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Deploying the Smart Energy Tool for Investment Simulation inside the HUBCAP Sandbox

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Abstract

Given its strategic characteristic, the energy management sector is transitioning into a cyber-physical system setting, where digital models, computation and associated tools provide decision support and find the set-points that optimally control the infrastructure at hand. The transition challenges the experts in the field that, in addition to the domain complexities, face the additional burden associated with adopting a new tool from the fast paced and ever-changing digital solutions market. To facilitate the adoption of energy management decision support tools and other digital assets, the HUBCAP project developed a cloud-based collaboration platform enabling tool providers to deploy tools in a sandbox, a protected and ready-to-use cloud environment, where users can experiment with candidate assets in a try-before-invest manner. In this paper, we report on research conducted to deploy the Smart Energy Investment Simulation tool into a HUBCAP sandbox. The tool is a cloud asset, so the deployment was straightforward migration between cloud providers, and the outcome was reviewed as positive. We expect that our results facilitate the adoption of other tools and attract other models and stakeholders interested in finding new partners and applications in the energy domain.

Keywords: Energy Management; Simulation; Investment; Platform

1. Introduction

Energy Management (EM) represents, nowadays, one of the most strategic and influential sectors worldwide. In 2015, the EU has defined a strategy for secure, competitive and sustainable energy (Commission, 2015), aiming to achieve at least 32.5% by 2030, according to the directive in (Commission, 2018a). A more efficient use of energy and a lower consumption can reduce energy bills, support to safeguard the environment, alleviate climate change, enhance the quality of life and also reduce the countries' dependence on external suppliers of oil and gas. Indeed, at companies' level, the always more constraining energy prices and sustainability requirements are impelling facility managers to enhance their organization's energy efficiency and to consider EM's optimization of great importance. However, although EM is generally not considered a key activity in the facility market, a support of digital technologies is needed to fill the gap (Francisco et al., 2020). Due to the high responsibilities of this sector on the pollution, and also to the opportunity to save energy and money optimizing the consumption based on a demand-side management approach, there is the always growing need and opportunity to exploit these technologies to innovate this market (Pierce and Andersson, 2017). However, often companies cannot internally exploit the competences and the digital leverage in the facility management context. The shortage of *technical capabilities and dedicated knowledge represent in these case significant hurdles in the digital technology application pursuit. In addition, also other secondary issues (e.g. fluctuating customer requirements, cultural and regulatory barriers, etc.) concur to impede the digital transformation towards services* (Forum, 2016; Baines et al., 2007; de J. Pacheco et al., 2019).

Flanked by the recent progress in the development of these technologies (gathered under the umbrella of Industry 4.0 (I4.0) (Rüßmann et al., 2015)), the use of Energy Management Systems (EMS) are enabling the rise in the market of Energy Service Companies (ESCOs) able to provide solutions and services aimed at the management and optimization of energy consumption in different industries (Industry 4.0 market, smart buildings and the multi-site Retail market).

The use of digital technologies is progressively revolutionizing the state of the art of EM. Traditionally limited to a monitoring capability, digital transition is now unveiling its potentiality to manage and directly enhance the EM sector according to a demand side approach.

Recent researches were aimed to bridge the gap between the extant high-level methodologies and the pragmatic use of modelling algorithms. (Gallagher et al., 2018) proposed an approach to measure the effectiveness of energy efficiency interventions with Machine Learning methods, enabling a precise quantification of the savings obtained in the industrial buildings sector. (Villa and Sassanelli, 2020) developed an innovative data-driven non-recursive multi-step approach for estimating in a dynamic way the interior temperature of a building, unveiling the relevant energy savings that can be obtained through the adoption of smart technologies in the facility management sector.

Once overwhelmed the main barriers for adopting digital technologies in the EM of the facility sector (e.g. a strong fragmentation and specific traditional communication protocols (Commission, 2017)), this kind of technologies are entitled to play a strategic role in the exploitation of the data and knowledge deriving by the delivery of new services and to reinforce the value proposition offered by new Product-Service systems (PSS) providers (Sassanelli et al., 2020, 2019; Zuo et al., 2013). Moreover, the full exploitation of data through adoption of I4.0 technologies in smart facilities will also strongly collaborate to reduce greenhouse gas emission (Zuo et al., 2013). Researchers have detected three of them (Internet of things, cloud computing and predictive analytics) as the best ones to better sustain the entire life cycle of data (spacing among generation, collection, transmission, storing, aggregation and processing) (Ardolino et al., 2016) but many more are supposed to strongly contribute in the future, also in a combined way, to the EM sector.

