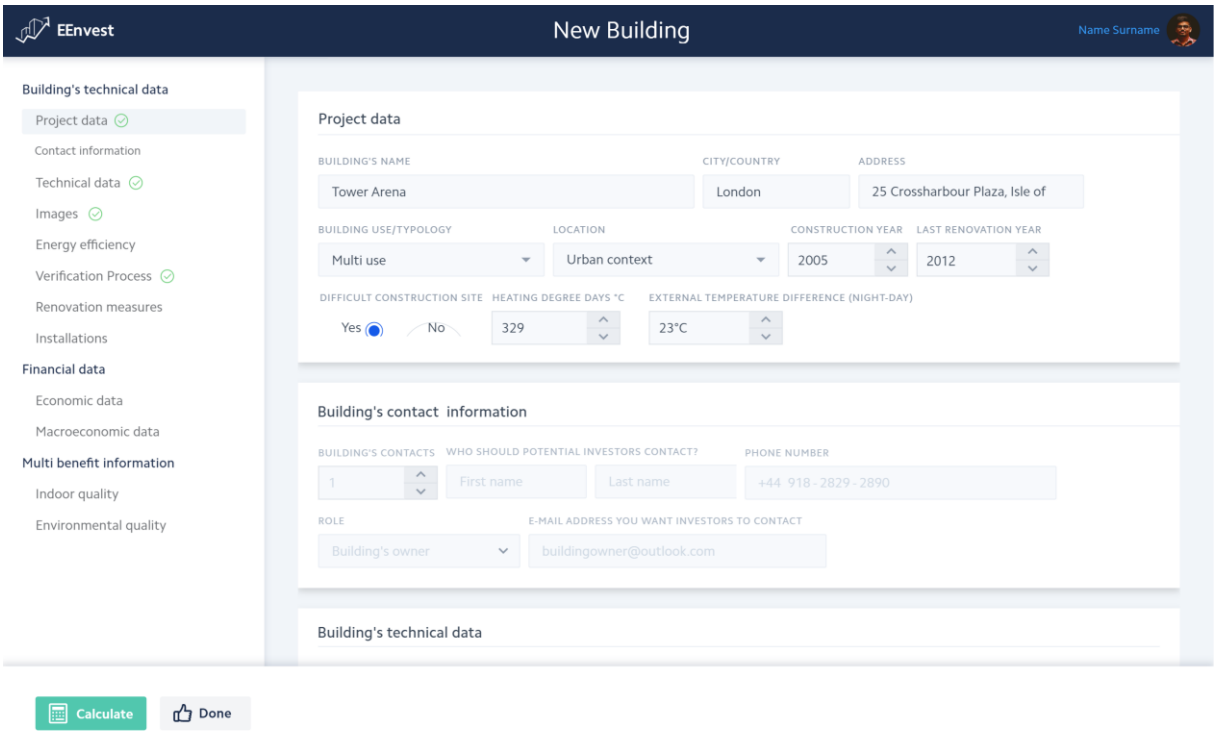



**Figure 2: Data collection sheet for Building promoters in EEnvest interactive prototype**

## 1.3 THE EENVEST USER ROLES

Two are the main user roles as the end-users of the platform, besides an administrator that has full control of the platform. These are:

- The Building Owner (Project Promoter) that seeks for investment in their building's energy retrofit project and advertises the project in the platform, by detailing the project and running the investment performance calculation.
- The Investor that can navigate to screen different investment opportunities advertised in the market place, benchmark them and get exhaustive information on the selected investment.

Below are the profiles of our two potential users:

The Building Owner (promoter) can be either a tenant, a building owner or an Energy Service Company (ESCo) that has identified that their building needs to be retrofitted for energy efficiency to benefit from energy savings and potential value increase. When approaching the service, the Building Owner has performed an audit of the status of the building, including identifying the current status, potential retrofit scenarios and their associated energy savings, then it needs to quantify the risks associated to the proposed project and eventually self-assess the project quality.

The Investor represents a financial institution or a fund, interested in investing in promising projects that can bring back revenue and impacts. The investor is trying to find the best investment opportunities based on risk profiles and investment performance that match at best the investor needs and strategy. The investor needs easy to grasp and reliable information about investment performance and risks related to such project, connect with potential Building Owners and trust that the data they process is genuine.

## 1.4 WORKFLOW AND CONCEPT

The platform is based on a Search & Match concept, that requires the various users to actively contribute to the growth of the platform. The platform operates fully on the cloud and is accessible by the users via User Interface on a web browser, responsive to all types of screens and devices, and by APIs interfaces.

The workflow is the following:

1. The Project Owner logs into the portal and uploads information which is describing their building and potential retrofit project
2. Data is initially stored on a centralised cloud database
3. Calculation of investment performance indicators is triggered by the Project Uploader/Viewer
4. The EEnvest calculation model is activated, it collects all necessary data from the risk database and additional sources to calculate risks and indicators, then it returns results to the database
5. Results are ready for display to the user Project Uploader/Viewer, who selects if they want to publish their project to the investors or not
6. To ensure the integrity of the data a blockchain validation mechanism is triggered which encrypts all the data and the calculation model
7. The encryption message is stored as a new transaction on a public blockchain (e.g., Ethereum)
8. Public blockchain nodes verify the transaction
9. The User Interface automatically requests a check that stored data is validated, generates encrypted message and compares it with the one stored in public blockchain
10. The steps 1 to 9 require just a few minutes. Then any Investor is ready to view the public projects in the User Interface and filter/customise results to find the best investment option based on their needs

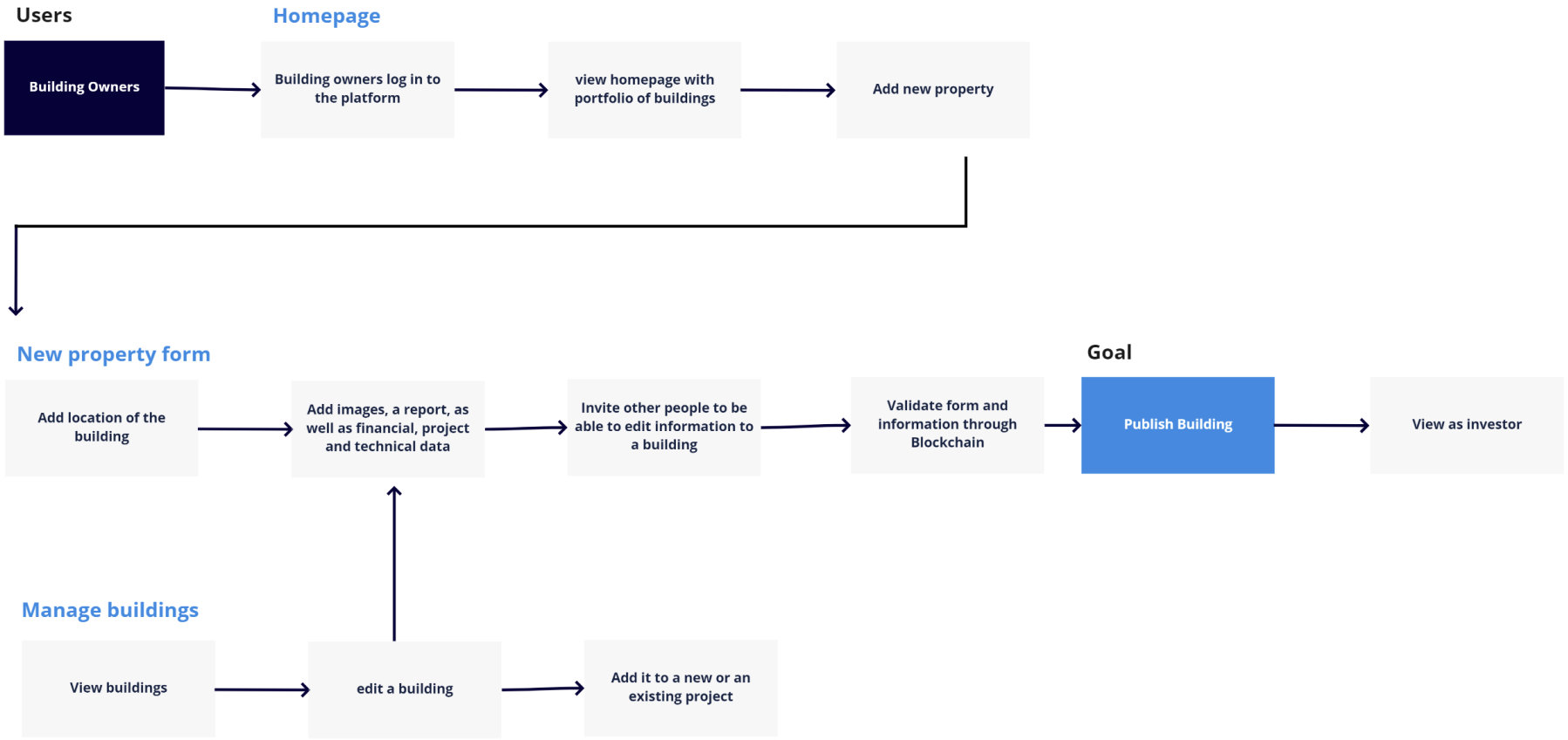



**Figure 3: Building Promoter user workflow presented in Requirements and specifications for the EEnvest platform (D5.2)**

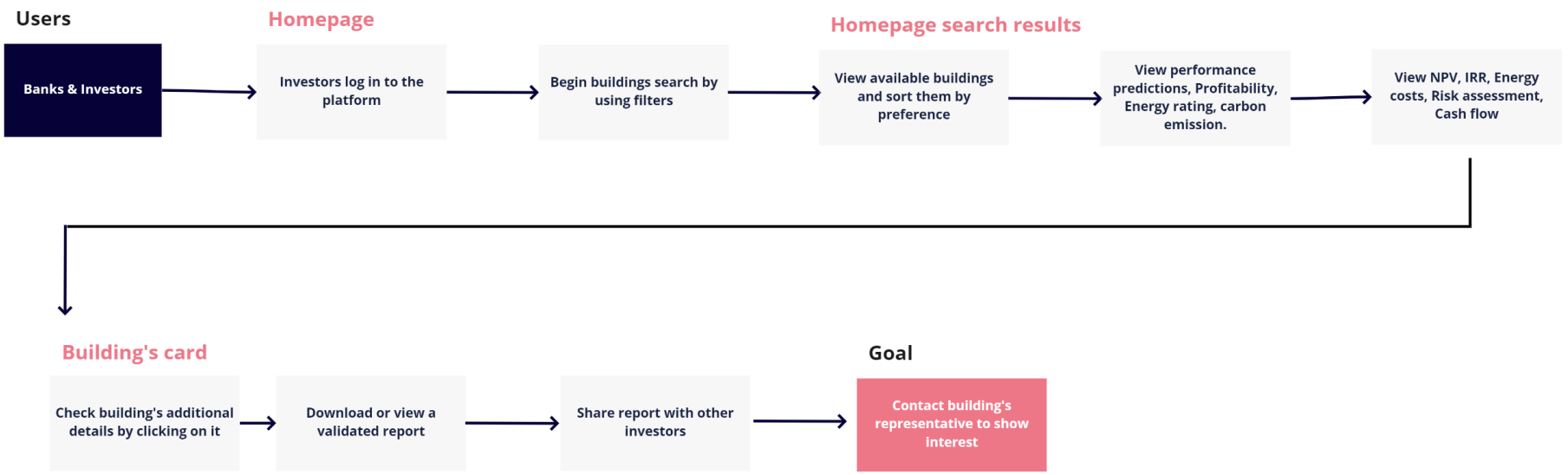



**Figure 4: Investor user workflow presented in Requirements and specifications for the EEnvest platform (D5.2)**

## 1.5 CALCULATION MODELS – HIGH LEVEL DESCRIPTION

This paragraph includes high-level background information about the technical and financial risk calculation models developed by the technical and financial risk development teams respectively, and programmed and deployed on the cloud by the software development team in IES to be executed by the Building Promoters in the platform. The results and output passed to the software development team were spreadsheets that have been converted in programming code that are executed sequentially with a simple press of a button in the platform.

### 1.5.1 Technical Risk Calculations

The technical risks analysis connected to the renovation of existing buildings is a complex matter due to the wide number of phases, stakeholders, parameters, and choices involved in the process that directly influence in the economic investment. EEnvest technical risk models quantifies two indicators for the technical risks:

- **"Energy performance gap"**, or underperformance: it is the risk connected to the lower performance than expected of the renovation measures implemented, affecting the costs of energy consumption.
- **"Damage"**: the risk of failure/breakage of the installed renovation measures, causing the need for additional investments to replace or repair the installed renovation measures.

Figure 5 provides an overview on technical risk calculation process implemented as a service withing EEnvest web platform .

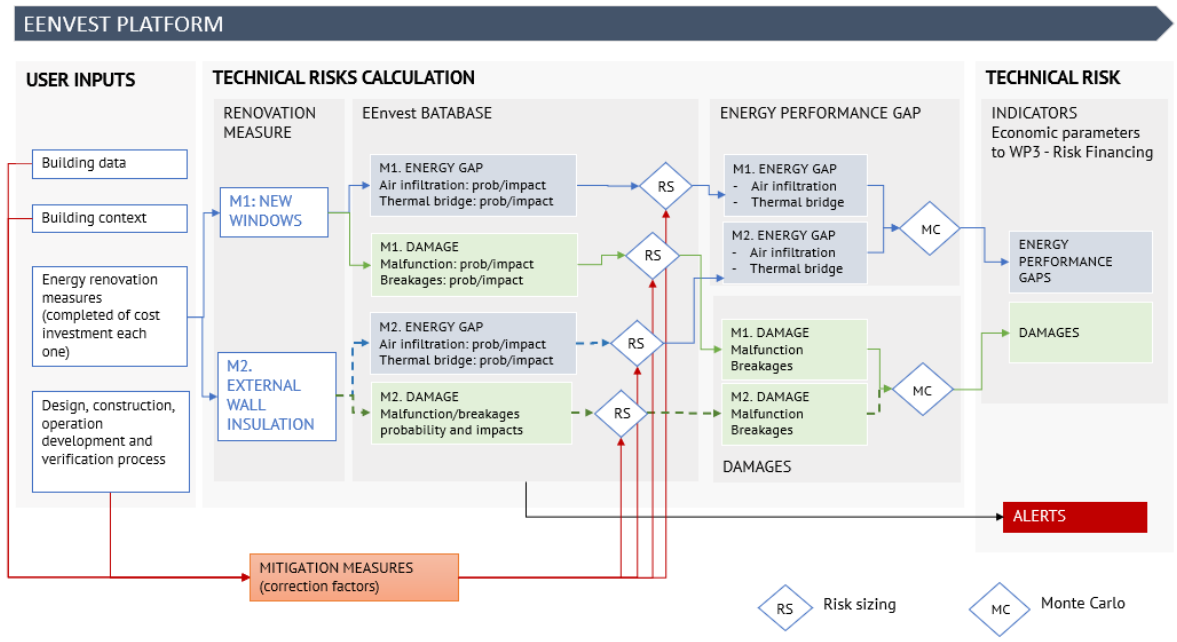



**Figure 5. Overview of technical risk evaluation process implemented in EEnvest platform**

### 1.5.2 Financial Risk Calculations

The EEnvest financial risk evaluation model calculates the financial risk related to an energy efficiency investment by providing a probability distribution of the relevant indicators (IRR, payback time, NPV, etc.). This probability distribution is based on four main risks:

- **"Energy performance gap"** and **"Damage", as previously described**;
- **Climate risk**: the risk that external temperatures during the heating season (degree days) are different than standard conditions, causing a higher or lower energy demand of the building.
- **Energy price risk**: the risk that energy prices vary from historical prices, making the investment more or less convenient from an economic point of view.

For each variable, the model estimates a probability distribution. As refers to the technical performance, the probability distributions for energy gap and damage are calculated as shown in the previous paragraph. The probability distributions for climate and energy prices, instead, are calculated based on historical series available from external data providers. The calculation of the financial impact of technical risks is therefore calculated based on the following assumptions:

- The event of damage causes an additional investment for extraordinary maintenance/repair. Therefore, in order to estimate its impact on the financial performance, the probability distribution of the damage random variable, expressed as a percentage, is applied to the investment cost, and considered as a negative economic component for the calculation of financial indicators.

- The event of underperformance causes a reduction of energy savings compared to expectations. Therefore, in order to estimate its impact on the financial performance, the probability distribution of the energy gap random variable is applied to the expected value of energy savings and considered as a negative economic component for the calculation of financial indicators.

This means that the two probability distributions are calculated, treated, and applied independently. Moreover, while the damage event is only related to technical risks, energy performance is affected by all three variables, namely energy gap, climate, and energy price. Provided that the three variables are assumed to be stochastically independent, the EEnvest model calculates the overall financial risk as the combination of the probability distributions of each of the three variables concerned through a Monte Carlo simulation. This method consists in drafting one random value from the probability distribution of each variable and then inputting those values into a formula in order to find one expected value of the cash flow, that is, in our case, the monetary value of the expected energy savings generated each year. The formula[1] used to calculate the cash flow is the following:

$$CashFlow = EES * EP * (1 - EnergyGap) * HDD - Investment * Damage$$

Where:

EES = Expected Energy Saving, expressed in kWh, provided by the user as input.

EP = Energy Price, expressed in €/kWh, provided by the user as input (based on actual prices observed for the energy audit) and linked to a probability distribution based on the analysis of historical series.

EnergyGap = Risk of technical underperformance as explained above, expressed as a probability distribution in terms of % of energy costs (thermal and electric ones).

HDD = Heating Degree Days, representing the climate risk in terms of a probability distribution calculated on the basis of the historical series.

Investment = Investment cost

Damage = Risk of technical damage as explained above, expressed as a probability distribution in terms of % of the investment cost.

Repeating the Monte Carlo simulation for a large enough number of times (i.e., more than 100.000), the result will be a series of values for Cash Flow that can be used to draft a probability distribution of the variable. The same series of values can be further exploited in order to calculate a series and a probability distribution of the relevant outputs of the financial analysis, such as the payback time and tie internal rate of return (IRR) of the investment.

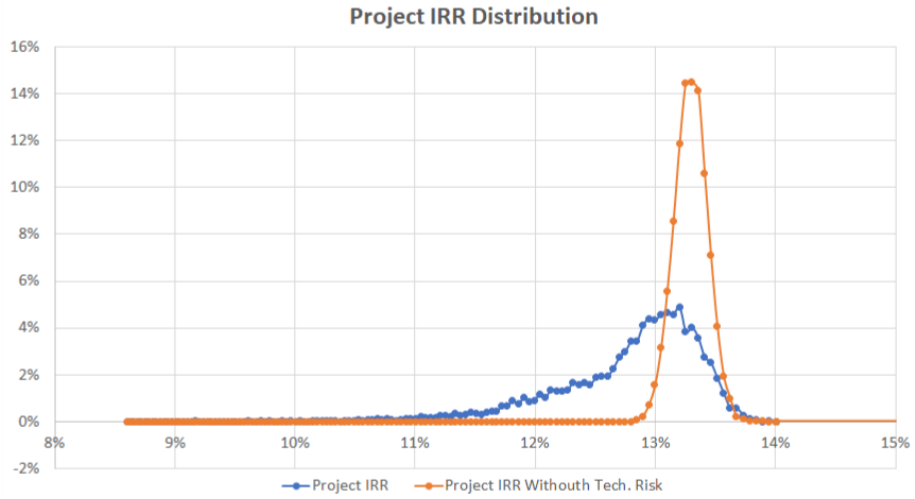



**Figure 6: Project IRR distribution example**

Please refer to previous technical EEnvest project reports for a more detailed description of the financial risk calculation model and the rationale behind it.

## 1.6 HOST PLATFORM – IES COLLABORATION CLOUD

The EEnvest Search & Match platform is developed based on the existing infrastructure of the IES Collaboration cloud (CC)[2]. The existing infrastructure of the Collaboration Cloud is already cloud based, and after careful inspection was found well advanced and suitable for EEnvest platform needs. This way we avoided re-inventing the wheel and focused on adapting CC to the needs of EEnvest platform.

The ICL[3] CC is a cloud-based information ecosystem of tools that facilitates the storage, retrieval, querying, manipulation, management and visualisation of urban models. CC tools are components of the Intelligent Community Lifecycle (ICL), a digital twin technology developed by IES to create virtual interactive models of any built environment and the visualisation of key performance indicators and data. The CC can scale from an interactive 3D environment that uses live data feeds from any ICL tool

[2] https://www.iesve.com/icl/collaboration-cloud
[3] https://www.iesve.com/icl

for community engagement with the digital twin to integrated view across communities at a national or even global level.

The CC is mainly composed by the CIM (or iCIM) and PIM (or iPIM) tools. CIM is the Community Information Model, capable to visualise a whole community of 3D representations of buildings with their metadata, while the PIM is the Portfolio Information Model, which is capable to store and visualise a portfolio of assets without their geometry.

From a technology perspective the CC breaks down into the following parts:

- Access API – A web API that allows the outside world to communicate with the CC.
- Data store - using Postgres.
- 2D - 3D viewer - a client of the Web API - that runs in any browser with WebGL support.