To support the adoption of such technologies, in the last decade EC introduced, under the big action called *Digitizing European Industry (DEI) Strategy (Commission and ", 2016)*, the ICT Innovation for Manufacturing SMEs (I4MS) initiative (`https://i4ms.eu/about`) and the Smart Anything Everywhere (SAE) *(Commission, 2018b)*. The objective is to assert Digital Innovation Hubs (DIH) role in fostering SMEs digital transition. Many projects have been financed in the last years. Among them, HUBCAP (Macedo et al., 2021) focuses on the adoption of Cyber-Physical Systems (CPS) through the easy use of Model-Based Design (MBD) models and tools in an online platform. It allows *user companies needing to invest in digital technologies, once put in contact with companies supplying MBD model and tools, to explore, familiarize, test and touch with hands these technologies, unveiling the potential benefits that they could trigger in their business.*

Therefore, the role of digital technologies embedded in EMSs to sustain the entire lifecycle of data is still not fully clear. This paper represents a first attempt to unveil digital technologies potentiality to manage and directly enhance the EM sector according to a demand side approach. In particular, the aim of this paper is to propose a tool for the simulation of energy systems embedded in the HUBCAP platform for MBD. This tool can be used on one hand by ESCOs to easily assess the energy systems of a facility, since it simulates their investments on such systems based on the energy consumption trend in the past months and on the estimated energy savings that will be gained. As well, on the other hand, the tool also helps facility managers in their decision making process letting them understand and realize in an easier way which could be the strengths and weaknesses of their systems.

The paper is structured as follows. Section 2 introduces the research context, mainly presenting the HUBCAP platform for MBD of CPSs in which this EM tool is embedded. Then, Section 3 provides some details about the research methodology and the case used. Next, Section 4 presents the main result of the study, i.e. the tool for simulation of energy systems embedded in the HUBCAP platform, also including their discussion and raising found limitations. Then, Section 5 presents a discussion of the results. Finally, Section 6 provides our concluding remarks and further research directions.

2. The HUBCAP Platform

The HUBCAP project (www.hubcap.eu) delivers a collaboration platform in the form of a web-portal providing a one-stop-shop containing assets (models and tools) used in the development of CPSs. The platform end users are expected to be members in a community (Robinson et al., 2021) aggregating providers of MBD assets and/or developers of CPS solutions. In addition, we expect it to be open to members interested in adopting MBD assets. The platform secured funding within the Smart Anything Everywhere initiative to lower the entry barriers for European SMEs looking to adopt MBD in the development process of their CPSs, but we envision the opening of the platform to the worldwide community of MBD asset providers and consumers in the future.

The portal is based on the existing DIHIWARE collaboration platform, which provides users with a web portal and several social collaboration features. Going beyond the collaborative aspect, HUBCAP provides two catalogues listing available models and tools (Figure 1) available for experimentation in a test before invest approach. The innovative aspect and addition of the current project to the platform is a sandbox environment that facilitates users to access such advanced CPS design and engineering tools and models using a ready to use solution.

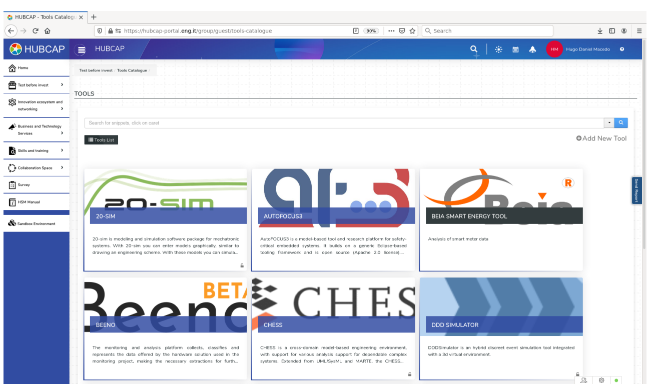


Figure 1. The Tool Catalog view in the HUBCAP Platform featuring the Smart Energy Investment Assessment Tool in the top of the third column.