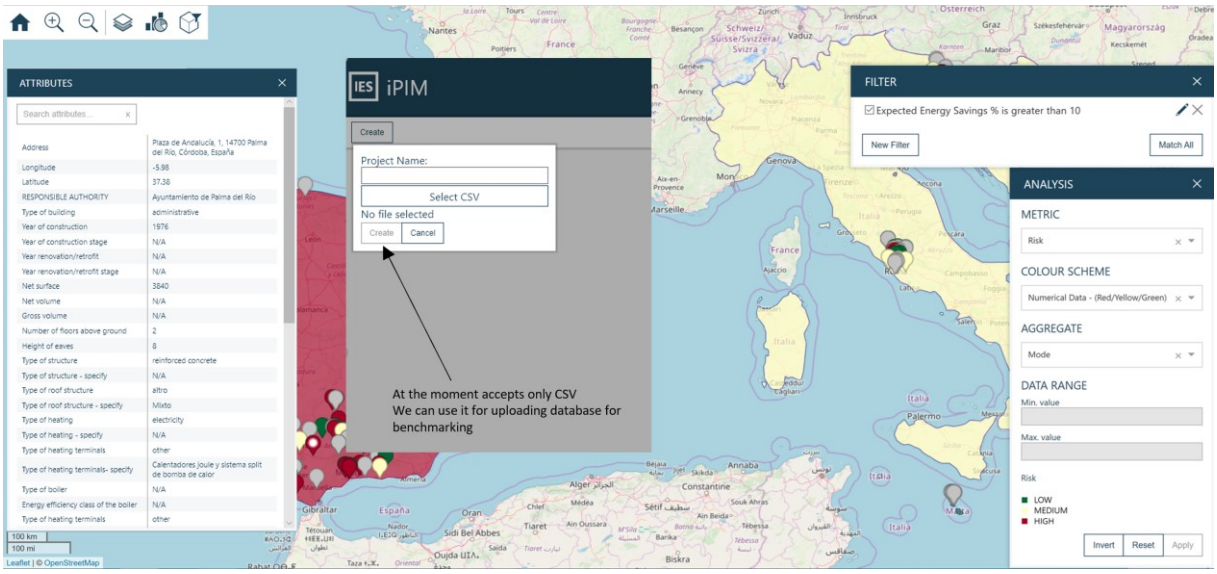



**Figure 7: The ICL collaboration cloud, view of the intelligent portfolio (iPIM) tool in 2019**

The ICL CC has been repurposed and new features introduced to suit the needs of the Search & Match platform according to the specifications identified during EEnvest project. Figure 7 illustrates the status of the PIM before the EEnvest project started. Back then, the only way to upload data in this platform was to upload a CSV file with all the data prepopulated and display them geolocated on the map. Section 2 describes the new features introduced, while the new user manual of the platform is described with all functionalities and publicly available on the project website.

# 2 Platform Implementation

## 2.1 SOFTWARE ARCHITECTURE

The software architecture of the EEnvest Search & Match platform is described in the diagram below. On the left-hand side, the Collaboration Cloud, hosting the EEnvest platform, hosted in Microsoft (MS) Azure Blob Storage. API connections are set up to execute the Risk Assessment and PDF report generator cloud calculations. Furthermore, the blockchain endpoint is creating and validating a digital report of the asset using Blockcerts and Ethereum. User interactions are taking place in the Collaboration cloud UI. The deliverable 7.10 is explaining how the user interacts with the software. For more detailed software specifications please refer to D5.2.

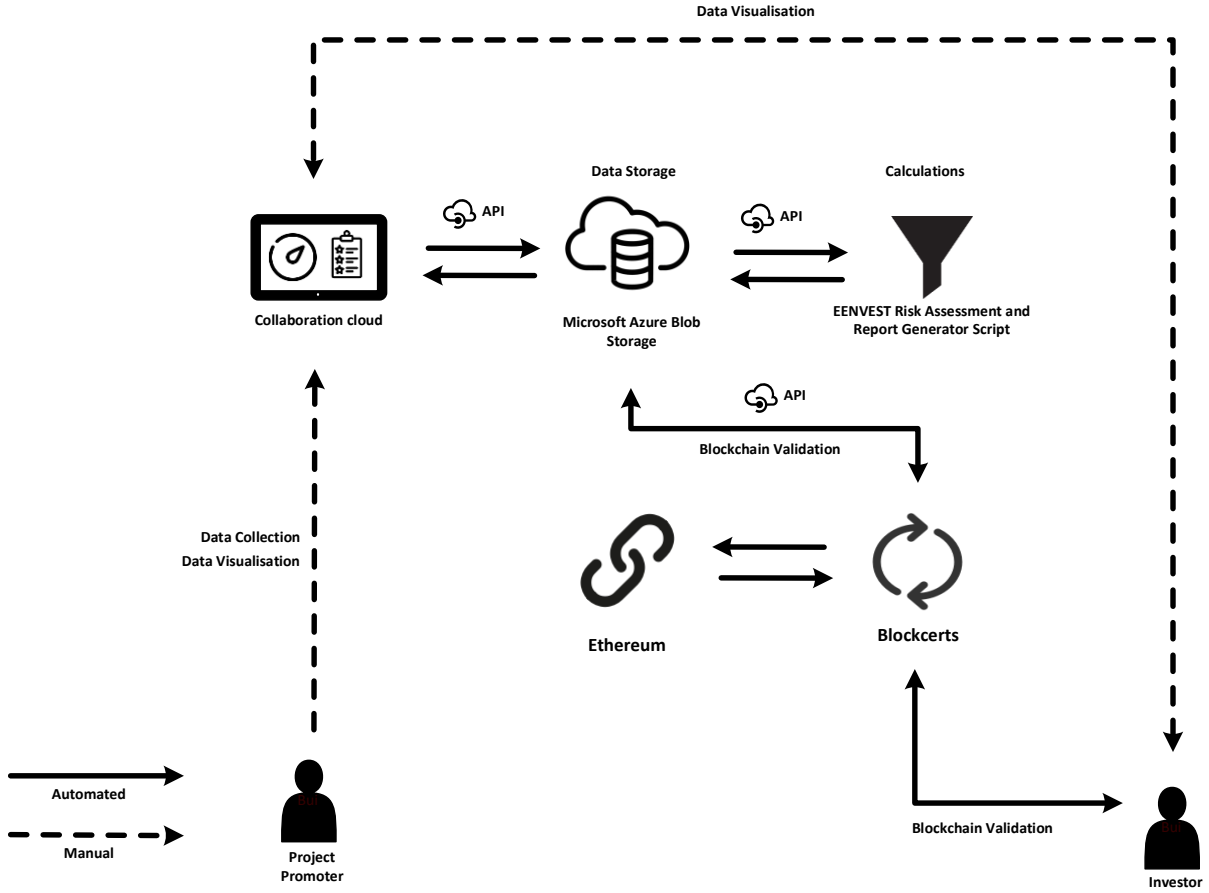



**Figure 8: EEnvest platform system architecture**

This reference architecture below is used to deploy the calculation model on the cloud and shows a serverless web application. The application serves static content from MS Azure Blob Storage and implements an API using MS Azure Functions. The API reads data from Cosmos DB and returns the results to the web app.

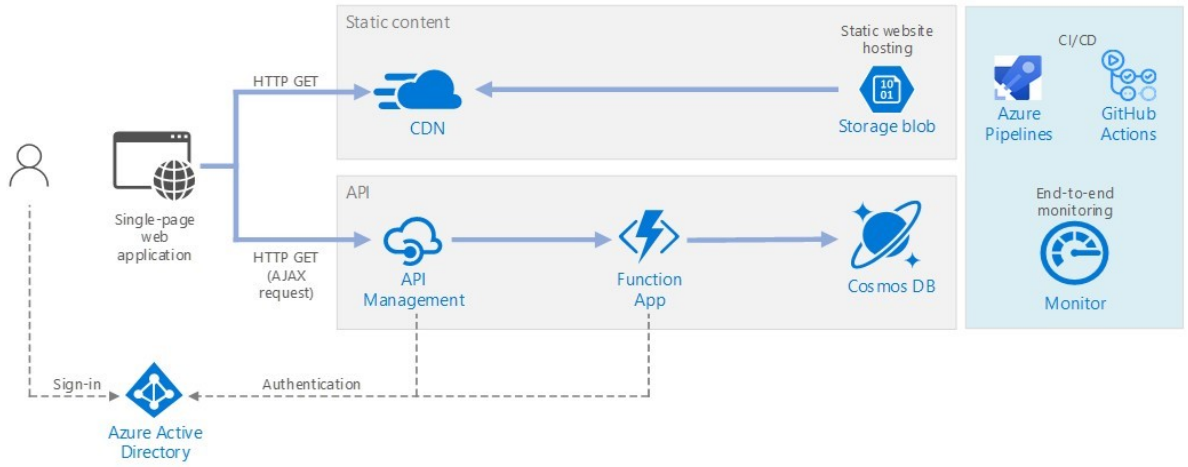



**Figure 9: Cloud reference architecture implemented in EEnvest calculations**

The term serverless has two distinct but related meanings:

Backend as a service (BaaS). Back-end cloud services, such as databases and storage, provide APIs that enable client applications to connect directly to these services.

Functions as a service (FaaS). In this model, a "function" is a piece of code that is deployed to the cloud and runs inside a hosting environment that completely abstracts the servers that run the code.

Both definitions have in common the idea that developers and DevOps personnel do not need to deploy, configure, or manage servers. This reference architecture focuses on FaaS using MS Azure Functions, although serving web content from MS Azure Blob Storage could be an example of BaaS. Important characteristics of FaaS are:

- Compute resources are allocated dynamically as needed by the platform.
- Consumption-based pricing: users charged only for the compute resources used to execute the computations.
- The compute resources scale on demand based on traffic/load, without the developer needing to do any configuration.

Functions are executed when an external trigger occurs, such as an HTTP request or a message arriving on a queue. This makes an event-driven architecture style natural for serverless architectures. To coordinate work between components in the architecture, consider using message brokers or pub/sub patterns.

Functions. For the consumption plan, the HTTP trigger scales based on the traffic. There is a limit to the number of concurrent function instances, but each instance can process more than one request at a time. For an App Service plan, the HTTP trigger scales according to the number of VM instances, which can be a fixed value or can scale based on a set of autoscaling rules.[4]

The GetStatus API in the reference implementation uses MS Azure AD to authenticate requests. MS Azure AD supports the OpenID Connect protocol, which is an authentication protocol built on top of the OAuth 2 protocol.

In this architecture, the client application is a single-page application (SPA) that runs in the browser. This type of client application cannot keep a client secret, or an authorization code hidden, so the implicit grant flow is appropriate.

[4] https://docs.microsoft.com/en-us/azure/architecture/reference-architectures/serverless/web-app

Both calculation model and blockchain were designed using open-source tools and platform agnostic. The EEnvest calculation can be executed outside the platform or connected to another platform. This way, interoperability is considered.

## 2.2 CALCULATION MODELS - PROGRAMMING AND CLOUD DEPLOYMENT

### 2.2.1 Programming

The Risk and KPI calculation models were prototyped in Microsoft Excel format, then converted to Python code and deployed to the cloud. The initial plan for software architecture was to:

- Deploy on the cloud and execute the risk calculation model directly from the Excel file.
- Convert the financial calculation model from Excel to Python code

All the programming and cloud infrastructure development has been taken over by IES which is the partner in the consortium carrying deep expertise in software development.

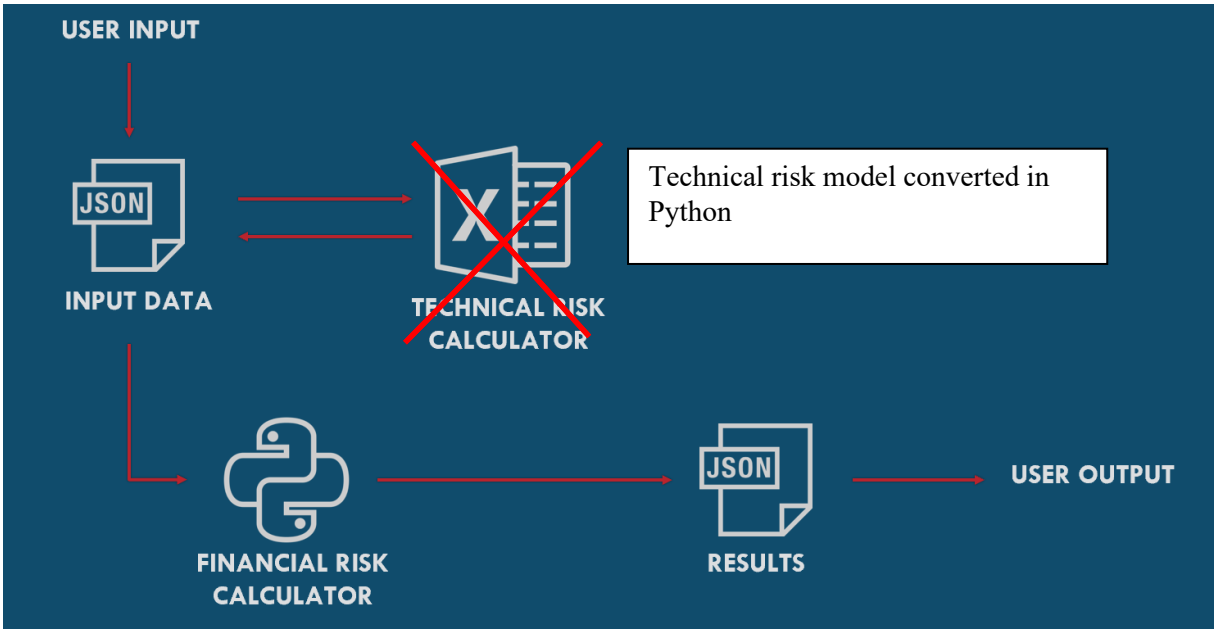



**Figure 10: Calculation model high-level architecture plans changed**

As seen above, the user inputs are collected and converted in a json format. Then, the technical risk calculator is executed and return results that become input to the financial risk calculator model, which was converted into Python code. Once calculation is completed, the results return back to the script in json format, suitable for the EEnvest platform.

However, due to shortcomings and many problems in using the technical calculation model directly from the Excel file on the cloud, it was decided to convert it to Python as well. Due to the remarkably high complexity of the model, it caused the development of the platform to be delayed. The main advantages to choose python coding include: easier coding, maintenance, versioning, execution, debugging, interfacing, reduction of complexity of the software architecture, as well as not to rely on proprietary environment which may not be usable on cloud due to MS Excel licensing

More specifically, the calculation model is implemented by a series of interconnected Python code scripts which take user inputs from the EENVEST platform and returns the outputs in json format. The calculation model returns these calculated results, along with the user inputs, back to the EENVEST platform and to other python scripts where it is then used for the report generation.

In depth modelling of the financial, multi-benefits and technical calculations followed the processes set out in Excel spreadsheet provided by the technical and financial model development teams. This process broke down each result and input required for the calculation to be represented within the python code. The completed programming script is then sent to cloud deployment to enable asynchronous operations.

Following the calculations required for results, the calculation model was broken down into its respectful components. The primary scripts used for the calculation process were:

- I/O data handling – Responsible for acquiring the user's inputs from the EENVEST platform and returning the technical and financial risk outputs back to the platform. (Provide results via an endpoint)
- Technical and Financial Risks module - Performs all the technical and financial risk calculations.
    - Technical Calculation – Performs all the damage and energy gap calculations for thermal, electric and damage.
    - Energy price uncertainty calculation – Performs electricity and gas price calculations.
    - Climate Assessment – Performs climate calculations.
    - Financial calculations – performs financial KPIs and risks calculation and generating plots
    - EEnvest report generator – populates the report template with results
- Blockchain validation API – converts the report in encrypted certificate and 1-page consolidated digital report

The diagram below illustrates the full architecture of the back end that executes the EEnvest Calculation models and blockchain verification:

- The input required from the models is provided by the user, either from a UI or in a structured text file when using the model outside the platform (I.e., through APIs)
- The input is converted to json and populates the technical risk calculator code
- The calculator is executed, and the results become input for the financial calculation model
- The financial risk calculator code is executed, and all the results are packaged in a json file that can be displayed as text or in the UI
- The output of the calculations together with user provided info, become input to the report generator code that populates an empty pre-defined EEnvest report template and generates the report
- The blockchain validation API is activated packages and encrypts the inputs and outputs of the calculations, converts it in a unique hash and stores the information to Ethereum blockchain, and returns a json certificate as an output. This json is the digital report that can be verified in a third party tool

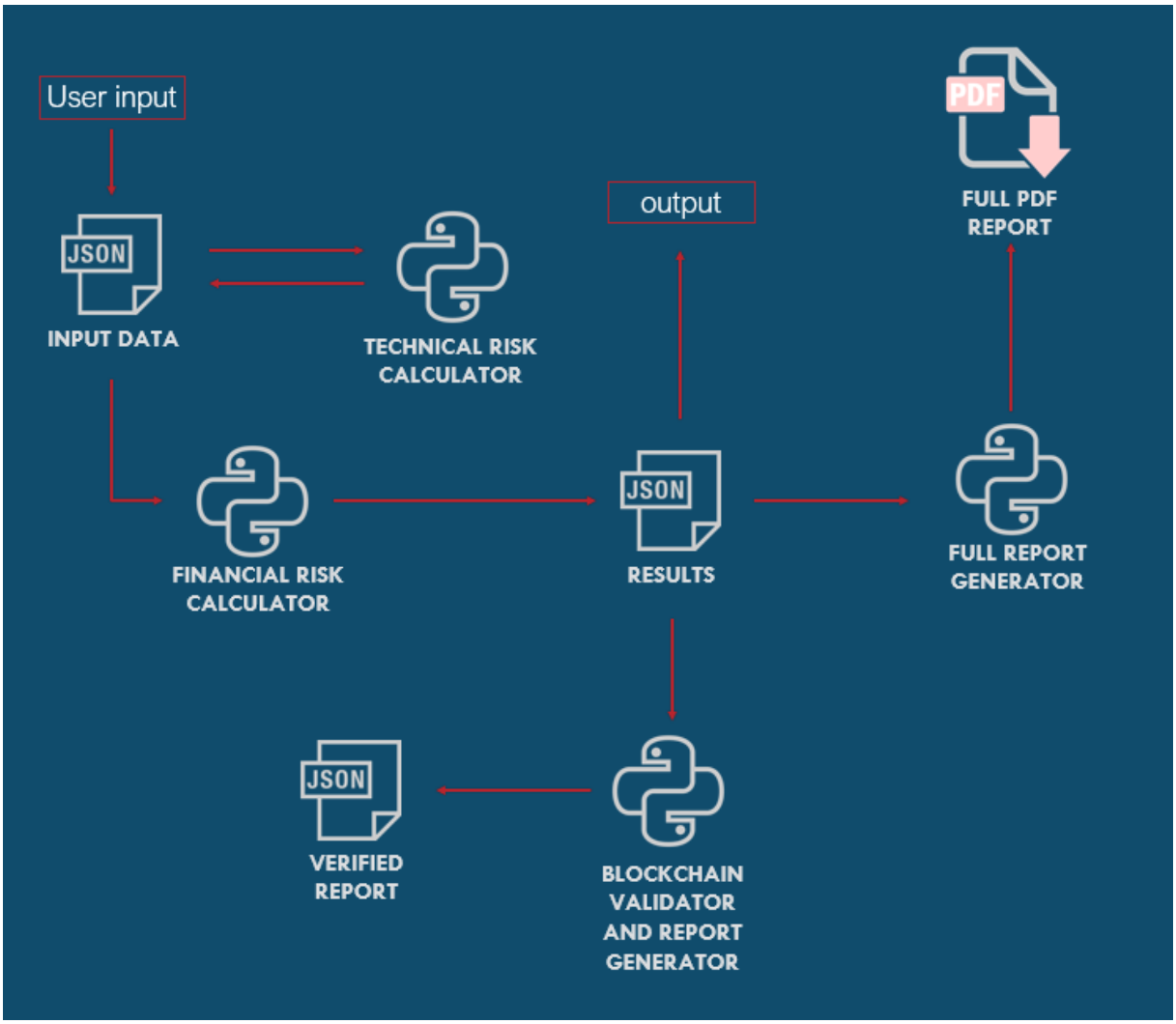



**Figure 11: Risk calculation model and blockchain verification – full workflow**

## 2.2.2 Cloud deployment

The EENVEST code is deployed on MS Azure batch, which help running large scale parallel and high-performance computing applications efficiently in the cloud. Once the code is hosted on MS Azure batch, the calculation model is an asynchronous operation having three different endpoints. The code is documented in Swagger but can be executed by any tool that can work with APIs such as POSTMAN.