The sandbox enables users to pick models and tools into a cart and launch them in a cloud environment following the architecture described in (Larsen et al., 2020) and depicted in Figure 2, which caters for the different software environments (Operating System, Libraries and other Dependencies) required to run the tools and models, and allows several users to co-develop a model by sharing the user interface of virtual machines hosted in a cloud and secure (Kulik et al., 2020) environment. As the platform is accessible via a web browser, the required tools a user needs to interact with a model are already available in the user's machine, and the complexity associated with such experiments is lowered. Furthermore the ability to invite other users as guests to a sandbox environment facilitates training and demoing of the assets.

The initial community experiments with the platform were performed by assets in the portfolio of the DIH network, and by integrating the assets from a group of initial SMEs in the community. The results of the deployment of the SME assets are documented as short video demos [1], and the conclusion and results from the initial experiments pushed the sandbox prototype forward. We expect the development of the sandbox features to continue, as new assets are deployed into the platform. The HUBCAP project features a timeline of open calls providing funding to providers interested in listing their assets in the platform's catalogue and to leverage the sandbox enviroment.

In summary, the HUBCAP platform intends to change how we develop CPSs. It provides a cloud-based platform to facilitate collaboration, that intends to lower the entry barrier to SMEs intending to adopt model-based design tools and assets. It does so by deploying a sandbox and a catalogue of ready-to-use tools and models. In addition, it establishes a network of DIHs and runs an open call programme to build up a community interested in moving the frontiers of CPS.

3. The Smart Energy Tool

The Smart Energy Tool is built upon a smart energy monitoring and simulation platform for real-time energy production and consumption monitoring, simulation of energy production potential and assessment of the economic viability of various investments in the field of energy. The simulations are performed using the information provided by the EnergyPlus open source software for building energy simulations, by the IoT network within the building premises and by Aermod dispersion model for of meteorological data.

For the investment simulation functionality, the tool uses historical data to assess the consumption trends specific to the end-user and weather data to estimate energy savings that will be gained using a certain configuration defined by the user. Different scenarios can be simulated to determine which investment is most appropriate for financing, thus reducing investment risks and promoting better management decisions for new project implementations. The platform enables smart energy efficiency investments, as it allows the simulation of multiple scenarios for the same investment plan and their evaluation using key performance indicators like Internal Rate of Return (IRR), Net Present Value (NPV) and others. Within the HUBCAP ecosystem we

1 See https://youtube.com/playlist?list=PLbVe239TJ_ZKWiD4FYZhW-GTJ21gAeR9o

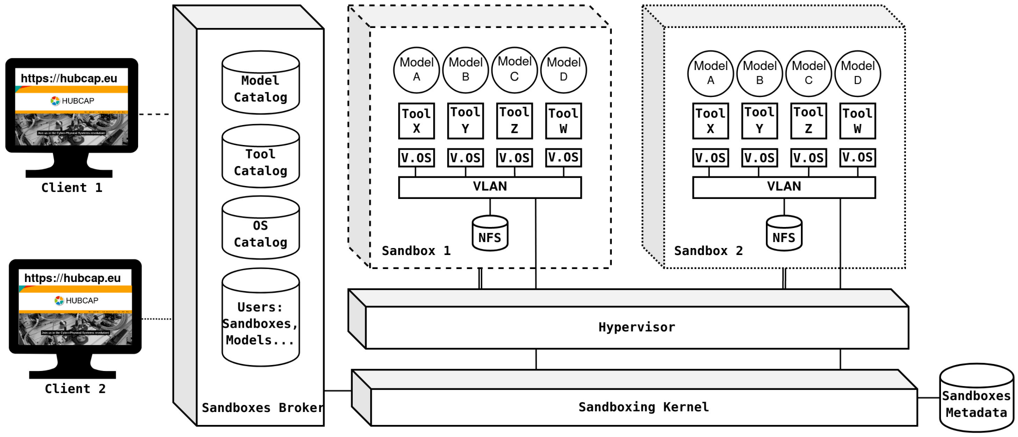


Figure 2. The HUBCAP Sandbox architecture (taken from Larsen et al. (2020))

are exploring various options of offering the platform components as services, including certifying GDPR and ISO27001 compliance.

The main functionalities offered by the platform are:

- Multiple energy investment simulations.
- Side-by-side scenario comparison as depicted in Figure 3.
- Key Performance Indicators computation for each scenario.
- Energy consumption management and future consumption predictions.

Figure 3. Investment plans comparison

The aim of energy monitoring is to gather the output parameters of energy measuring devices and to send the information (temperature, solar radiation and luminosity) to data visualization platforms and other tools for energy forecasting and management. Power forecasting is crucial for energy planning, as renewable generation sources are dependent on environmental factors, which can heavily influence reliability of supply and operating costs.

The business intelligence functionality of the tool employs the data collected using IoT devices, energy production simulation data, based on the user's location and financial inputs defined by the user regarding the type of investment. The consumption data can be determined from the information collected through IoT devices or it can be provided by the user based on the past energy bills, in energy or monetary units. The tool further calculates the average consumption for certain time frames.

The KPI scenarios simulation was developed using web technologies and is based on a REST architecture. For the front-end SemanticUI was used for the structure and styling of each page, jQuery and Ajax for asynchronous calls of the back-end services and ChartJS for the graphical data representation. The back-end consists of a SQLite3 database and Python Flask REST services for data fetching and processing. The scenario-based KPIs provided by the tool can be visualized using tables, graphs and diagrams and include Return of Investment (ROI), Internal Rate of Return (IRR), Net Present Value (NPV) and the distribution of savings between an ESCO and their client. These KPIs and their values from multiple scenarios can be compared to determine the most suitable energy efficiency investment. In case of the need for KPI forecasting, additional user inputs are required in order to perform the estimations (contract duration, total investment, parties involved, etc.).

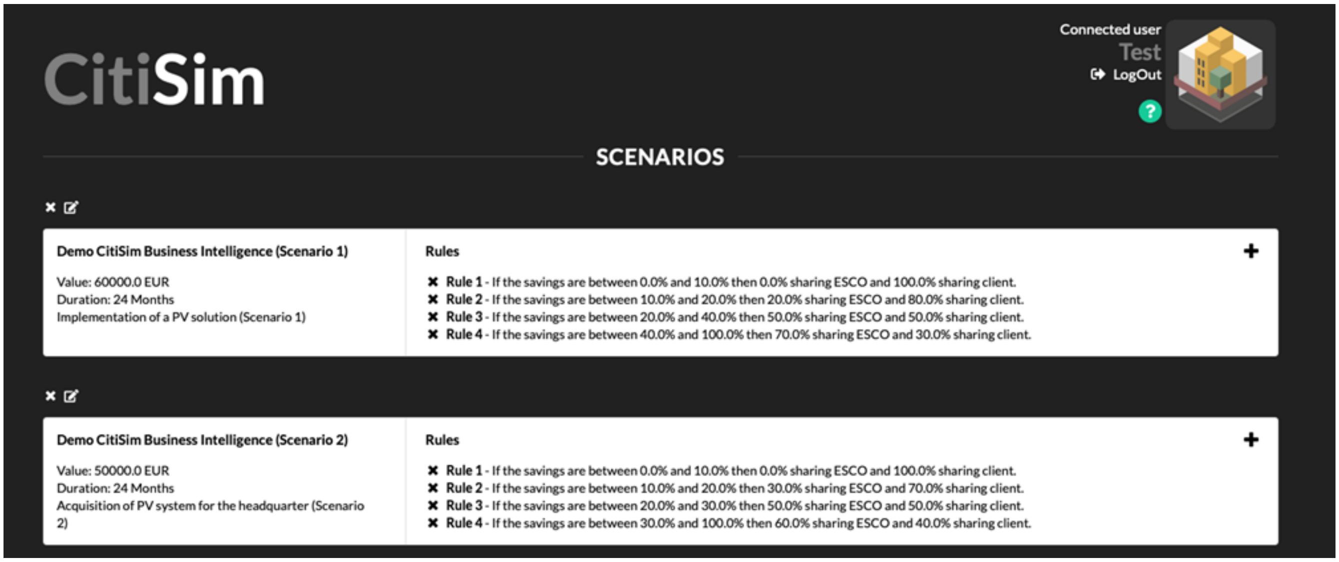


Figure 4. Scenario visualization

4. Integrating the Smart Energy Tool in HUBCAP

After an initial requirements analysis, the integration of the Smart Energy Tool within the HUBCAP ecosystem was carried out in two stages: the virtualization process (including local VM tests) and the consolidation of the tool within the HUBCAP sandbox.