In Swagger, the calculation models can be accessed by:

https://ies-eenvest-web-app-01.azurewebsites.net/swagger

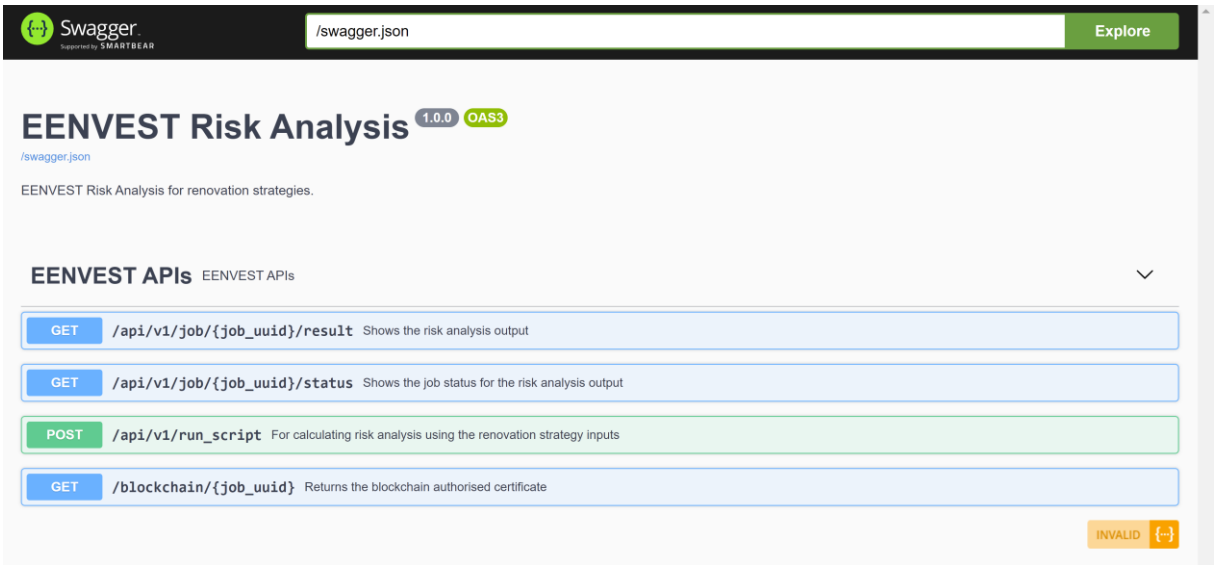
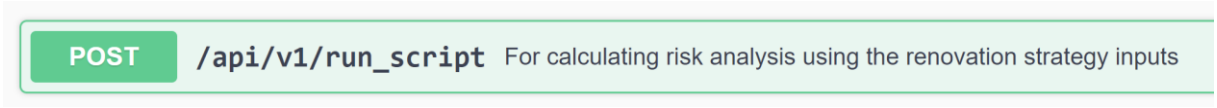



**Figure 12: View of the Swagger cloud deployment and documentation of the calculation models**

Inputs defined by users are implemented on the cloud deployment via the POST end point




which extracts the inputs from the EENVEST platform and delivers them to the cloud calculation.

In the screenshot below, by pressing “Try it out” and clicking “Post” the calculation can be executed outside the Platform in an open-source manner to enhance openness and interoperability of the platform. This allowed the testing of the calculation model as well outside the development of the User Interface new features. All the inputs to the calculation are found in the black box.

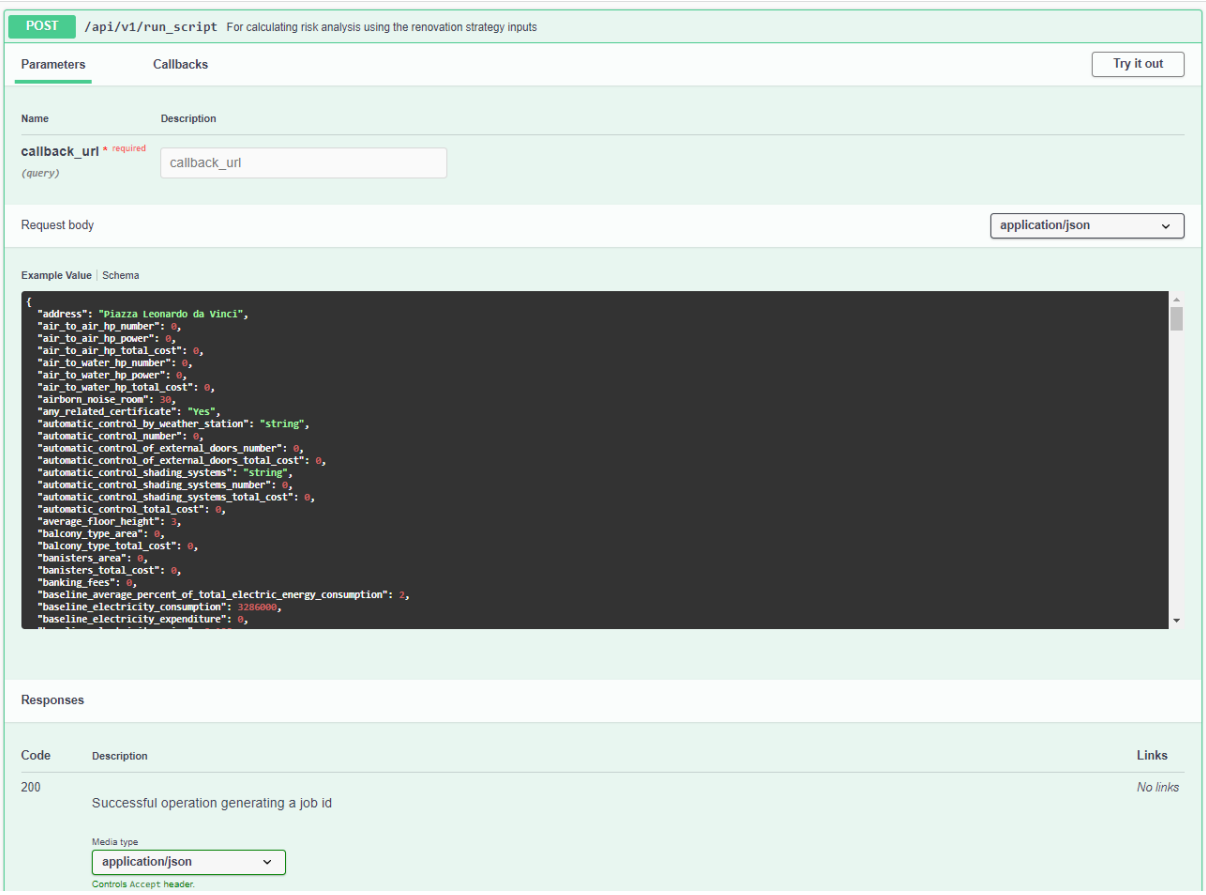
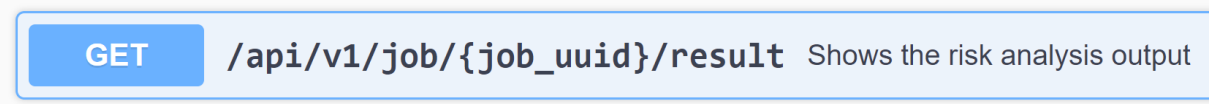



**Figure 13: Swagger POST process, used to insert inputs run the script manually**

This way, the calculation model is flexible to be integrated to any User Interface.

Furthermore, the asynchronous callbacks feature was implemented. Asynchronous programming is a technique that enables the code to start a potentially long-running task and still be able to be responsive to other events while that task runs, rather than having to wait until that task has finished. Once that task has finished, your program is presented with the result.

The end point GET returns the result of the calculation, which is sent to the EENVEST platform and report generators.




The above figures show the MS Azure Swagger process for testing the script, this is referred to as the Open-Source process where the explicit workings of the code can be examined and fixed. This occurs before the MS Azure deployment is connected to the EENVEST platform and is hidden from the end user. The programmer inputs sample inputs via the POST function and executes the server to begin the calculations. The programmer can then check the status of the calculations, this can normally take longer than 1 minute, via the GET Status function. Once the GET Status function has returned “Completed” the tester can then investigate the in-detail results of the calculation script via the GET Results function to fully understand what, if anything, is returning errors.

Once deployed and connected to the EENVEST platform the calculation script is ready to be tested from the platform.

The EEnvest calculation mode is composed with more than 10,000 lines of code as shown in the image below.

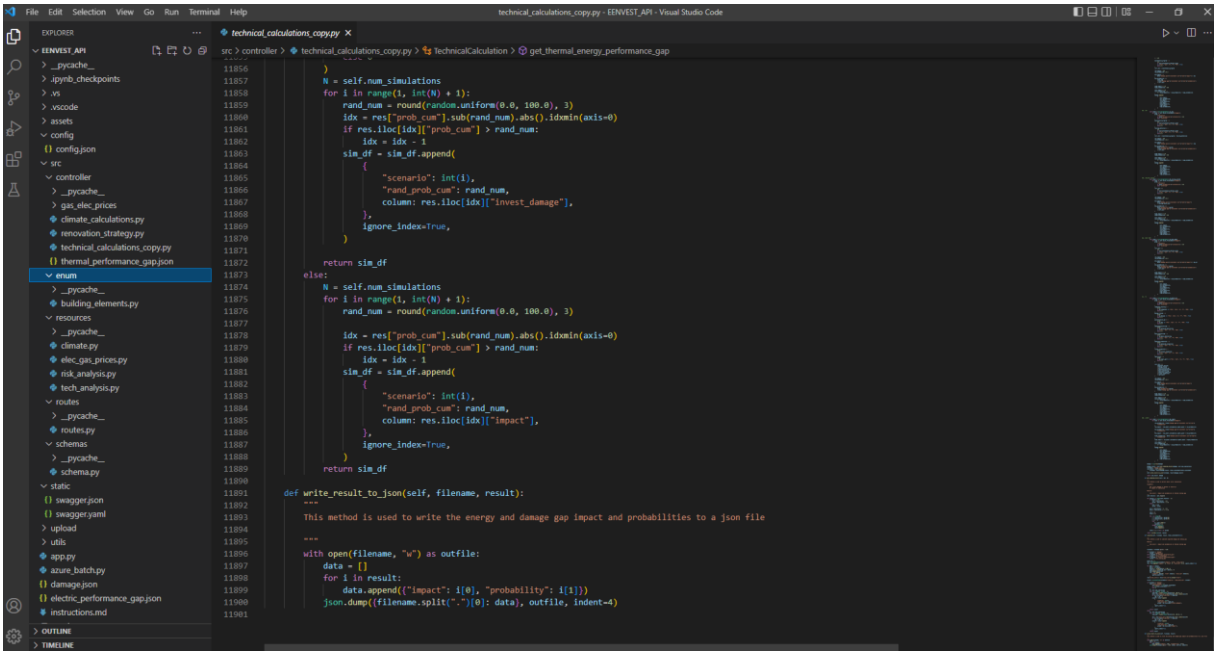


**Figure 14: Screenshot from the calculation model code**

## 2.2.3 Integration with the EEnvest Platform

The calculation model has been integrated with EEnvest platform using the new infrastructure of Actions, as described in: 2.5.10. A new action is created and named by the platform administrator, then in the field “Endpoint location”, the endpoint of the calculation model is provided.

https://ies-eenvest-web-app-01.azurewebsites.net/swagger.json

In the “Action path” field the “/api/v1/run_script” is selected, and in “Action method” “POST” is selected.

The next step is to provide the correct inputs from the platform to the calculation models. The full process is described in the user manual.

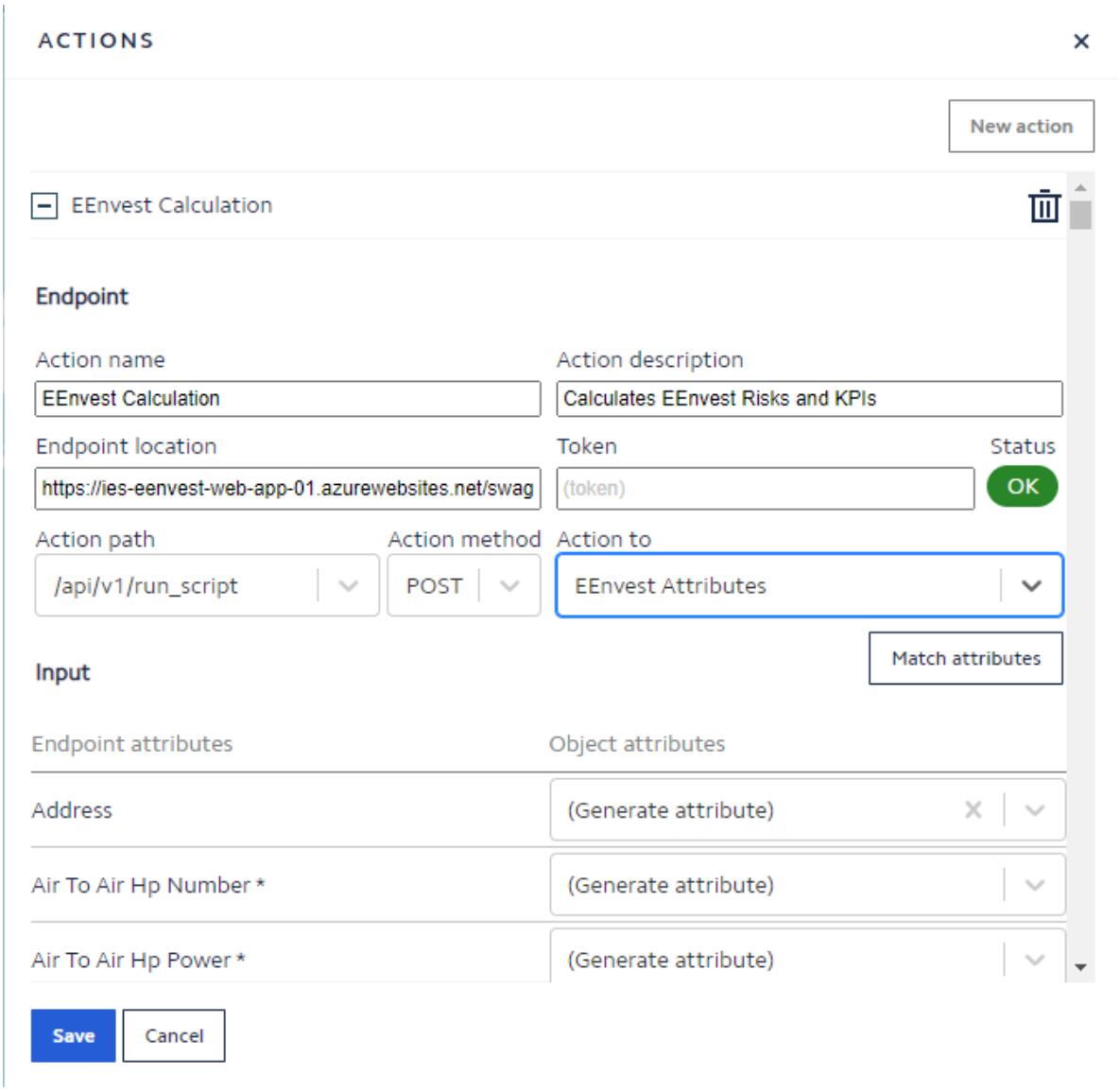



**Figure 15: Integrating Calculation model with EEnvest Platform**

## 2.3 REPORT GENERATORS – PROGRAMMING

The report generator consists of two separate python scripts which produce the PDF and Digital reports. Both report generators make use of the python module docxtpl[5], which takes a Word doc template file and populates it with inputs via the docxtpl python module. The inputs used for the reports come from both the user inputs via the EENVEST platform and the results calculated from the calculation model. The templates were designed by POLIMI and R2M, while all consortium members had the chance to provide input and propose refinements of the template, based on the needs of the investor stakeholders.

[5] https://docxtpl.readthedocs.io/

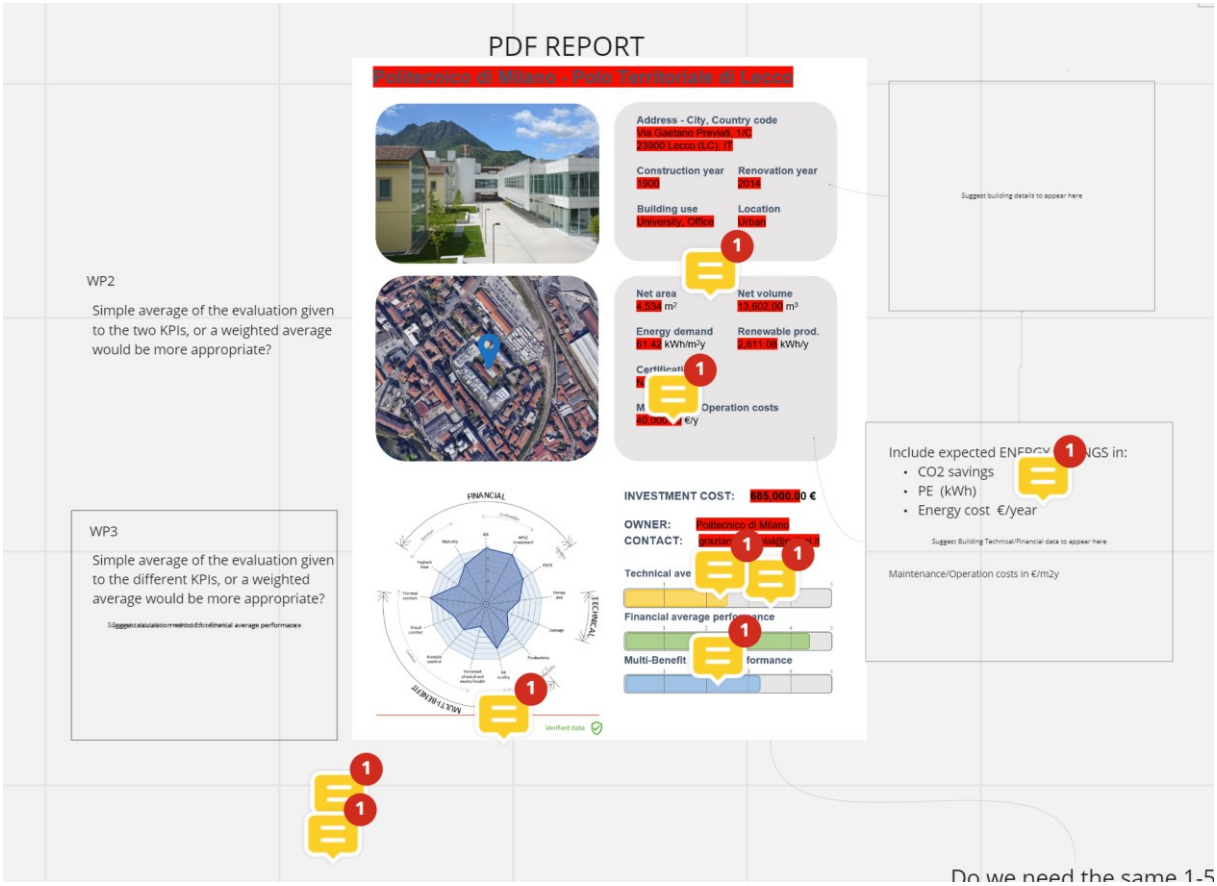



**Figure 16: Screenshot from the collaborative board in MIRO tool**

For this purpose, IES have set up a MIRO board to enable all partners to add comments to the drafts proposed.

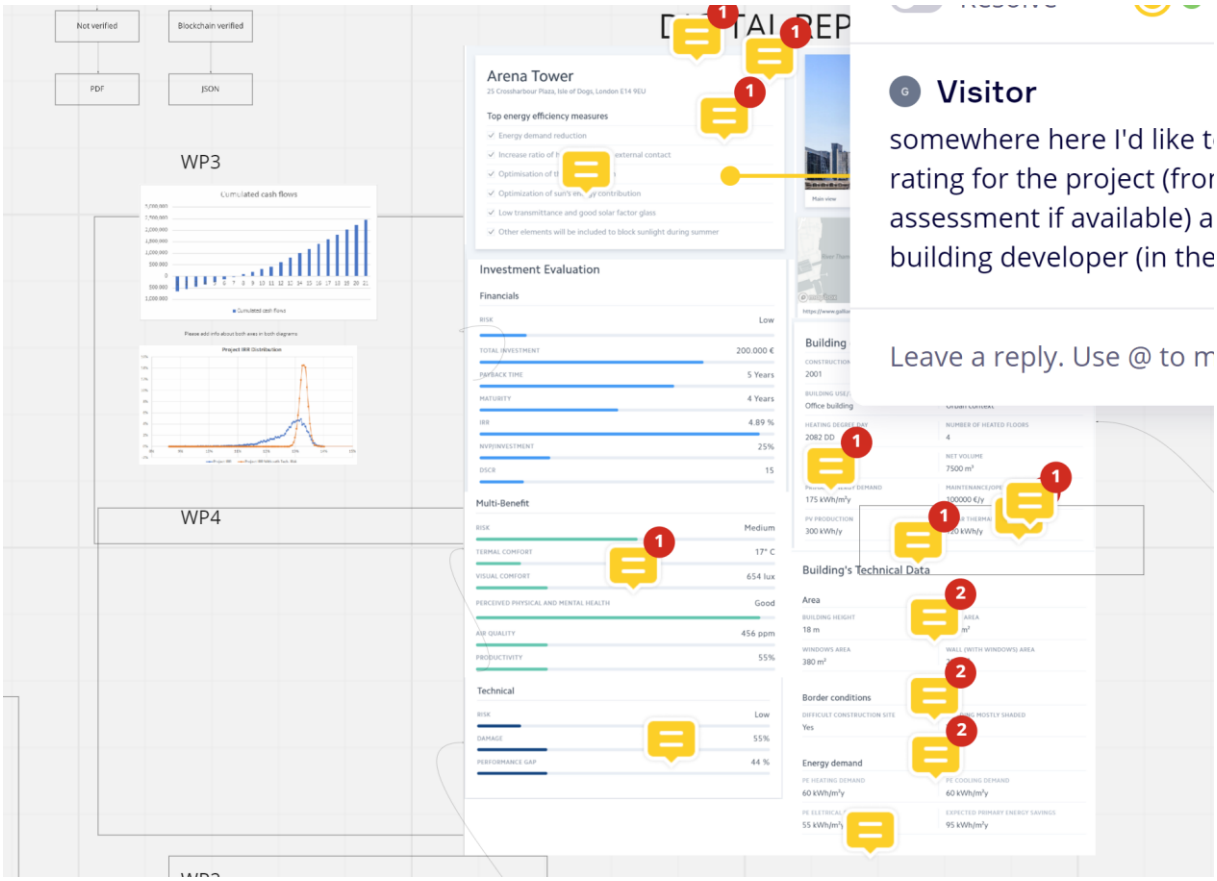



**Figure 17: Initial draft layout for Digital Report, view of the MIRO board**

The report generators are executed after the calculation and blockchain validation is completed. It was agreed that the non-verified report is the full report, while the blockchain verified one is a 1-page summary suitable for investor's needs.