4.1. The Virtualization Process

The virtual setup was made on a virtual machine. The parameters were chosen specifically to meet the needed requirements and the hardware configuration was met. Hardware specifications (50GB of memory, 4GB of RAM, Ubuntu 18 OS). No adaptations were made for the execution of the tool.

Experiments of the tool were performed:

4.1.1. Access, Account creation, Platform authentication

The platform can be accessed over the internet at the address `https://smart-energy.beia-telemetrie.ro/`. For the first attempt, there is no authenticated user so the page is redirected to the form. At this stage a new account can be created by clicking on the Join Now button underneath the form. A new account has been created (`test@mail.ro`). During the account creation process, no error was encountered. Using the new account credentials, the user can login to the smart energy platform.

4.1.2. Scenario creation

To evaluate this functionality, two different scenarios have been created. For each scenario, specific rules have been defined, describing the investment opportunity and details regarding the EPC (Energy Performance Contract). After they have been created, the scenarios can be visualized in the tool's interface, as depicted in Figure 4.

4.1.3. Economic performance simulation and Scenario comparison

The user can visualize data as: potential savings (monetary units or percent), ROI, amount to be returned, IRR, NPV, and sharing of savings between the ESCO and the customer. The data can be visualized in tabular form or as graphs, columns, pie charts. Two different scenarios can be compared using tables, diagrams, pie charts or graphs. By the information derived from this comparison, energy managers or other stakeholders can substantiate investment decisions and reduce the associated risks. By the information derived from this comparison, energy managers or other stakeholders can substantiate investment decisions and reduce the associated risks. Figure 5 presents a graph representation of the two scenarios created previously.

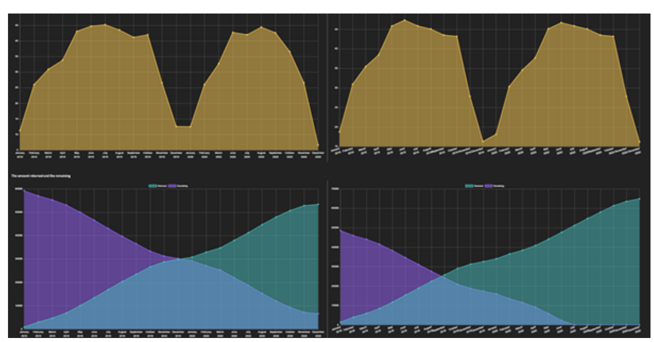


Figure 5. Comparing the results of two scenarios using graphs

Figure 6. Interface for sensor data visualization using Grafana

4.1.4. Sensors data visualization

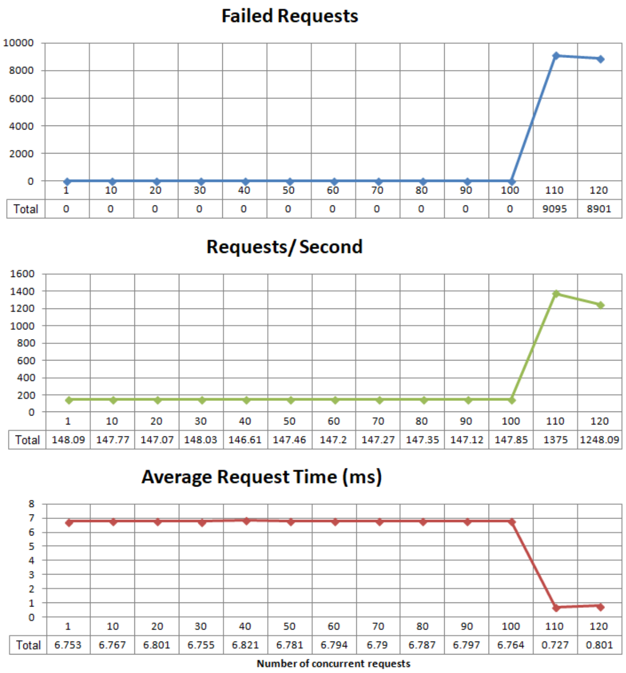
The sensor data visualization interface integrated in the Smart Energy Tool software allows selecting the sensor ID and the timeframe for the representation. There are three types of timeframes that allow a very granular data analysis. For a certain sensor, the evolution of energy consumption can be plotted for one day (hourly consumption), one month (daily consumption) or for several months in a selected interval. An alternative for sensor data visualization is represented by Grafana, which provides high flexibility regarding adding new data sources, new visualization and notification methods, and data export as shown in Figure 6. Grafana served as an alternative for energy monitoring and sensor data visualization because the platform was used to validate the initial application.

The tool's performance was tested with good results. For the back-end performance we used Apache Bench. Each test used 10 000 requests, varying the number of concurrently requests from 1 to 120. We drove tests for both authenticated (Figure 7a) and unauthenticated (Figure 7b) users and in both cases the average time and the number of requests solved per second is approximately constant up to 100 simultaneous requests. If the requests number raises above 100 the server is overwhelmed and drops a vast majority of them. For the front-end performance and to get an overall score of user experience we used Google PageSpeed Insights, a cloud service that generates suggestions to make your pages' load faster based on the content of a web page. It returns scores for both mobile and desktop browsers and as it can be seen in Figure 8, the results are good. After the test, we were suggested to eliminate render-blocking resources, to properly size images, to use next-generation formats for images, to remove unused CSS and to minimise the use of JavaScript.

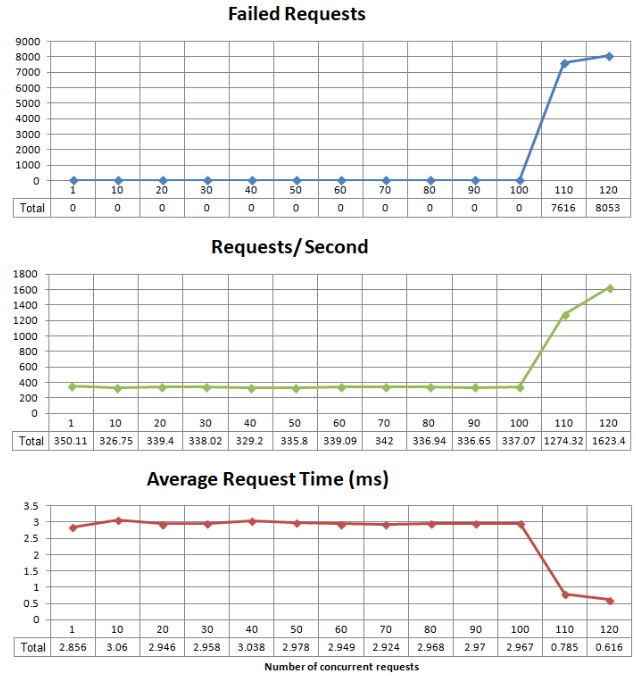
4.2. The Sandbox Setup

For the setup of the HUBCAP Sandbox, the following configuration has been chosen: Ubuntu OS 18 minimal [XFCE GUI + Firefox], two cores and 4 GB RAM capacity. In order to execute the Smart Energy Tool platform, commercially called CitiSim Suciu et al. (2018), on the HUBCAP Sandbox with Ubuntu 18.04 we created a Docker version of the platform. First, we installed the Docker application on the HUBCAP Sandbox. After that we deployed the docker version of the Smart Energy application by downloading it from the address: `https://github.com/beia/beialand/tree/master/projects/CitisimWebApp` and installed the application by using the `Readme.md`.

Subsequently, the application was tested and the results indicated that the performance of the tool is not influenced by the sandbox environment. Moreover, we observed no limitations or restrictions due to the sandbox environment. The CitiSim business application runs without major problems as it is a web based application and it needs a web browser in order to run on the HUBCAP Sandbox with Ubuntu 18.04. The browser



(a) Authenticated user performance test



(b) Unauthenticated user performance test

Figure 7. User performance plots

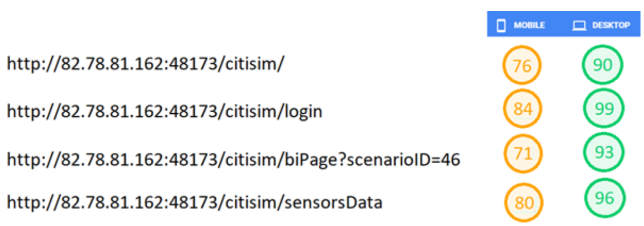


Figure 8. Client-side performance

used in this case is the Firefox Web browser.