Samples of the generated reports are found in the Annex.

## 2.4 BLOCKCHAIN VALIDATION FRAMEWORK - PROGRAMMING AND CLOUD DEPLOYMENT

The blockchain validation framework was implemented, as designed in blockchain architecture report.

The digital report is populated with semantic data from the platform object (EEnvest project) based on a template agreed in T5.4. The blockchain API is converting the report in a unique hash[6] using SHA-256 encryption and stores in on Ethereum blockchain. The user can download the certificate and verify it in a third party independent open-source verifier. The workflow from the end-user perspective is explained in the user manual.

In more detail, blockchain certificate is a digital record that is cryptographically signed by the issuing authority, tamper proof & independently verified by using blockchain as a notary.

The blockchain is an immutable and distributed store of transactions, with each block building upon the last. When a certificate is issued, its data is compressed into a hash and logged on the blockchain. This generates a "receipt" that can always be checked at a later date. The verification service validates the signature of the issuer and the certificate data.

[6] https://en.wikipedia.org/wiki/Cryptographic_hash_function

For validation we are using Blockcerts[7], an open standard for building apps that issue and verify blockchain-based official records. It consists of open-source libraries, enabling a decentralized, standards-based, recipient-centric ecosystem, enabling trustless verification through blockchain technologies.

### 2.4.1 Benefits

Blockchain is a distributed and immutable ledger to record transaction. That stores transaction across global decentralised network.

Its capable of storing any type of information. This information is encrypted in one-way hashes. So EEnvest in not storing the confidential data on a public network but just the hash values.

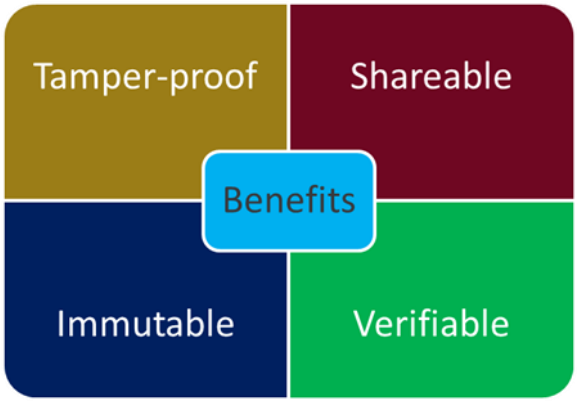



**Figure 18: Benefits of blockchain validation**

When issuer signs a certificate, it basically parsing the hash of the content and encrypting it to a shorter hash. And that encrypted hash goes into the blockchain as certificate.

Later the issuer public key, which is there in the certificate will be used to decrypt it to original certificate hash.

The core benefits of using this method for sharing digital certificates are:

a. Preventing any modification in the investment report.
b. Create a report that can be authenticated.
c. Verified by anyone easily.
d. Generate trust.
e. Easily share certificate with anyone.

### 2.4.2 Workflow

In brief the key steps executed are described below, while the full workflow from the user perspective is explained in blockchain architecture report.

1. Building owner creates an account in the platform and uploads building data.
2. Risk Assessment calculation
3. Create Certificate with building information and Risk Calculations

[7] https://www.blockcerts.org/

4. Generate Hash of the certificate and issue the certificate putting the hash of the certificate onto the Ethereum blockchain
5. Generate and share Certificate URL in MS Azure blob.
6. Issued Certificate and transaction ID can be globally verified in Blockcerts or Ethereum.

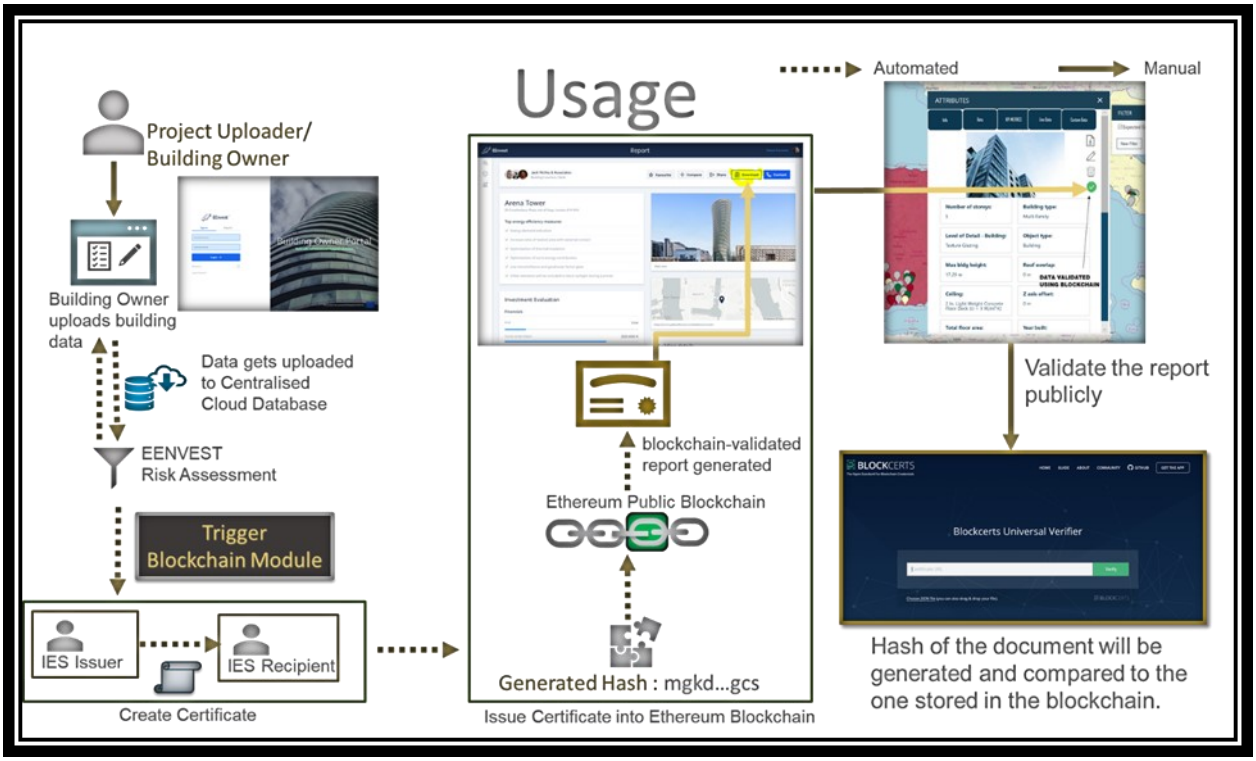



**Figure 19: EEnvest blockchain validation workflow**

## 2.6.3 Usability

Within the EENVEST platform two actions take place:

- risk and investment KPIs calculation
- Blockchain validation

After running risk calculation model, blockchain action runs automatically and does the following:

1. Create & Issue digital certificate to Blockchain (Ethereum), containing building information & Risk calculation from EEnvest Portal.
2. Upload the certificate to cloud.
3. Outside the EEnvest platform, the user verifies the certificate for its authenticity

## 2.4.3 Main Modules

### 2.4.3.1 cert tools

This module is required to create a certificate. This will be the first step that kicks off in the blockchain pipeline.

Here all details that are shown in the certificate/report are added in code.

Selected HTML styling of the blockchain verified report was designed and added to the configuration file . Therefore, any template designed by EEnvest can be used as a digital certificate.

After getting the building information a certificate image is generated and we use that image while generating the certificate. This module was taken by Blockcerts and customised to suit the EEnvest platform purpose.

#### 2.4.3.2 **Cert-Issuer**

Cert-Issuer is another module required to execute the blockchain validation using Blockcerts.

- Cert-Issuer[8] takes a JSON certificate, creates a hash (a short string that can be used to uniquely identify a larger digital file) of the certificate, and issues a certificate by broadcasting a Bitcoin transaction from the issuing institution's address to a recipient's address with the hash embedded within the OP_RETURN field.
- Cert-issuer signs the contents of the certificate using a private key and append that signature to the certificate itself.
- Next, we create a hash, which is a short string that can be used to verify that nobody has tampered with the content of the certificate. And finally, we use our private key again to create a record on the Ethereum blockchain that states we issued a certain certificate to a certain person on a certain date.
- A certificate issuer signs a well-structured digital certificate and stores its hash within a blockchain transaction. A transaction output is assigned to the recipient.

The cryptographic hash of the credential file, which is a long string of letters and numbers that can be used to verify that nobody has tampered with the contents of the certificate is created and stored on the Ethereum blockchain. There is exactly one possible combination of letters and numbers that corresponds to a digital file, and any change to the file would result in a different hash.

### 2.4.4 Cloud Deployment of blockchain validation

The usage and access to the blockchain validation is done using the new Blockchain API, which is a new microservice developed for EEnvest platform and deployed on MS Azure cloud.

The cloud deployment consists of deploying a docker container running flask web app. A container is a standard unit of software that packages up code and all its dependencies, so the application runs quickly and reliably from one computing environment to another. A Docker container image is a lightweight, standalone, executable package of software that includes everything needed to run an application: code, runtime, system tools, system libraries and settings.[9] Flask is a small and lightweight Python web framework that provides useful tools and features that make creating web applications in Python easier. It gives developers flexibility and is a more accessible framework for new developers since you can build a web application quickly using only a single Python file.[10] This flask app is responsible for:

- Receiving building image after risk calculations.

[8] https://github.com/digital-certificates/cert-issuer
[9] https://www.docker.com/resources/what-container/
[10] https://www.digitalocean.com/community/tutorials/how-to-make-a-web-application-using-flask-in-python-3

- Creating a certificate and generating hash value for it.
- Issuing certificate into Ethereum blockchain
- Uploading certificate to MS Azure Blob storage and
- Generating and return a sharable URL for the blockchain certificate.

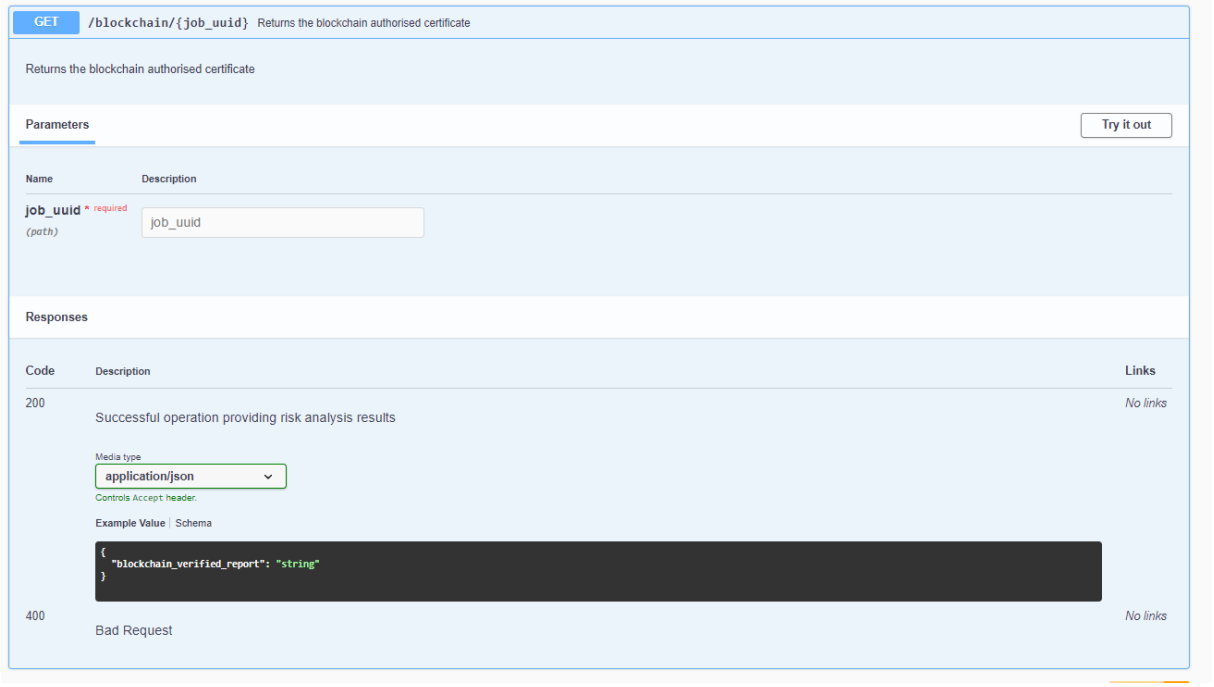



**Figure 20: Blockchain endpoint deployed to swagger**

As seen in the screenshot above, the Blockchain endpoint is deployed on the cloud and can be executed from Swagger for testing, debugging and interoperability purposes. The input is the job_uuid, which represents the unique id of the calculation model execution. No interactions required for the user of the platform since this model is sequenced to be executed automatically.

## 2.4.5 Integration with the EEnvest Platform

The blockchain validation has been integrated with EEnvest platform using the new infrastructure of Actions, as described in: 2.5.10. The URL of the blockchain action is: https://ies-eenvest-web-app-01.azurewebsites.net/swagger.json

Once calculation is executed, the blockchain validation runs automatically and returns the URL to download the verification certificate in json format, which can later be verified in Blockcerts.org.

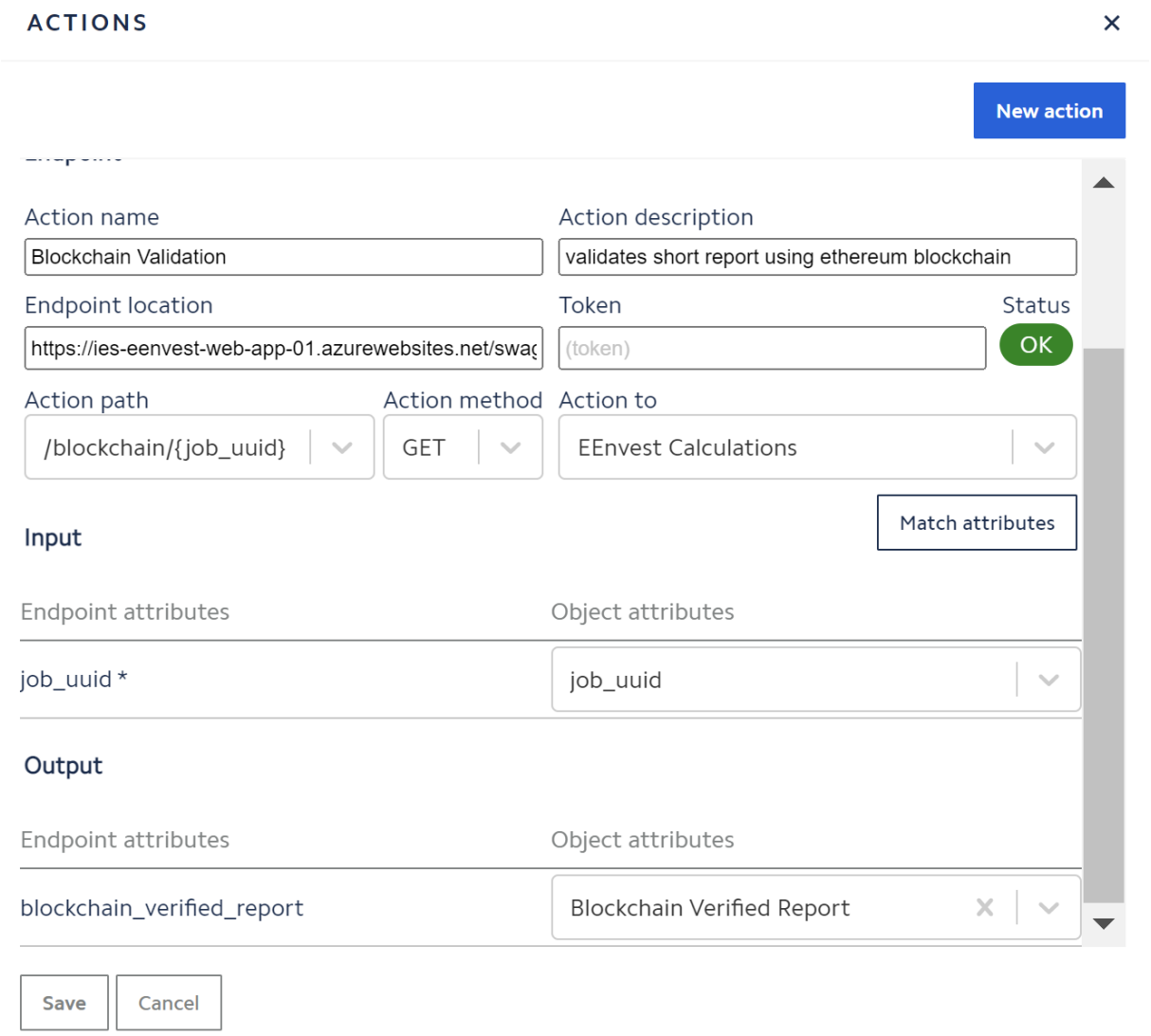



**Figure 21: EEnvest platform – setting up blockchain validation in the new Actions dialog – Administrator workflow**

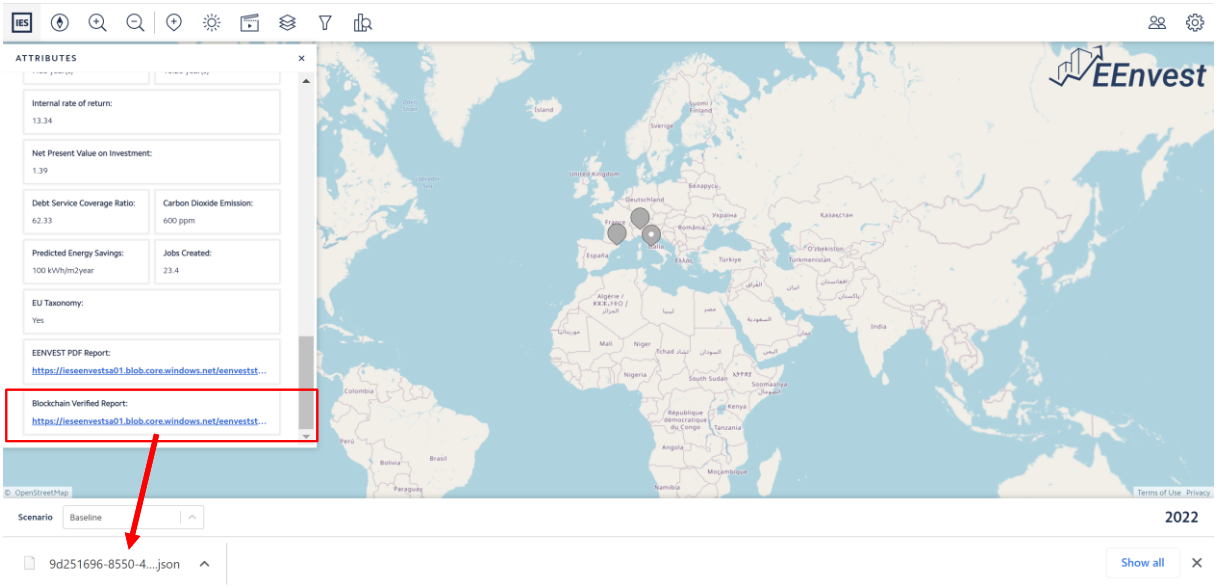



**Figure 22: Downloading the digital report in json format**

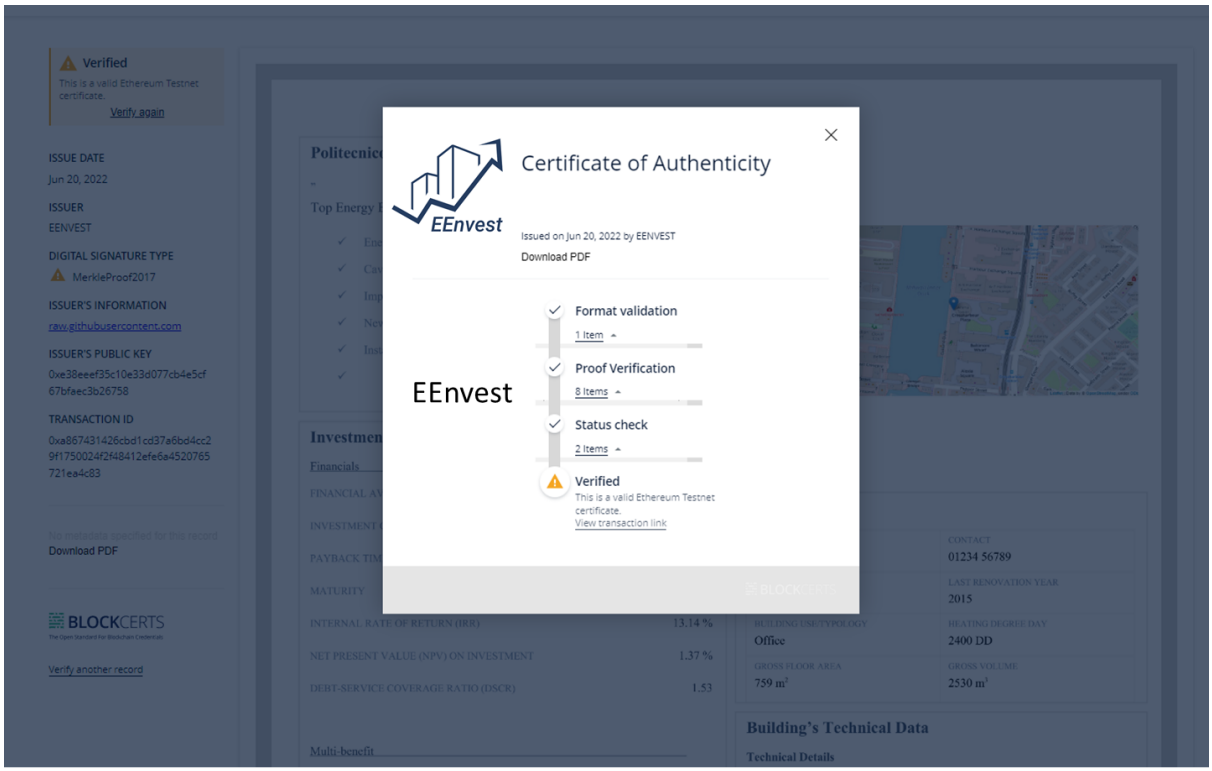



**Figure 23: Verifying and displaying the digital report in third party tool**

## 2.5 FRONT END DEVELOPMENT – KEY FUNCTIONALITIES INTRODUCED

### 2.5.1 Dedicated deployment for testing

A dedicated deployment has been implemented on MS Azure and supports all the developed EEnvest features. Code submitted from internal IES Feature branches to Main branch, is then submitted to the research deployment after Quality Assurance process which is usually followed in development of IES commercial products. This enables the latest code changes to be tested by the EEnvest partners and report back issues, and suggestions for improvement.