In order to test the tool functionalities within the sandbox environment, the experiments were performed:

Access, Account creation, Platform authentication. The user can log-in into the CitiSim application.

Scenario creation. The user can create different business scenarios, as shown in Figure 9. After they have been created, the scenarios can be visualized in the Smart Energy tool interface.

Sensors data visualization. The sensors data can be visualized by choosing the relevant time intervals to show the granular data, as shown in Figure 10.

Scenario comparison. Different scenarios can be easily compared using tables, diagrams, pie charts or graphs, based on the previously generated financial information, as depicted in Figure 11.

To sum up, the process of integrating the Business Intelligence Tool in the HUBCAP Sandbox environment was straightforward, without major impediments. We created a new Sandbox with the Ubuntu 18.04 operating system. The Smart Energy Tool application was easily installed because it runs inside Docker containers. The sandbox created contains also a version of Mozilla Firefox which represents the only web application that is necessary for running the Smart Energy Tool application.

5. Discussion

With the endeavor of integrating a smart energy tool within the cloud-based open collaboration platform with 'sandbox' capabilities (the HUBCAP platform), it has been intended to create an approachable means for SMEs to seek smart investments in the energy field. This will be facilitated through the opportunity offered to the SMEs to trial new CPSs design technology. Thus, the barriers towards a wider adoption of these systems are lowered, and a proper evaluation of the economic performance perspective of energy efficiency is allowed.

It has to be raised that due to prevalent global regulations regarding resource optimization and consumption reduction, stakeholders must face the challenges of integrating new renewable resources into their energy

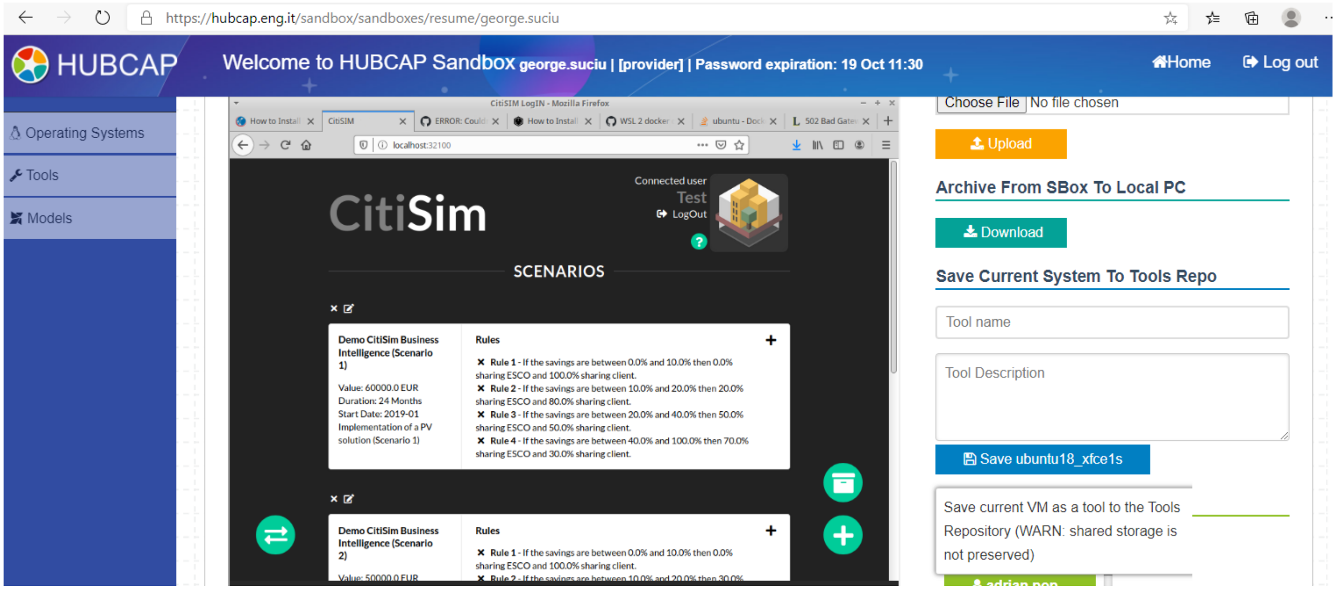


Figure 9. The scenarios created in the CitiSim application deployed in the HUBCAP Sandbox.