Deployment URL: https://icim-research.iesve.com/#/

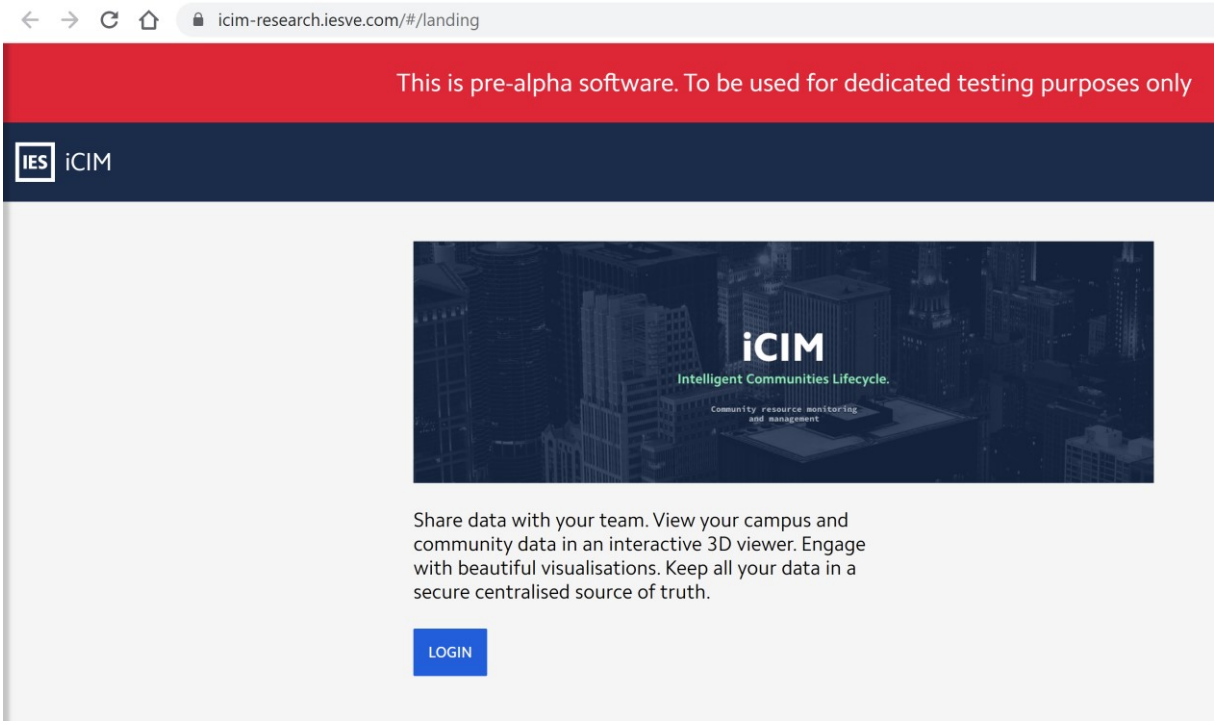



**Figure 24: iCIM-Research deployment**

The licence agreement can be found in: https://www.iesve.com/legal/terms while the privacy policy is found in: https://www.iesve.com/legal/privacy

### 2.5.2 EEnvest special build for 1st Release

Prior to the set-up of a dedicated research deployment, a special 'EEnvest' deployment was set-up and shared with EEnvest consortium. This enabled all EEnvest partners to test and provide early feedback on development of new features. A number of issues have been addressed during EEnvest partner feedback such as missing custom objects from the viewer, incorrect colouring of metrics, missing attributes, blank project etc. This build was used in the first release of the platform from July 2021 until March 2022.

### 2.5.3 Create project

The EEnvest platform originates from a blank project. Prior to EEnvest platform within the collaboration cloud, users could not create new projects via the Projects Page.

A new project, in this instance created by IES admin, is generated by selecting the 'Create Project' [button] on the research deployment Projects Page.

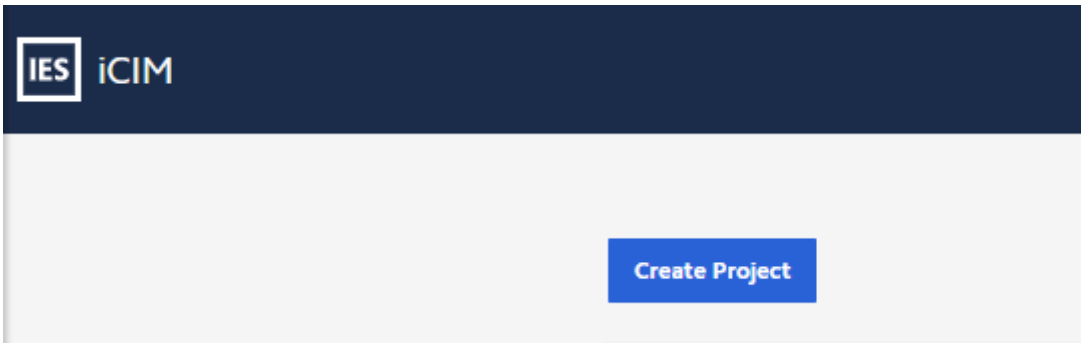



**Figure 25: Create a new project in iCIM**

The user then fills in the 'Name' and Description 'Field'.

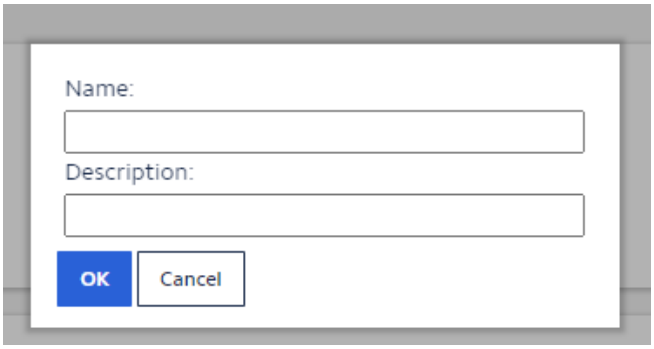



**Figure 26: Create a new project in iCIM – dialog to add name and description of the new project**

Upon selection of the 'OK' [button] a new project is added to the deployments Projects Page.

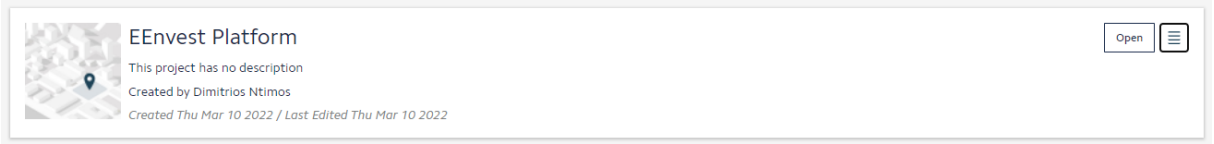



**Figure 27: New project view of administrator**

This way, a new project is automatically added in the database. In EEnvest, this is the Search & Match platform.

### 2.5.4 Project landing page

Users can be added to projects on a deployment. Projects are displayed in the users Project Page when signing in. However, this workflow is less than ideal for the EEnvest platform, as only one project shall be listed.

A new feature has been implemented to redirect users to a custom focused landing page. This feature is accessed via the projects 'Publish' [button] located within the hamburger menu of the project of focus.

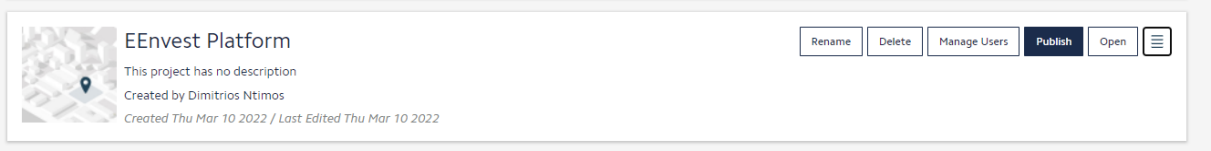



**Figure 28: Publish page access view of administrator**

Selection of the 'Publish' [button] launches the Publish panel.

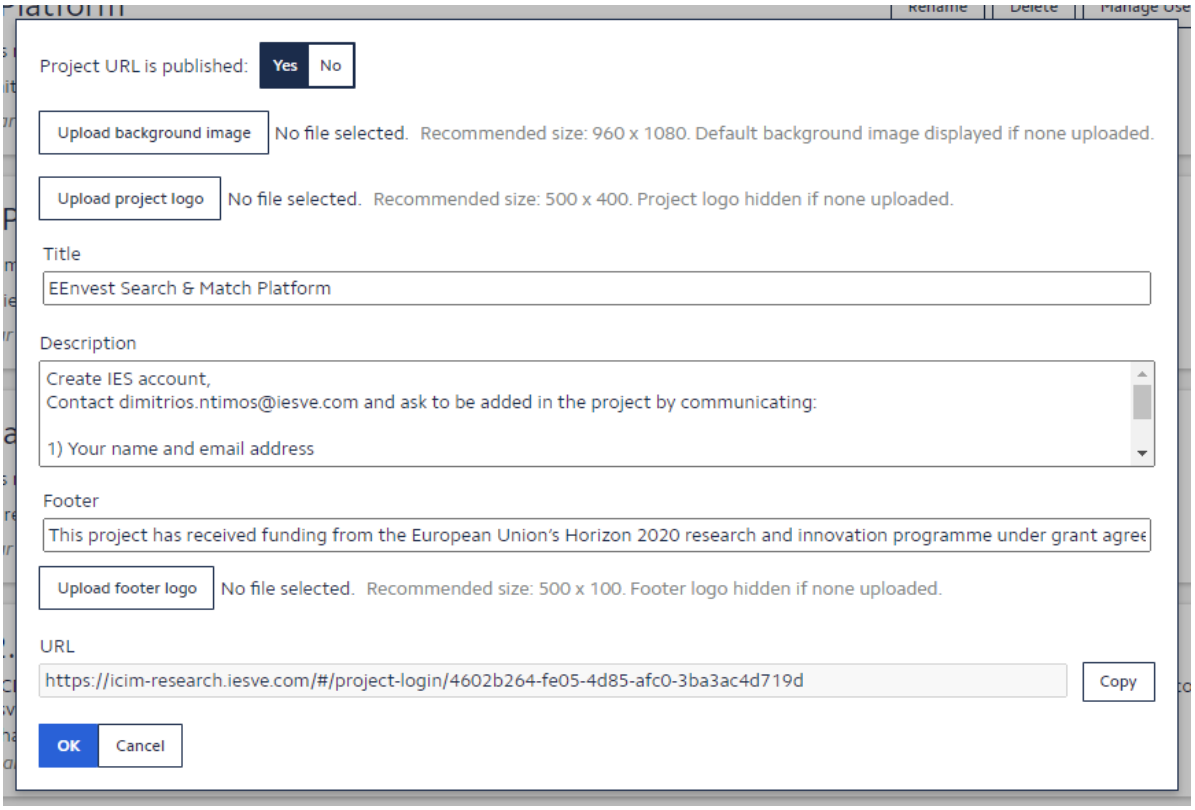



**Figure 29: New Publish page feature – view of administrator**

The EEnvest platform custom landing page is accessible by selecting the link below:

https://icim-research.iesve.com/#/project-login/22556466-8c02-4970-90e5-4284933c8f7c

A screenshot of the EEnvest landing page is shown below.

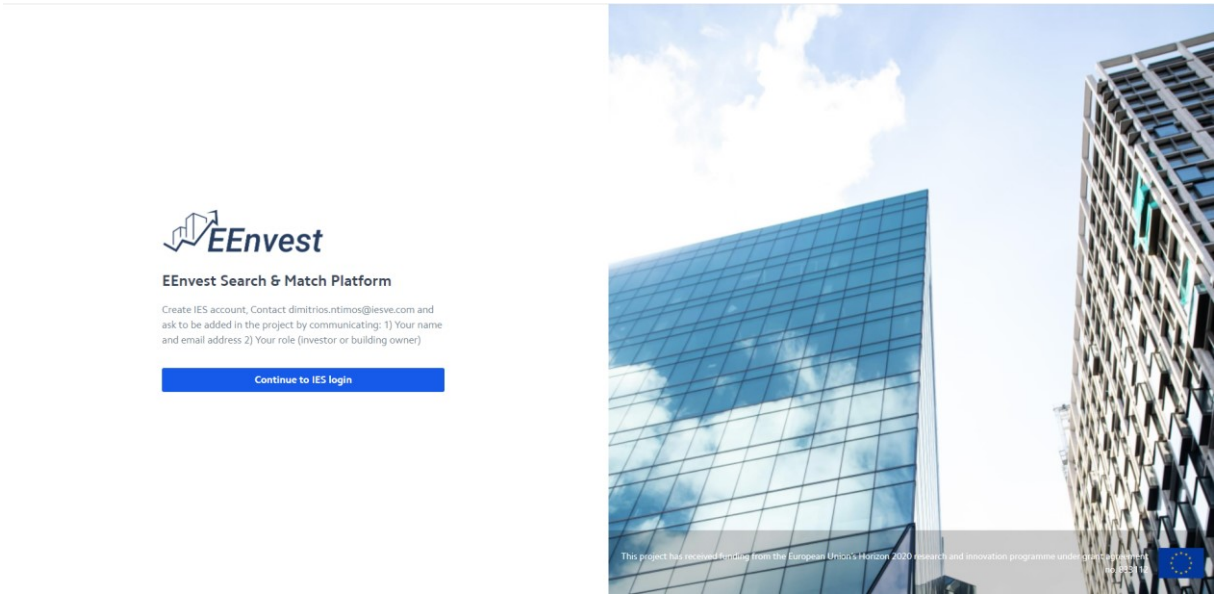



**Figure 30: EEnvest landing page**

Selection of the 'Continue to IES login' [button] redirects the user to an OpenID sign in page. Upon sign in, where user is permitted to, the user is redirected to the EEnvest platform viewer.

### 2.5.5 Custom Objects

It was decided early on the EEnvest project that 3D geometry was not a requirement for the EEnvest platform. The Custom Objects feature has been implemented for the EEnvest platform, to enable permitted users to add pins to the platform to represent their building of interest.

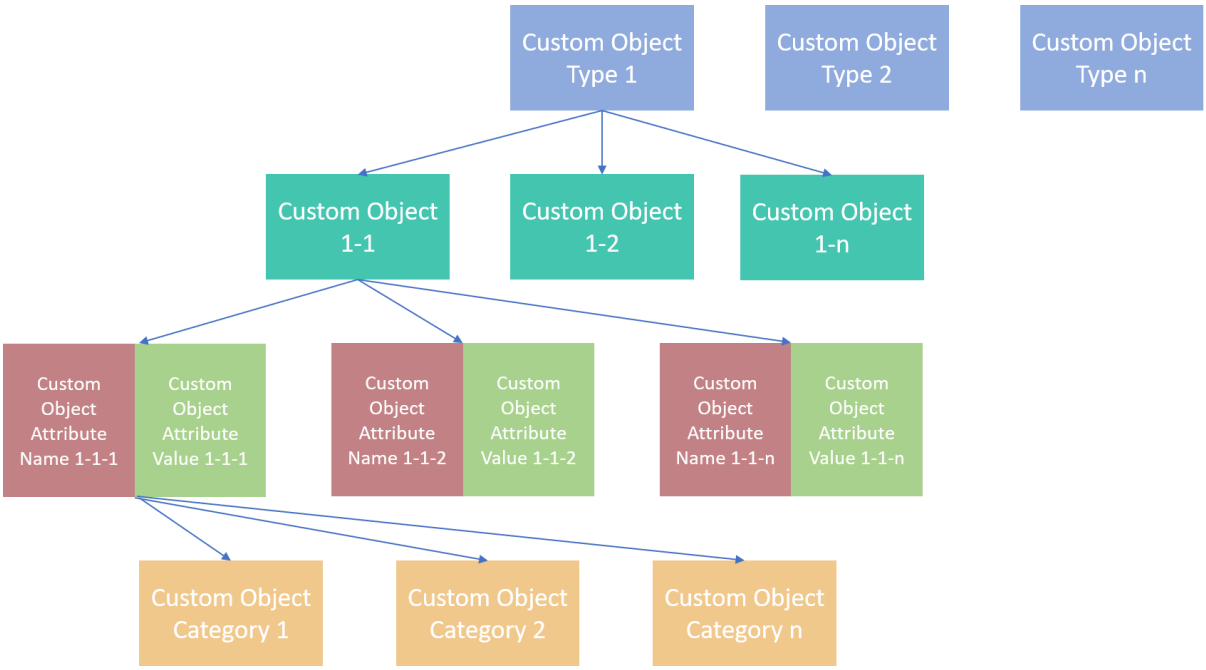



**Figure 31: Architecture of custom objects feature**

The architecture of Custom Objects can be found in the figure above. On the high level, there are custom object types, which, in simple terms are groups of objects. For example, in a wider and more flexible context, object type 1 can be buildings, object type 2 streetlights, object type 3 PV panels etc. Therefore, in the object type 1 a user can create an object which represents a building, which is also the EEnvest platform use case. Every building is a Custom Object in the database. Now all custom objects have metadata called Attributes. Each building has "Attribute Names" and "Attribute Values". All the data input required to execute the EEnvest risk calculation are Attribute Names in the Custom Object database in the CIM. For example, A building's "construction year" is an Attribute Name, while 1972 is the value for this attribute. Finally, each Attribute can be tagged and categorised and have multiple tags. For example, "construction year" attribute can be tagged as" Building Information"

In the User Interface, in the map view of CIM, a new button was added, as highlighted in the screenshot below to add a new project.

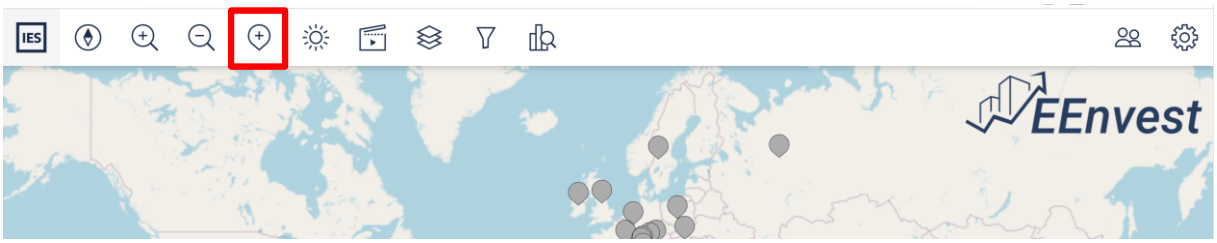



**Figure 32: Custom object - New button added in CIM toolbar**

Selection of the 'Custom Object' [button] launches the new Custom Object panel developed where a new custom object can be added.

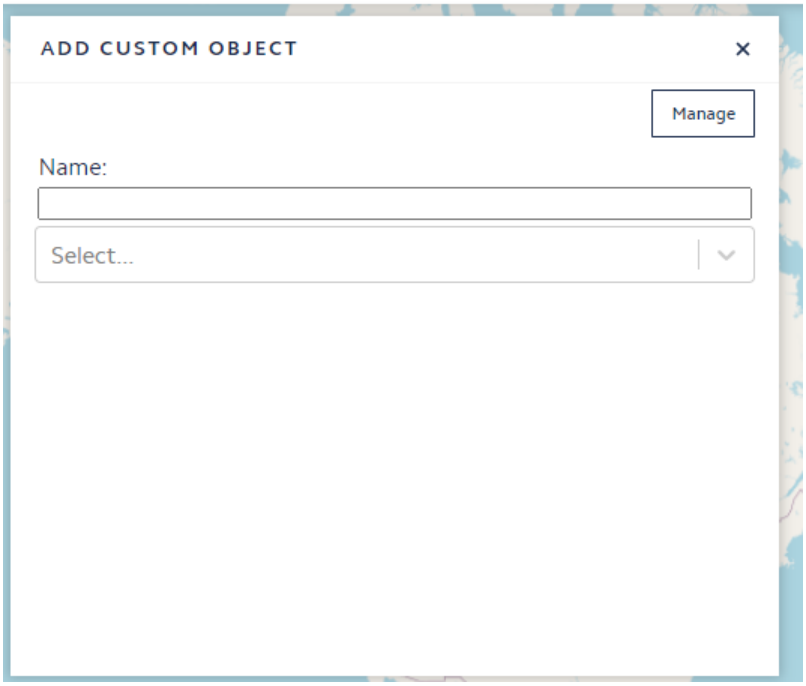



**Figure 33: New add custom object dialog**

For the EEnvest platform administrator we have set-up a number of features (prior to Building Owners using the EEnvest platform).