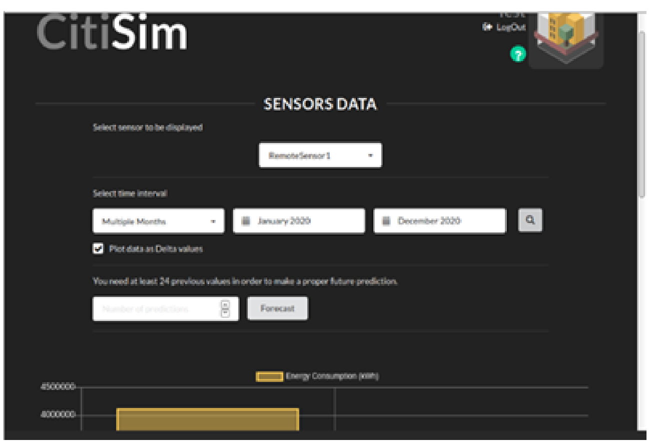


Figure 10. The sensor data from the CitiSim application deployed in the HUBCAP Sandbox.

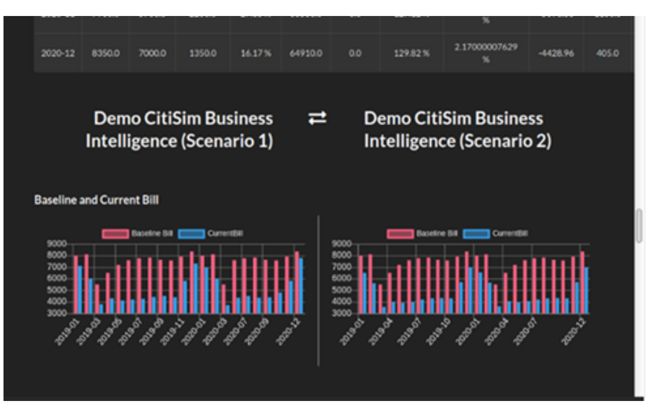


Figure 11. The comparison of scenarios created in the CitiSim application deployed in the HUBCAP Sandbox.

mix and of accommodating to new models of the energy grid, while also maintaining economic viability. Companies are compelled to adopt innovative energy efficiency solutions, but the decision to implement these measures is complex, due to a unique combination of factors that influence the rentability of these projects, such as laws and regulations, local energy pricing, available resources, specific energy demand, environmental conditions and so on. In addition, business analytics play a significant role in assessing the middle and long-term economic efficiency of investment decisions. These relevant internal and external factors that can potentially enhance or threaten the feasibility of any energy project should be properly evaluated by each company prior to implementation. In this context, the visual tool proposed helps companies to monitor energy production and consumption within various cost-centers, forecast the energy production potential and simulate the economic efficiency for multiple investment scenarios. The tool uses energy data collected by sensors along with business analytics to simulate the economic efficiency of multiple investment scenarios of projects based on energy efficiency measures. The Smart Energy tool provides a comprehensible overview of the most commonly used and relevant economic key performance indicators for any pre-feasibility evaluation in the field of energy investments. The platform is therefore a useful tool that can contribute to the materialization of investment decisions, thus enhancing the success rate of energy efficiency projects.

6. Conclusions

This paper reports on the work carried on to deploy the Smart Energy Investment Simulation tool into a cloud-based platform. The tool is a cloud asset, so the deployment was a straightforward migration between cloud providers, and the outcome was reviewed as positive. We expect that our results facilitate the adoption of other tools and to attract other models and tools interested in finding new partners and applications in the energy domain.

As future work we want to implement the functionality of collecting real-time data from the sensors. This was one of the functionalities of the initial tool, but it could not be tested in the HUBCAP platform remotely.

Acknowledgements

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