- Creation of Custom Object type and attributes
- Creation of Action (discussed below)
-

## 2.5.6 Create-edit-delete attribute

This dialog below was created to allow administrator user to create attributes and choose Name, Description, Type, Unit, Default Value and Tags. Once they click create the attribute is saved in the database.

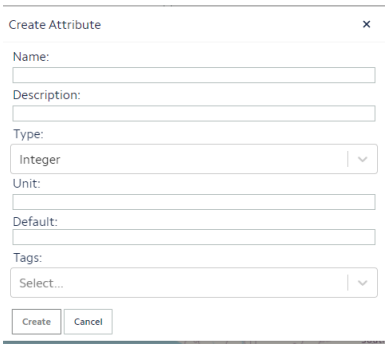



**Figure 34: Create attribute dialog**

The screenshot below shows the input to the database when adding the attribute called: “Final Cooling Energy Consumption”.

```
},
"final_cooling_energy_consumption": {
  "example": 300,
  "format": "float",
  "type": "number",
  "x-ies-frc-meta": {
    "category": "Building Information - Energy Efficiency of
      Renovation Project",
    "display_name": "Final Cooling Energy Consumption",
    "required": true,
    "unit": "kWh/m2year",
    "version": "1.0:frc"
```


**Figure 35: Example attribute with meta data**

Below is an example of the EEnvest Risk calculation Custom object and attributes dialog developed for the platform to enable the flexible creation and management of attributes required to calculate the risks of EEnvest, upon selection of the 'Manage' [button].

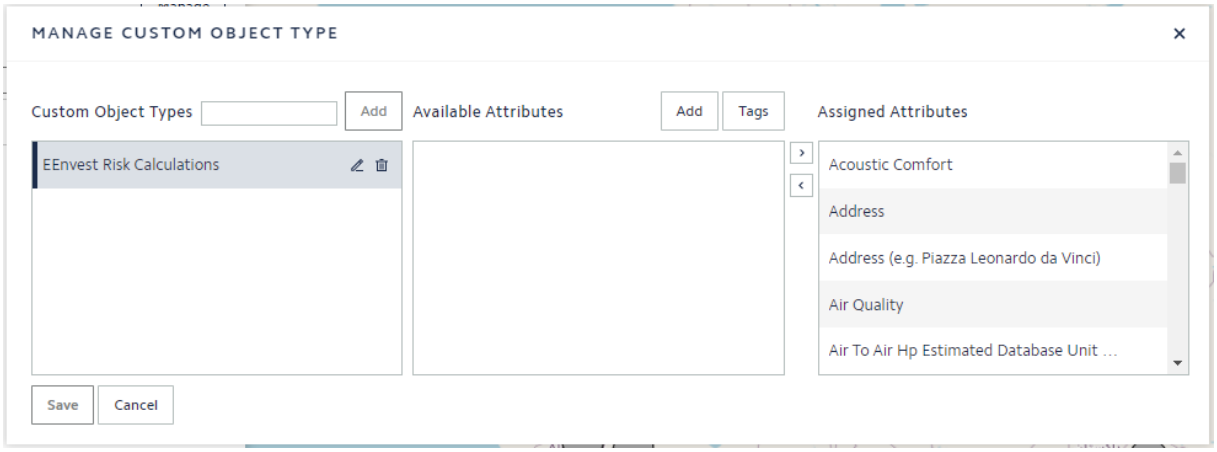



**Figure 36: Manage Custom Object Type dialog**

In the Attributes panel, a new button was added to enable entering values for the attributes listed.


**Figure 37: New "Edit" button in Attributes dialog in iCIM**

Within the objects edit panel, a permitted user can:

- Select category headings
- Edit attribute values
- Delete object
- Run actions (see below)

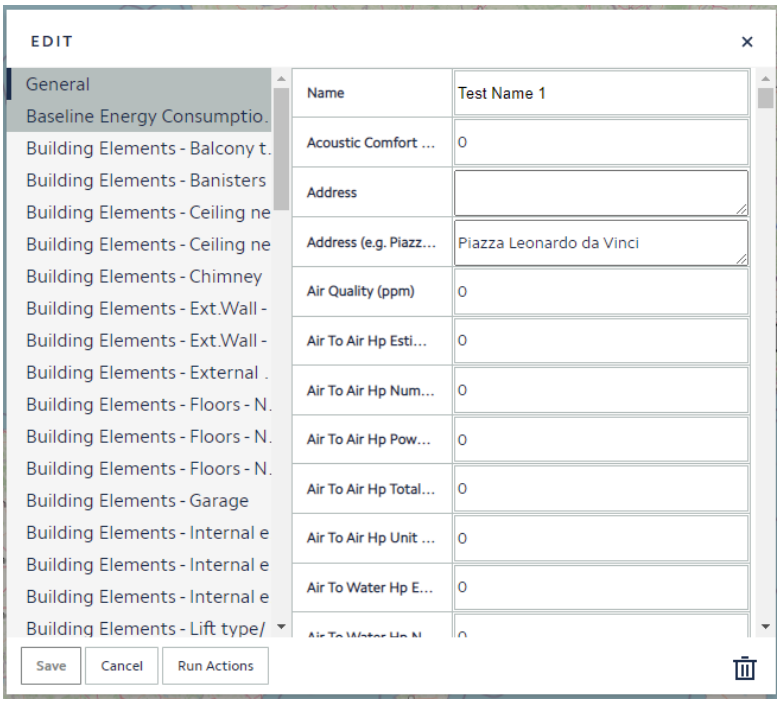



**Figure 38: Edit dialog in iCIM Attributes panel**

Upon saving changes, selection of 'Save' [button], changes are updated within the projects database.

Clicking the bin button at the bottom right, the user can delete the custom object.

The UI of the Edit dialog was agreed to only reach the minimum viable stage during EEnvest development, since it was not fully validated with building owners during EEnvest, as well as the available resources were limited due to the shortcomings in the development of the Risk Calculation models.

### 2.5.7 Tags

The 'Tags' feature has been implemented as part of the Custom object manage panel, discussed above. This enables a user to assign custom object attributes to tags, and tags are displayed as category headings in the objects attribute panel.

Permitted users; Project Owner, Project Editor and Object Owner, can edit a custom objects attribute. Selection of the 'Edit' [button] within the attribute panel launches the objects Edit panel.

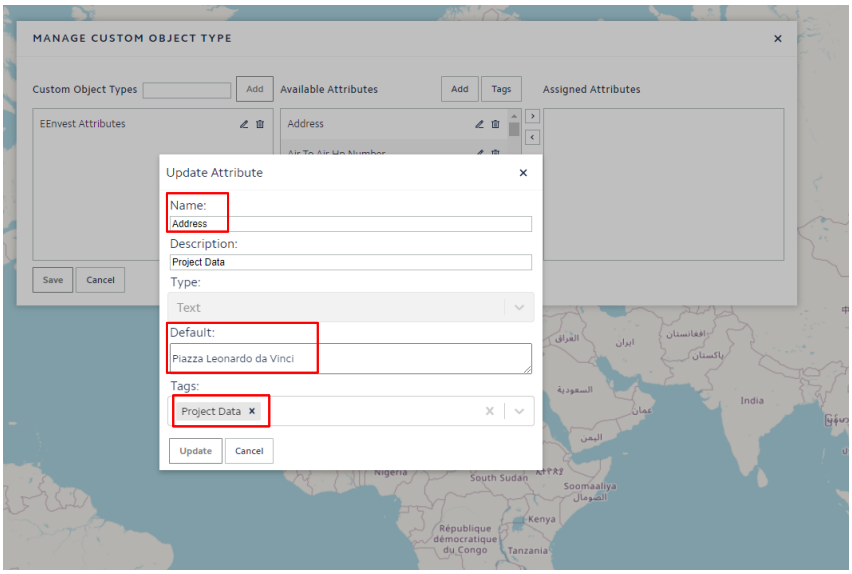
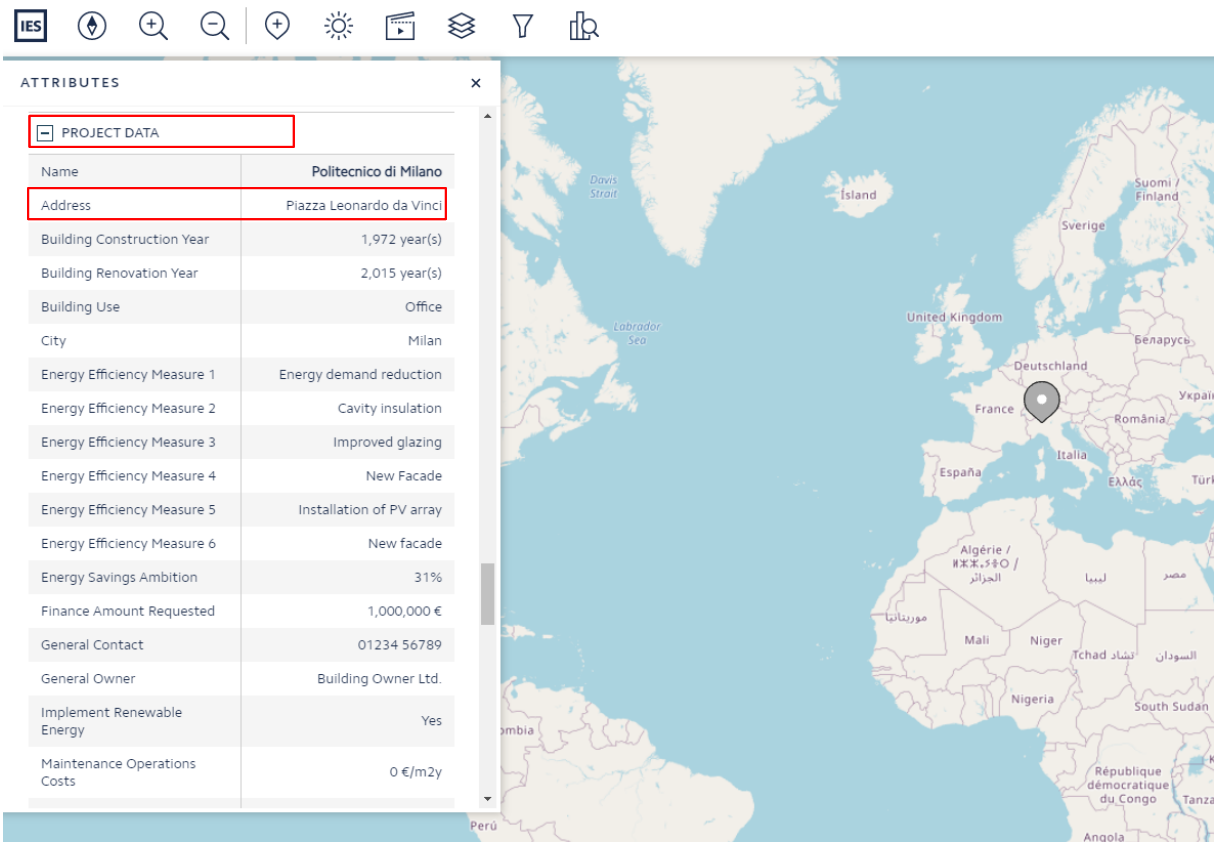



**Figure 39: Attributes metadata including tags**

In the screenshot above, the dialog to assign tags to attributes is displayed, while below is an example of how an attribute appears in a category when assigned a tag.



## 2.5.8 User permissions

New user permissions functionality was required to cover the EEnvest user workflows (see 1.3). Prior to EEnvest, the CIM platform could only split between editors, admins and users, but did not have roles for specific custom objects. The use case that a building owner is only owner of their custom object and not owner of other users' objects was not covered.

Also, building Owners do not have permission to create new Custom object types and attributes. However, Building Owners require the rights and permissions to add new Custom objects to the viewer.

This required an extension of the Project roles and permissions. A new role 'Contributor' has been implemented as part of the EEnvest platform. This feature enables Building Owners, who are assigned the role of Project Contributor to add custom objects to the viewer. They become Object Owners of the custom objects they add to the viewer and have full responsibility of editing these objects. But this restricts them to edit objects added by other users, unless the administrator assigns them that role.

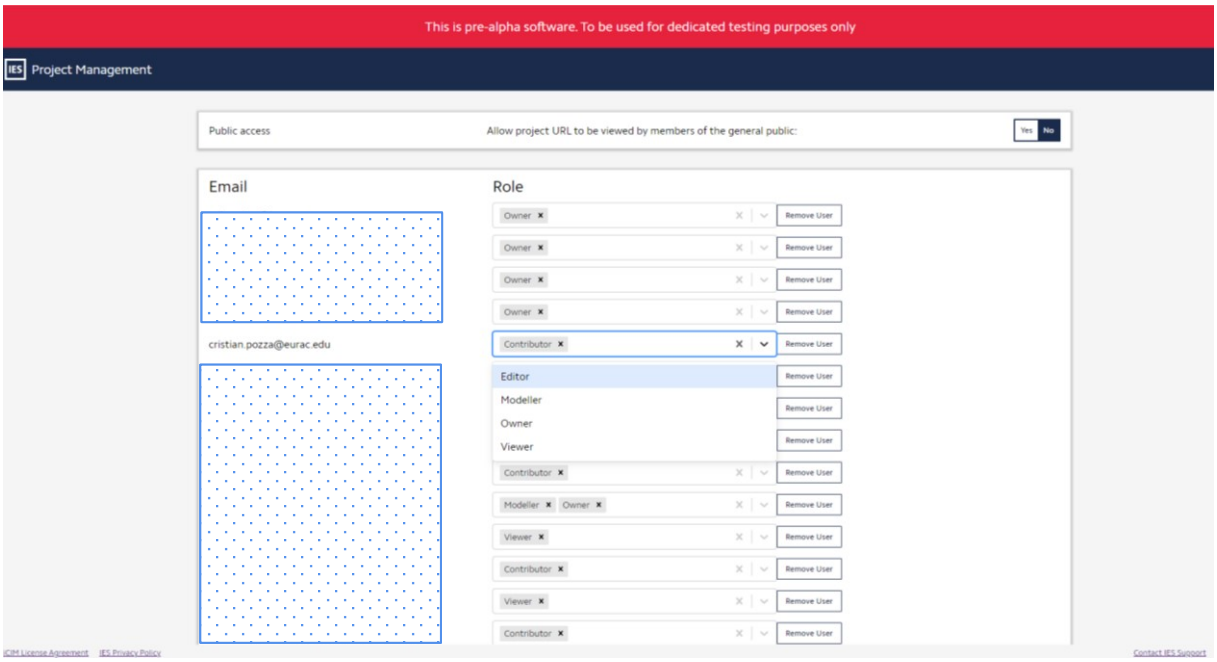



**Figure 40: iCIM project Management**

Figure 40, is a screenshot of the platform user management page. The new role added for EEnvest is the Contributor, as explained above.

A brief description of roles and their permissions in the platform is found in the table below:

**Table 1**

| **Role** | Manage Platform | Manage Users | Manage all Projects | Manage their own Projects | View Results |
|---|---|---|---|---|---|
| Owner (administrator) | ✓ | ✓ | ✓ | ✓ | ✓ |
| Contributor (Building owner) | | | | ✓ | ✓ |

| | | | | | |
|---|---|---|---|---|---|
| Viewer (Investor) | | | | | ✓ |

*Editor and Modeller roles are not used in EEnvest.

- Manage Platform: Create, edit, delete EEnvest platform
- Manage users: Add, edit permissions, delete users
- Manage all projects: Add, edit, run calculations and delete ALL custom objects
- Manage their own projects: Add, edit, run calculations only for the projects that they are owners or editors
- View Results: See the Attribute values and EEnvest Risk calculation results of ALL projects.

Public access: At the top of user management page in Figure 40, a new functionality has been added to allow the Administration to publish the project for free access. This way, the platform can be promoted to investors for example, without asking them to create an account first.

### 2.5.9 Object Level Permissions

In addition, further granularity on roles and permissions has been added at the Custom Object level. This adds a finer layer of control and granularity on who can and cannot edit objects within the viewer. This new feature is necessary for the EEnvest platform as the platform will consist of one-to-many Building Owners and Investors. Without Object level control within the platform, then Building Owners and Investors could edit one and another's objects within the platform. The introduction of Project Contributor and Object level permissions resolves this issue from occurring.

Below is the new 'Manage users' panel, accessible via the toolbar upon selecting the 'Users' [button].

**Figure 41: Manage users button**

At present, only Project Owners can access the panel.

In this example below, example user "cristian.pozza" is owner of the object called "Building 1", Italian case study – IFAD" and is editor of "Fem Nucli". This means that this user can edit the attributes of these buildings only, and run calculations of these buildings only. The difference is that the owner can delete the project, while the editor can only edit the attribute values and execute the Risk calculations.

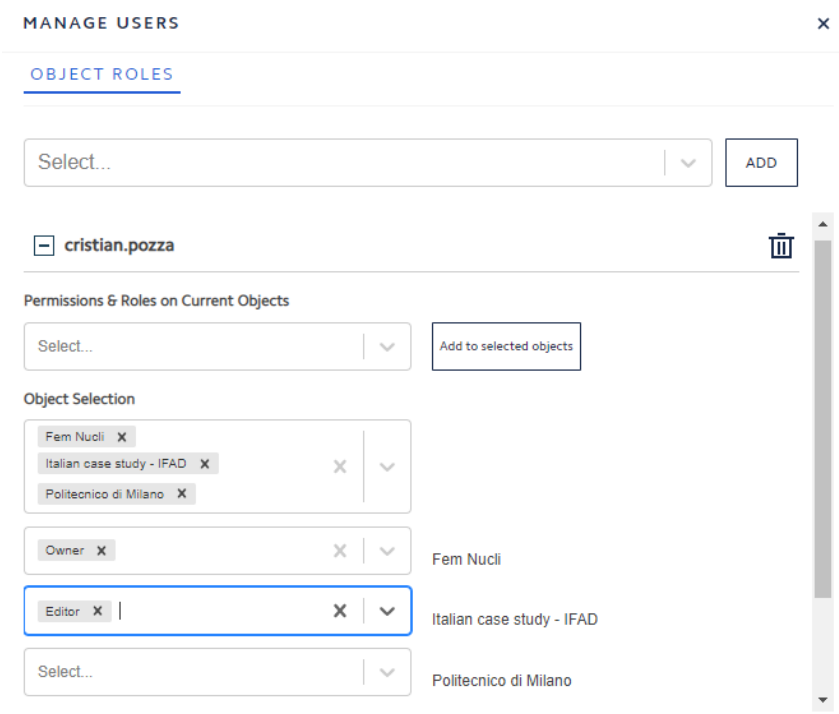



**Figure 42: Custom object roles example**

## 2.5.10 Actions

Actions is the new feature introduced in CIM to allow calculations and returning results with input given by the attributes in a custom object.

Actions, to be set-up by IES admin for the EEnvest platform, are created by selecting the toolbar 'Settings' [button].


**Figure 43: New actions functionality in the settings dialog**

Selection of the Action ‘Manage’ [button] launches the Actions panel. Actions enable a permitted user to connect to a remote server, for parsing inputs and outputs from the EEnvest platform and the remote server.

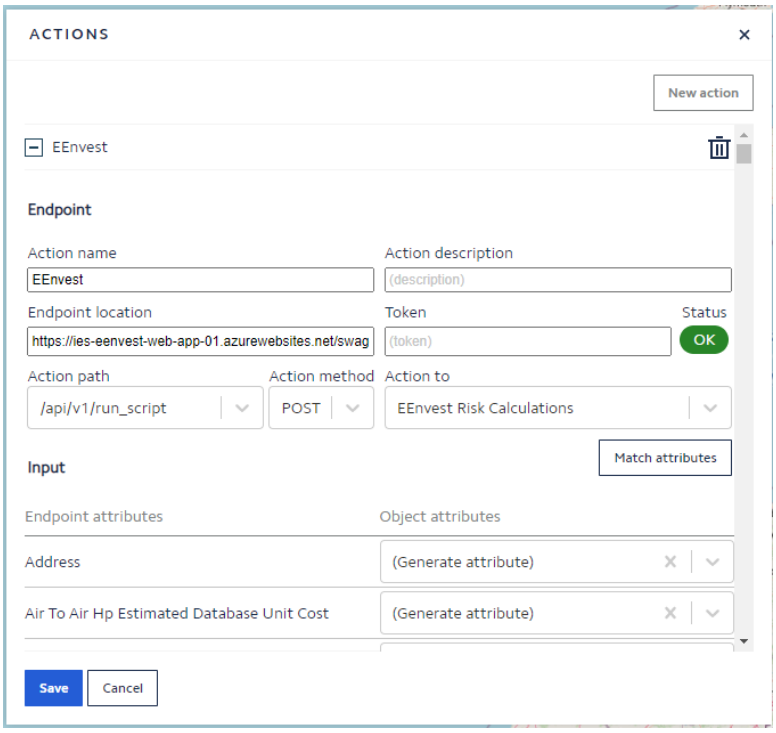



**Figure 44: New actions dialog**

Actions are triggered via the custom objects edit panel upon selection of the ‘Run actions’ [button]. Selection of the ‘Run actions’ [button] parses object attribute values to the server. Server-side calculations are performed, and results are returned in the form of outputs. Outputs update attributes values at the object level.

Within the EENVEST platform two actions take place:

- Financial risk calculation (refer to section 1.5 for further details)
- Blockchain validation (refer to section 2.4 for further details)

Upon completion of running actions, Investors can identify opportunities by selecting the Metric Viewer [button] via the toolbar, as described in user manual.

Custom object attributes of interest can be plotted within the viewer for example. Below is an example of the Internal Rate of Return (%).

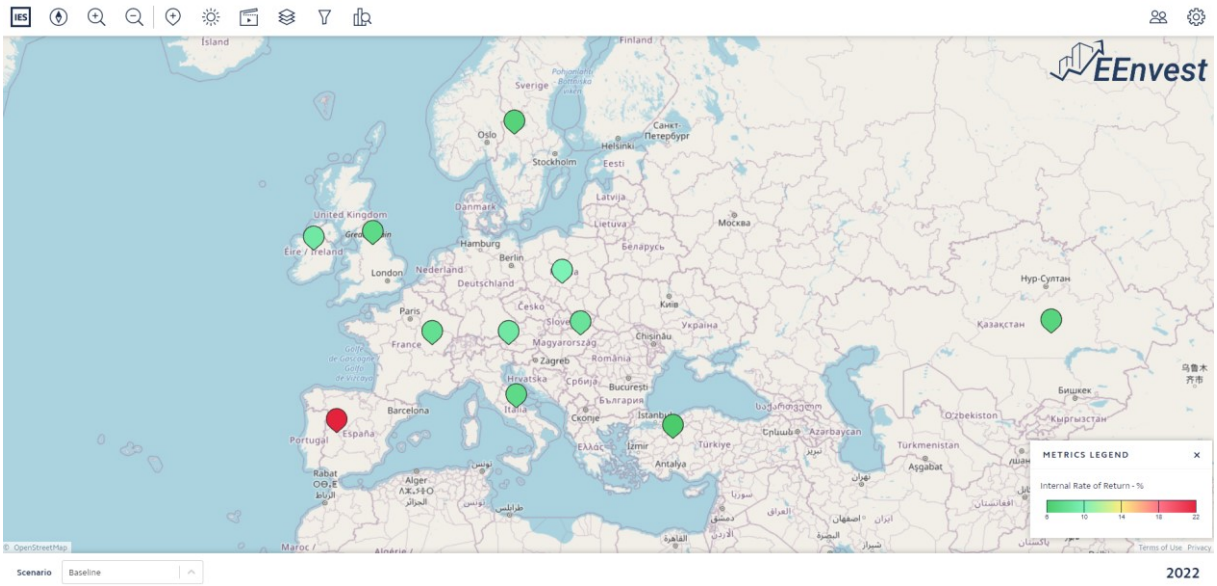



**Figure 45: Filtering and Metric Viewer functionalities extended to custom objects**

## 2.6 UI PREPARATION FOR TESTING AND USABILITY VALIDATION

Due to the number of custom attributes required for EEnvest (approx. four hundred) the above Custom object type, attributes and tags were generated via use of the Custom object API via a new Python script developed for that reason. The Custom object API is accessible via:

- https://icim-research.iesve.com/cim/api_version

An example of the Custom object API is displayed below.

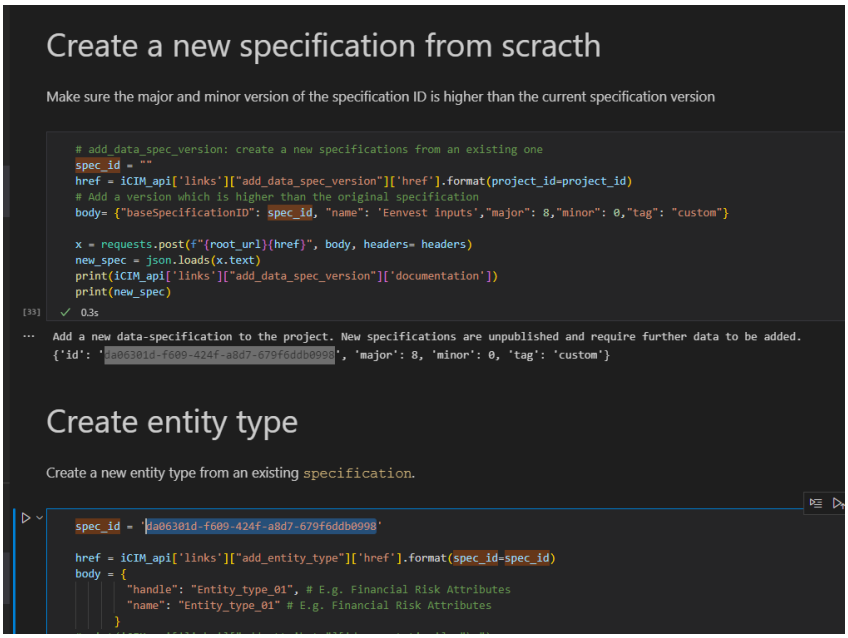



**Figure 46: Script that populates the platform with the required attributes**

Version of the Custom object data specification can be accessed via the F12 > Console.

This way we reduced the manual work required to populate the database with EEnvest attributes considerably.

The rest of the process is described in 2.5.3, 2.5.4 and in user manuak, where EEnvest platform is initiated as a new project in the CIM database, while landing page and logos are customised to suit EEnvest platform purpose.

## 2.7 PLATFORM RELEASES

According to the plan in software development of EEnvest, the platform has been released early in the project to enable testing by the consortium partners. For every release, this document was prepared and shared with consortium members as a draft.

### 2.7.1 1st Release

The first release of the platform was scheduled for M24 of the project, in June 2021. A special build was created within a server owned by IES, for testing purposes only.

In that first release of the tool, the users were able to:

- Create an account as Admin User
- Login in a dedicated login page
- Add a new project on the map
- Enter attributes for the project
- Filtering of Attribute values
- Comparison-benchmarking with other projects
- Edit/Delete project
- Edit/Delete attributes
- Use a translated version of platform to all available languages (using Google Translate)

### 2.7.2 2nd Release

The second release of the platform was done in M33 of the project (March 2022). This release reflected the work undertaken in the period since first release. More specifically, besides bug fixing, the key new features introduced included:

- Platform deployed and hosted in MS Azure
- User permissions and user management
- Ability to execute actions in Swagger

The platform was made available for showcasing in public events as well as testing by consortium members in the same framework as described in the previous paragraph.

In this version, the consortium members were able to populate projects with real attributes and perform user acceptance testing within the platform.

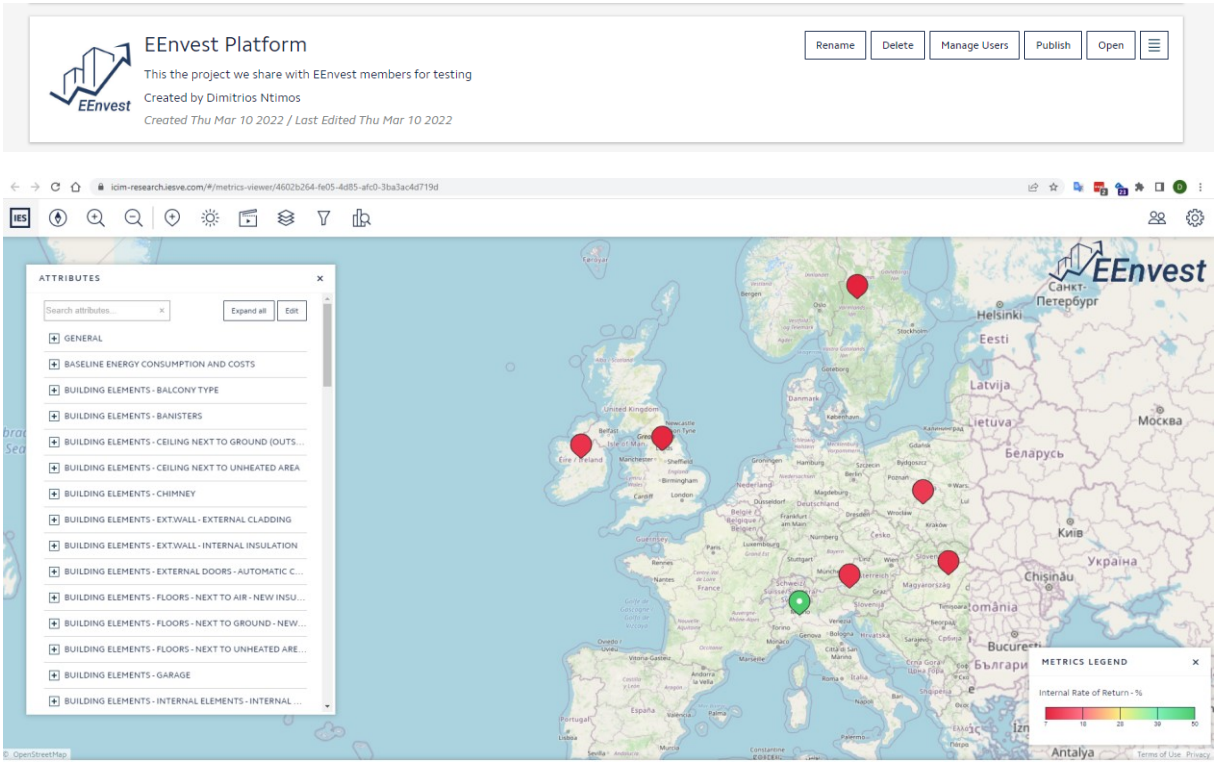



**Figure 47: second release of the EEnvest platform**

## 2.7.3 3rd Release

The third release of the platform was completed in M36 of the project, with the final version. In this release it is possible to execute the whole EEnvest workflow from entering the data to downloading the report and blockchain validation. This version incorporated all the development issue fixed; improvements made to allow the platform execute calculations.

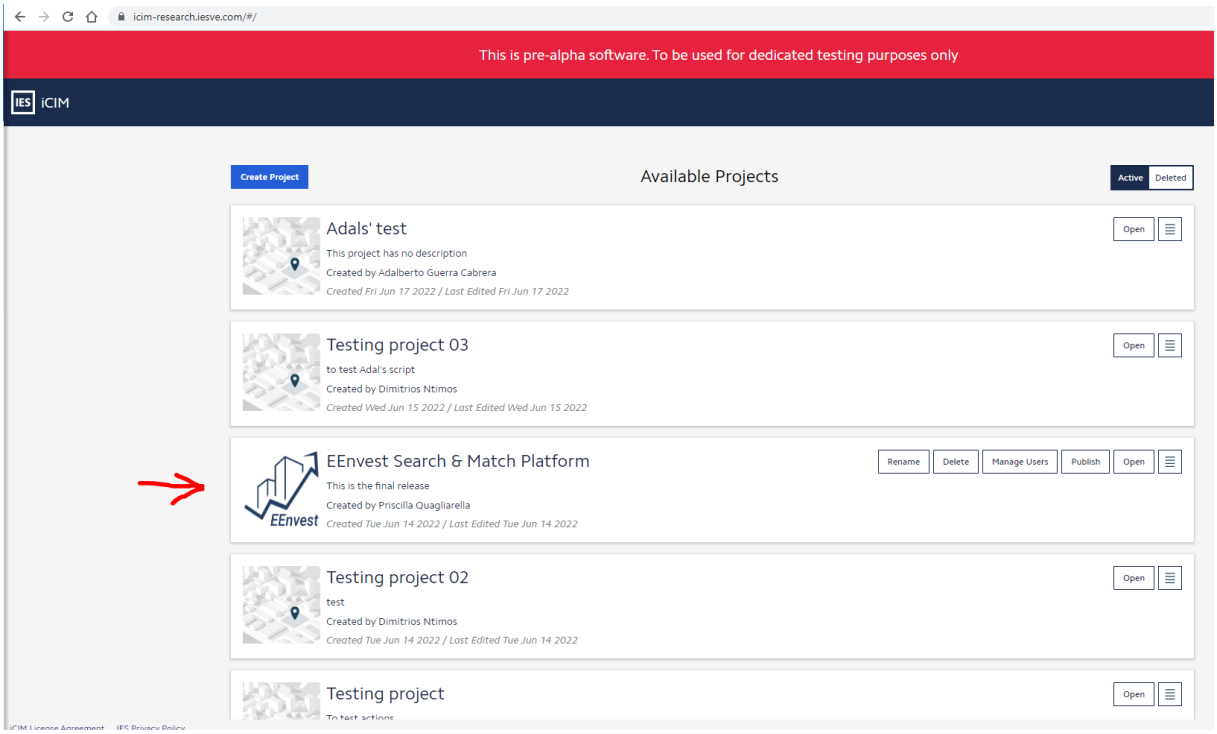



**Figure 48: Final release of EEnvest platform – Administrator view**

# 3 Platform Testing and Improvements

Testing is the act of examining the new features and the behaviour of the software under test by validation and verification. During testing it involved:

- Quality assurance, by executing activities within the platform and examining behaviour, while reporting issues back to software developers to get them fixed
- Calculation models end-to-end testing, where the Risk calculations were compared between the Excel sheet calculator and the implemented cloud model
- Blockchain model end-to-end testing, making sure the digital report is blockchain verified in Ethereum testnet
- User Acceptance testing and, End-user Usability validation, where EEnvest partners acting as end-users provided feedback about development issues, suggestions for improvement and new features required.

The testing period started in July 2021 and ended in June 2022. Below are some more details about each part of testing process.

## 3.1 QUALITY ASSURANCE

In order to ensure the usability of the platform, the testing process had an essential and extended role. A specific attention was put in considering the user point of view, trying to think both as Building Owner and Investor, and to identify their difficulties, doubts and needs while using the platform. This allowed to make the workflow user friendly as much as possible.

All consortium members have been given early access to the platform first release and were enabled and encouraged to conduct testing and report back issues, suggestions and features required.

At this stage all the new features are tested extensively and pass the Quality Assurance process. Most critical development issues are identified, such as slow/absent/unexpected response to inputs, and directly addressed in case they prevented too much the smooth use of the platform. A dedicated team undertook these tests and signed off the new features. Once signed off, the new features were deployed to the platform for user testing.

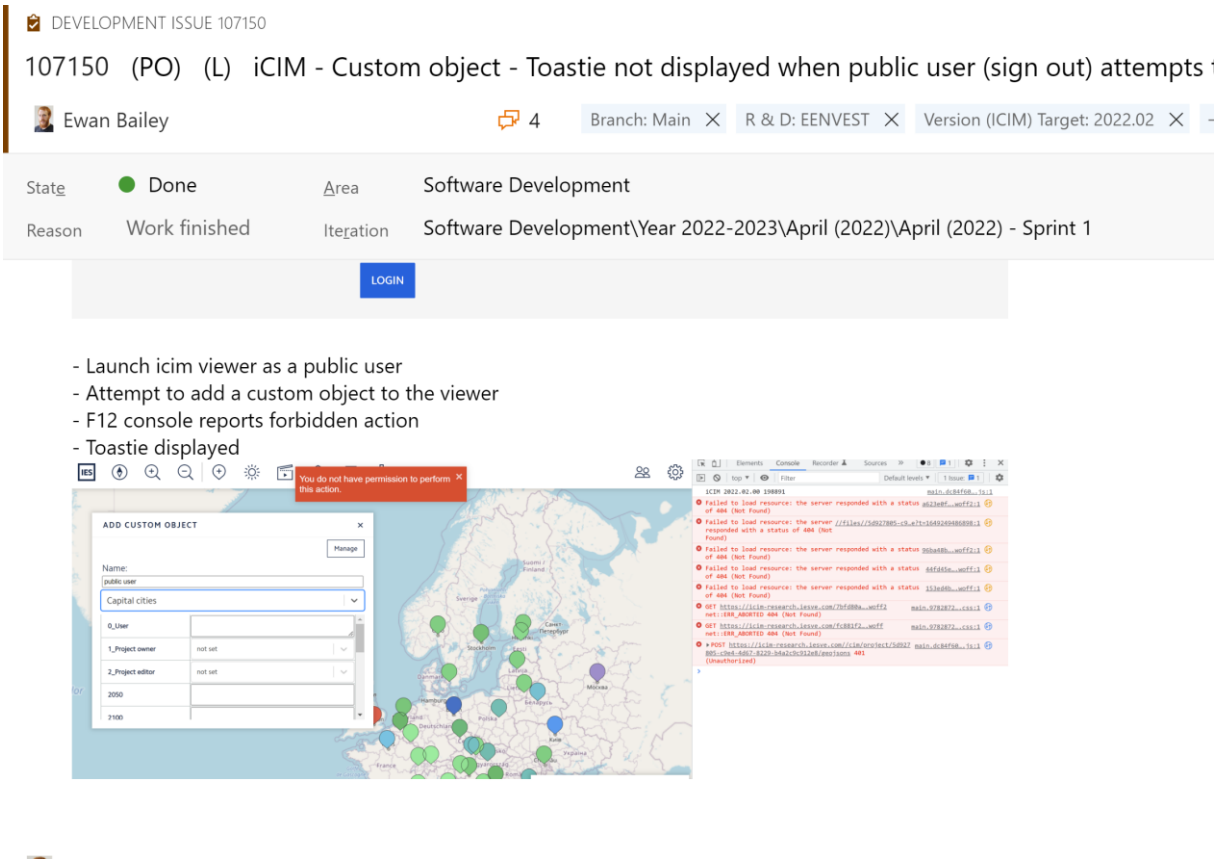



**Figure 49: Example of Development Issue found on EEnvest platform and recorded in internal IES issue tracker**

A list of existing and resolved development issues identified and fixed during the development phase is available on request, a small sample is found below.

| ID | QA passed | Description |
|---|---|---|
| 102839 | Yes | (PO) (H) iCIM viewer - Action - User cannot delete an action (Main) |
| 108478 | Yes | (PO) (L) iCIM viewer - Action - Panel changes size when non object owner or object editor attempts to run a action (Main) [2022.02] |
| 102815 | Yes | (PO) (H) iCIM viewer - Action - Adjust save logic (Main) |
| 102789 | Yes | (PO) (M) iCIM viewer - Action - Grey background on opening of panel (R&D) (Main) |
| 111200 | Yes | (PO) iCIM - Actions - Running action now forces a refresh to show result in the edit tab and attribute tab (Main) |
| 108464 | Yes | (PO) (H) iCIM viewer - Action - Actions collapse and expand [+ / -] button has moved from the left of the panel to the right-hand side (Main) [2022.03] |
| 107534 | Yes | (PO) ICIM - Authentication on Actions (Main) |
| 108412 | Yes | (PO) (H) iCIM - Actions - no custom object types are displayed in the 'Action to' dropdown menu (Main) |
| 108142 | Yes | (PO) (H) iCIM viewer - Action - Switching between action paths does not update the action method (Main) |
| 102825 | Yes | (PO) (L) iCIM viewer - Action - Adjust scroll bars (Main) [2022.03] |
| 103930 | Yes | (--) iCIM - Actions - Ensure action routes are not callable when Action feature flag is set to false (R&D) (Main) |
| 109687 | Yes | (QA) (L) iCIM - Action - Edit panel reduces in size when actions are running (Main) [2022.03] |
| 110181 | Yes | [Split] (L) iCIM - Action - Edit panel reduces in size when actions are running (Main) [2022.03] |
| 108821 | Yes | [Split] (H) iCIM - Actions - Old values used when running an action with unsaved edits (Main) [2022.03] |
| 112416 | Yes | (PO) (H) iCIM - Actions - Old values used when running an action with unsaved edits (Main) [2022.03] |

## 3.2 CALCULATION MODELS END-TO-END TESTING

In this stage of development, the calculation models' results have been compared to ensure the development of the models is not producing any misleading results or errors.

Same inputs entered in:

- Excel calculation sheets
- Data input in platform

Results page compared between:

- Excel sheet calculation page
- Calculated results in Swagger
- Calculated results that appear in the platform
- Results that appear in the EEnvest PDF report
- Results that appear in the Blockchain validated report

Mismatches and bugs have been found and fixed during this process. In the end, comparison of calculations in the above revealed that the results match in all the above for the same case studies.

## 3.3 USER ACCEPTANCE TESTING

A testing framework has been set up within the cloud repository of EEnvest, for testers to submit their feedback. As seen below, the tester had to create a new listing, and specify the following:

- Title
- Description
- Date reported
- Images
- Originator
- Type
- Steps to reproduce
- Attachments

On IES developers' side, the development team had to assess the issues reported and fill in:

- Importance
- Priority

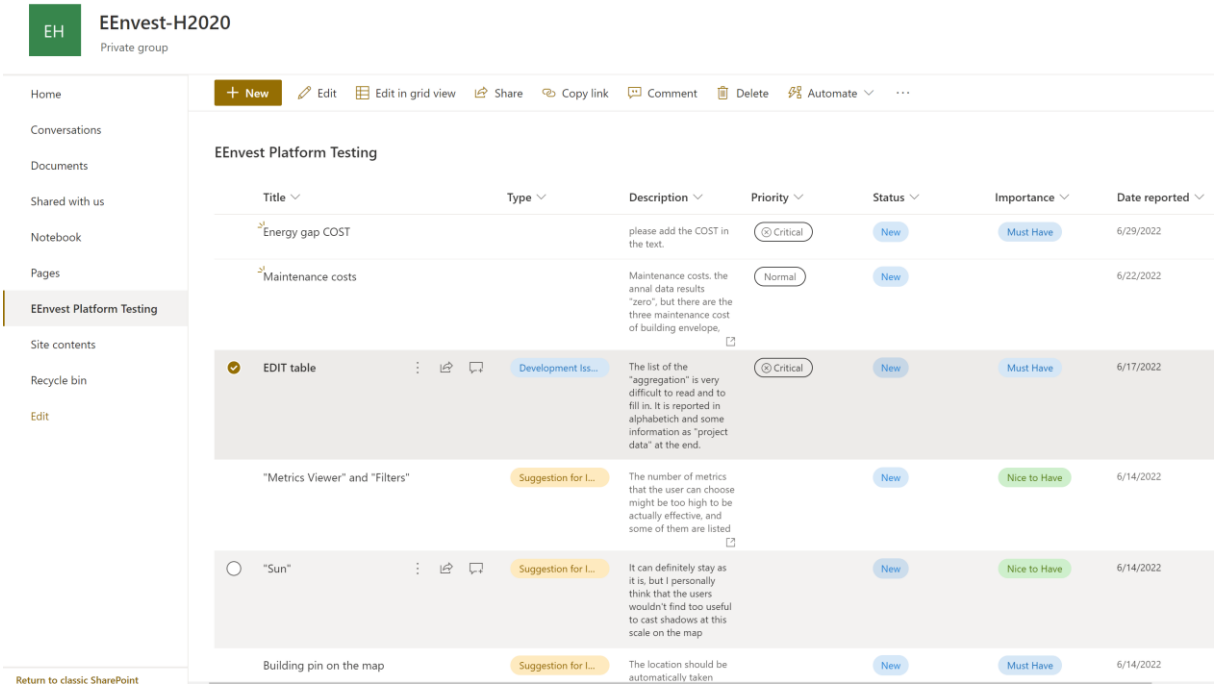



**Figure 50: EEnvest platform feedback collection tool**

User Acceptance testing, is the verification of the correct functionality of the features in a project available for all partners. However, the main contribution consists in the verification of the usability of the platform from a user point of view, which allows to open discussions about improvements. The following steps were followed during the process:

**Collection of the comments in a shared file by all EEnvest partners.**
All partners who tested the platform wrote their comments in a shared document. In this case, it was important to specify the category of such comments (suggestion of improvement, new feature requirement or development issue), level of priority (critical, high, normal, low) and importance (must have, nice to have). The image below shows the share file with the latest comments added.

**Address the comments through cooperation of the different teams**.
This stage includes discussion and definition of how to address the suggestion of improvement in order to implement the required actions. At the same time, the software development team solved the development issues. The issues are sized and prioritised in this stage.

Examples of user acceptance testing are found below.

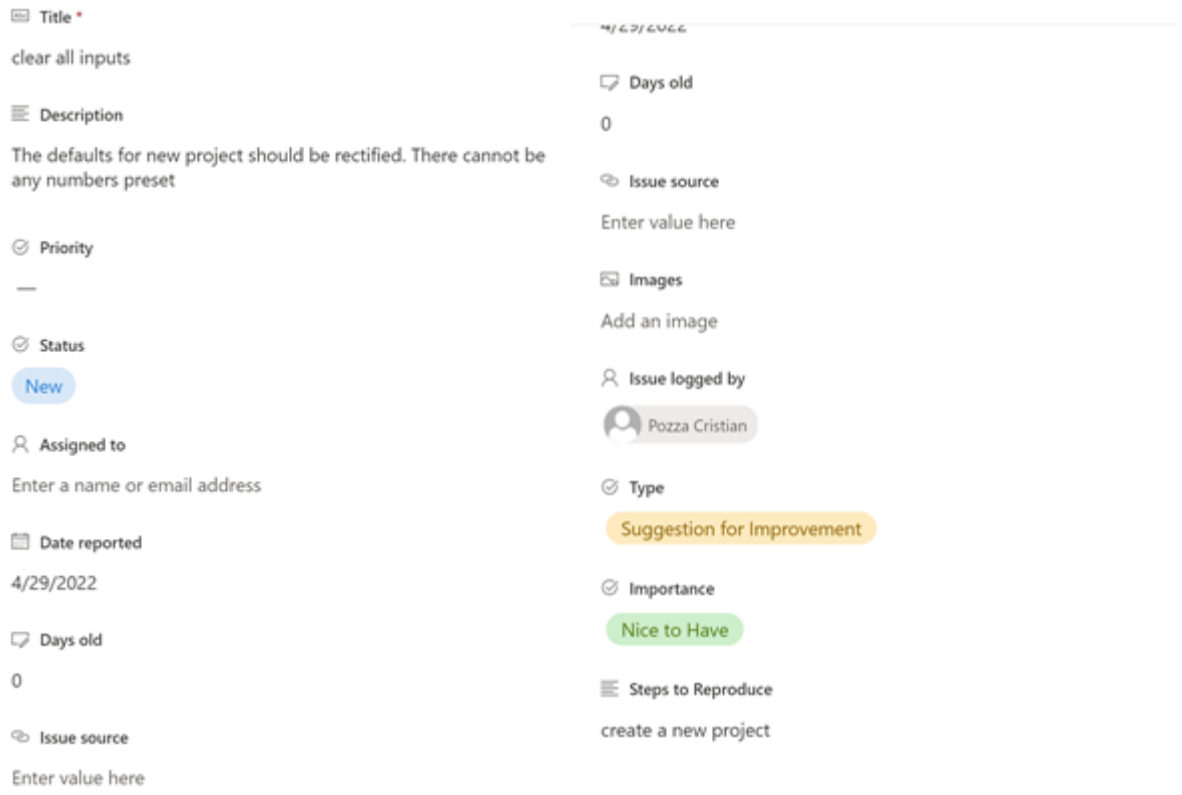



**Figure 51: Feedback collection tool**

As a last step, the development team prioritised the feedback and fixed the ones that were considered critical towards the successful delivery of the platform. All the rest were prioritised and will be considered in the commercial phase of the project. The full list of feedback is available upon request.

## 3.4 KNOWN ISSUES

This paragraph lists a sample of the known issues in the platform delivery by M36 of the project, identified by user testing:

- There are buttons in the UI that are not yet used, that need to be hidden until used
- UI features are not fully implemented, the projects are only visible in map view
- Not easy to create a new project, improvement needed
- Not easy to compare or use the metrics viewer
- The list of attributes is noticeably long and difficult to manage (four hundred attributes, including some metadata)
- The Filters and Scenes are global and not user specific
- The user journey is not self sufficient
- If the calculation fails, there is not feedback to the user and calculation is stuck at running
- The blockchain validation is set up to be executed in Ethereum Testnet.
- Maintenance costs are not calculated, new code is required
- There are improvements that can be made in the appearance of the reports

# 4 Roadmap to Commercialisation

After the end of EEnvest discussions will start with involved partners to agree next steps in commercialisation of EEnvest. During EEnvest, the Technology Readiness Level (TRL) was advanced from the region of 4-5 to the region of 7-8.[11]

In order to reach TRL 9, and prepare the platform for commercialisation, a few necessary functionalities can be introduced to the platform:

- Develop self-sufficiency, so that a user does not need any support to create account or execute tasks in the platform. For example, introduce a payment mechanism since at the moment the payment mechanism is manual, new users have to contact project partners to access the platform

- Release the platform to early adopters and validate the User Interface and User Experience (UI/UX) with early adopters, in order to collect their feedback and finalise the appearance. For example, the workflow to add a new project or search for existing ones is at very early prototype stage and needs to be improved based on user feedback

- Reduce the list of nearly four hundred inputs required to execute the calculations and support it with dynamic simulations tools, as the IESVE Apache Simulation engine. This way, the user would only provide data about the geometry, building use and retrofit options to consider, letting the platform to add other inputs

[11] https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

# 5 Conclusion

This document briefly describes the work done in implementation of the EEnvest platform with an introduction to the EEnvest platform scope, the user roles and platform architecture and requirements specifications, and then describes the new features introduced to fulfil these requirements.

EEnvest web platform functions as a search & match app and bridges the gap between building owners, interested in upgrading their buildings for reducing energy consumption, and investors that are willing to provide the capital investment that generates profits through savings and energy efficiency. In parallel, the platform promotes investing in energy efficiency in buildings by making the initial investment risk analysis simple and attractive for the potential investors. The focus is on commercial office buildings, while the solution will be scalable to be applicable to large databases and other building types globally. Finally, a blockchain validation mechanism will ensure the validity of the data in the platform, allowing the investors to trust that there is no reliance on a third party or there is no data tampering on the platform.

During EEnvest, the development of the platform is intended to reach the levels of a Minimum Viable Product (MVP) as a fully working prototype suitable with early adopting stakeholders, and in parallel though engagement with stakeholders during and after the projects ends to identify the improvements required to develop a Commercially Viable Product.

The platform allows the different users (or actors) to contribute to the growth of the platform. The EEnvest Search & Match operates fully on the cloud and is accessible by the users via a web User interface on a Web browser, responsive to all types of screens and devices.

According to the plan in WP5, the platform has been released early in the project to enable testing by the consortium partners and there were three releases in M24, M33 and M36.

The IES ICL Collaboration Cloud, is hosting the EEnvest platform UI. All the calculation models have been deployed on the MS Azure cloud and API connections are set up to execute the Risk Assessment and PDF report generator cloud calculations. Furthermore, the blockchain endpoint is creating and validating a digital report of the asset using Blockcerts and Ethereum.

Testing was a particularly important task in the platform development and was split in phases, examining the new features and the behaviour of the software under test by validation and verification. During testing it involved Quality assurance, by executing activities within the platform and examining behaviour, while reporting issues back to software developers to get them fixed, calculation models end-to-end testing, where the Risk calculations was compared between the Excel sheet calculator and the implemented cloud model, user Acceptance testing and, End-user Usability validation, where EEnvest partners acting as end-users provided feedback about development issues, suggestions for improvement and new features required. The final version of the platform was released in June 2022 together with the user manual (D7.10), a list of known issues, and a roadmap to commercialisation that was shared with Exploitation leaders of EEnvest project.

## Annex 1: Example PDF Report

## GENERAL DATA

Name: IFAD

Address: Via Paolo di Dono 44, Rome, IT

Building use/typology: Office

Owner: -

Contact: -

## TECHNICAL DATA

Construction year: 2001

Last renovation year: 2019

Gross floor area: 46,000 m²

Gross volume: 97,048 m³

HDD: 1,902


**Project size:**

**1,300,000.00 €**

**Financing amount requested:**

**1,300,000.00 €**

**Investment cost:**

**53.37 €/m²**

**Expected M&O costs:**

6.87 €/m²y

**Primary Energy savings:**

**27%**

**Primary Energy demand:**

**266 kWh/m²y**

**PV production:**

Yes: 43,200 KWh/y

**Solar thermal production:**

No

**Expected start date of the renovation:**

**01/01/2018**

**Expected end date of the renovation:**

**31/12/2018**

**Project ambition:**

Minimum primary energy cost saving of 35%.

**Renovation and mitigation measures adopted:**

Heating system
Cooling system
Ventilation system
Lighting system
PV system
Energy monitoring, LEED certification

**Project Quality Self-Assessment score:**

High probability of reliable, consistent and achievable energy savings. **370/400**

**Technical average risk**

| Mitigated | Needs attention | Needs action |
|---|---|---|

**Financial average performance**

| High | Medium | Low |
|---|---|---|

**Multi-benefit average performance**

| High | Medium | Low |
|---|---|---|

## TECHNICAL RISKS

### DAMAGE

The Damage indicator quantifies the investment deviation due to possible malfunctioning or failures of the energy renovation measures adopted in the renovation project. Such deviation is expressed as a percentage of the planned investment.

**0.30 %**

For this specific project, the Damage indicator has been estimated as:

### ENERGY GAP

The Energy gap indicator quantifies the energy performance deviation. It is expressed as a percentage of the calculated energy performance costs after the renovation project.

**1.04 %**

For this specific project, the estimated Energy gap is:

## FINANCIAL PERFORMANCE

### PAYBACK TIME

The Payback time is the amount of time that the investment will take to recover the initial cost when the length of the investment time reaches a breakeven point.

**8 years**

For this specific project, the estimated Payback time is:

### MATURITY

The Maturity is defined as the total duration of the project needed to achieve a zero NPV (IRR equal to cost of capital).

**12 years**

For this specific project, the estimated Maturity is:

### INTERNAL RATE OF RETURN (IRR)

The Internal Rate of Return (IRR) is the discount rate that makes the net present value (NPV) of a specific project equal to zero.

**12.70 %**

For this specific project, the Internal Rate of Return is:

### NET PRESENT VALUE ON INVESTMENT (NPV/investment)

The Net Present Value (NPV) is the value of all future cash flows (positive and negative) over the entire life of an investment discounted to the present. The NPV/investment ratio gives a measure of profitability of the project.

**0.71**

For this project, the estimated NPV/investment is:

### DEBT-SERVICE COVERAGE RATIO (DSCR)

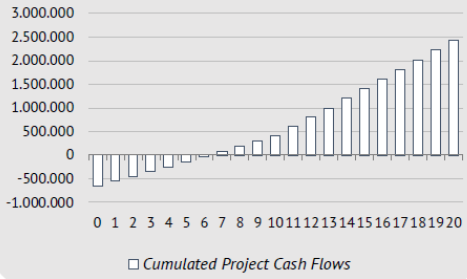
The Debt-Service Coverage Ratio (DSCR) is an indicator of the project's ability to repay a debt. It is calculated as the ratio between the operative cash flows generated by the project and the cash flows for debt, lease, or other obligations (debt service, both for interests and principal payment) due in one year.

**2.36**

For this project, the DSCR has been estimated equal to:

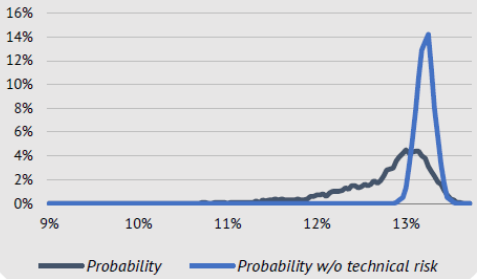
**Graph n.1 - Cumulated project cash flows**

This graph shows the cumulated cash flows generated by the project over time. The value for each one of the years is calculated as the simple sum of the cash flow of that year and all the previous cash flows. The graph below provides a quick view of the time needed to payback the initial investment cost.




**Graph n.2 - Project IRR Distribution**

This graph shows the probability distribution of IRR. Each value on the horizontal axis has a probability value. The area underneath the curve sums up to 100% probability. The dark blue curve includes all risks, so it's more extended to the left, meaning that there is higher probability that the IRR is low. The light blue curve includes only financial risks, so it's more concentrated around the expected value.




## MULTI-BENEFIT PERFORMANCE

### $CO_2$ EQUIVALENT EMISSION REDUCTION

The $CO_2$ Emission Reduction Indicator estimates the decrease of the $CO_2$ emissions as result of undertaking the renovation project. It is derived from the predicted energy savings, and it is applied a conversion factor that varies from country to country as well as the type of energy used in the building.

**21.35** kg/m²y

This KPI contributes to the following SDG targets: 8.4, 11.6, 11.9, 12.2

### PREDICTED ENERGY SAVINGS

The Predicted Energy Savings indicator is the difference between the actual energy consumption of the building (baseline) and the estimated energy consumption after the renovation project. It includes heating, cooling, lighting and ventilation.

**108.4** kWh/m²y

This KPI contributes to the following SDG targets: 7.3

For this project, the predicted energy savings are:

### NUMBER OF JOBS CREATED

The Number of Jobs Created metric refers to new jobs created as a result of the investment. This KPI is based on a proclaimed BPIE study that states that per 1 million euro invested on energy efficiency projects, 18 new jobs on average are created. It depends on the location of the building (for example, country) and the amount of the investment.

**23.5** jobs

This KPI contributes to the following SDG targets: 8.2, 8.5, 9.1

For this specific project, the number of jobs created is:

## EU TAXONOMY COMPLIANCE

The EU Taxonomy Compliance indicator defines whether or not the investment complies with the minimum requirements defined by the EU Taxonomy. In specific, whether the project being assessed has a minimum of 30% energy consumption reduction. Therefore, it's a binary metric.

**Yes**

## PROPERTY VALUE INCREASE

The Property Value Increase indicator brings light to the possible increment on the value of the asset after the renovation project. This is also referred as the `greemium`. In practical terms, it's not possible to predict this increase before the renovation project. Therefore, this metric is qualitative, and it provides a range of possible value increase backed-up by literature.

For this specific project, the Property Value Increase is:

**Rental price:**
**2-5 %**
**Sale price:**
**10-20 %**

## LINK TO SUSTAINABLE DEVELOPMENT GOALS (SDGs)

The Link to SDGs indicator depicts to which specific SDGs the project contributes to. It's a qualitative indicators that showcases the non-financial benefits of investing in the renovation project.


### Technical recommendations

A well-done renovation project reduces the difference between real energy consumption and estimated energy demand, guaranteeing the estimated energy savings for investments. To that hand, it is recommended to:

- engage an external expert to define the most relevant energy efficient and mitigation measures and improve the energy performance
- adopt standard protocols for the design and process verification (e.g., Passive House, LEED)
- include different specific analysis and tests during the construction
- assess the energy performance and management during the operation phase.

### Financial recommendations

In general terms, the financial performance of the investment can be improved by:

- revising the mix of energy conservation measures, focusing on the ones with lower payback time;
- using public incentives/grants to cover part of the investment costs;
- optimizing the financial structure of the project (e.g., through low-cost financing).

### Multi-benefit recommendations

The multi-benefit performance of the project can be improved by:

- selecting the mix of energy conservation with the highest impact on energy savings;
- implementing a standardized procedure to compute the multi-benefits for in-doors impact, such as thermal comfort, indoor air quality, acoustic comfort and productivity through smart sensors and questionnaires;
- optimizing the energy consumption levels on a monthly basis.

# Annex 2: Example Blockchain Verified Report

## EENVEST DIGITAL

### Italian case study - IFAD

"

Energy Efficiency Measures

- ✓ Energy demand reduction
- ✓ Cavity insulation
- ✓ Improved glazing
- ✓ New Facade
- ✓ Installation of PV array
- ✓

### Investment Evaluation

Financials

| | |
|---|---|
| FINANCIAL AVERAGE RISK | Low |
| INVESTMENT COST | 1300000 € |
| PAYBACK TIME | 7.6 years |
| MATURITY | 10.25 years |
| INTERNAL RATE OF RETURN (IRR) | 13.33 % |
| NET PRESENT VALUE (NPV) ON INVESTMENT | 1.39 % |
| DEBT-SERVICE COVERAGE RATIO (DSCR) | 3.12 |

Multi-benefit

| | |
|---|---|
| MULTI-BENEFIT AVERAGE RISK | Medium |
| CO2 EMISSION REDUCTION | 1,234 kg/kWhm² |
| CO2 EMISSION REDUCTION COST | 12,345 €/m²y |
| PREDICTED ENERGY SAVINGS | 98,765 kWh/m²y |
| PREDICTED ENERGY COST SAVINGS | 100 €/m²y |
| NUMBER OF JOBS CREATED | 23.4 jobs / €1,000,000 |
| EU TAXONOMY COMPLIANCE | Yes |

Technical

| | |
|---|---|
| TECHNICAL AVERAGE RISK | 171411.42 |
| DAMAGE | 0.0 % |
| ENERGY GAP | 44 % |

### Building Details

| | |
|---|---|
| OWNER<br>Building Owner Ltd. | CONTACT<br>01234 56789 |
| CONSTRUCTION YEAR<br>2001 | LAST RENOVATION YEAR<br>2019 |
| BUILDING USE/TYPOLOGY<br>Office | HEATING DEGREE DAY<br>1415 |
| GROSS FLOOR AREA<br>46000 m² | GROSS VOLUME<br>0 m³ |

### Building's Technical Data

**Technical Details**

| | |
|---|---|
| BUILDING HEIGHT<br>9 m | WINDOWS AREA<br>380 m² |
| PV PRODUCTION<br>43200 kWh/y | SOLAR THERMAL PRODUCTION<br>0 kWh/y |
| CO2 EMISSION REDUCTION<br>1234 kg/m²y | ENERGY SAVINGS AMBITION<br>31 % |
| MAINTENANCE/OPERATIONS COSTS<br>0 €/m²y | PROJECT QUAILITY SCORE<br>75/400 |

**Renovation & Mitigation Measures**

| | |
|---|---|
| RENOVATION START DATE<br>May | RENOVATION END DATE<br>May |
| ENERGY PERFORMANCE CERTIFICATE<br>Yes | FINANCING AMOUNT REQUESTED<br>€ 500000 |
| ENERGY PERFORMANCE MONITORING<br>Yes | IAQ & COMFORT MONITORING<br>Yes |
| RENOVATION OF HEATING SYSTEM<br>Yes | RENOVATION OF COOLING SYSTEM<br>Yes |
| RENOVATION OF DHW SYSTEM<br>Yes | RENOVATION OF VENTILATION SYSTEM<br>Yes |
| RENOVATION OF LIGHTING SYSTEM<br>Yes | IMPLEMENT RENEWABLE ENERGY<br>Yes |
| OPTIMISED OPAQUE COMPONENTS<br>Yes | OPTIMISED TRANSPARENT COMPONENTS<br>Yes |
| OPTIMISED SOLAR RADIATION<br>Yes | MAINTANENCE PROGRAMS<br>Yes |

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