DESIGN AND IMPLEMENTATION OF A NOVEL OPEN-SOURCE WEB-GIS APPLICATION FOR A HARMONIZED EPC DOCUMENTATION ACROSS EUROPE

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ABSTRACT

In recent years, there has been a growing demand for buildings that are energy efficient. As a result, there is a need for a standardized and advanced framework for issuing Energy Performance Certificates (EPCs). Various organizations, including the European Commission, have emphasized the importance of improving EPC schemes and propose the adoption of a common, homogenous scale of energy classes ranging from A to G. This framework will ensure a more accurate evaluation of the actual energy performance of buildings. Moreover, technological advancements and innovative digital Geographic Information System (GIS) and webGIS tools have enabled the capability to handle and visualize a huge amount of energy performance data. This, in turn, provides a more comprehensive and accessible representation of energy consumption and efficiency at various scales, including dwellings, buildings, regions, and countries. The EU-funded research project entitled "Next-generation Dynamic Digital EPCs for Enhanced Quality and User Awareness" (D^2EPC GA 892984) introduces a comprehensive approach to next-generation Energy Performance Certificates. This approach addresses the main challenges and gaps in the buildings' energy assessment process, based on a common methodology for buildings across the European Union. The webGIS tool, as a part of the overall solution, offers advanced analytical tools, querying, and visualization functionalities, which include mapping and comparison of Energy Performance Certificates (EPCs) statistics across various geographical scales, attribute and geographical querying, and 3D visualization through the integration of Building Information Models. Our tool also facilitates data interoperability, ensuring seamless data exchange and analysis.

Keywords: Building Energy Performance, GIS, EPC documentation, Digital Platform, BIM, Data analytics

1. INTRODUCTION

Energy efficiency has become a top priority in recent years, with a growing demand for buildings that consume less energy, leading to the need for a more standardized and advanced framework for issuing Energy Performance Certificates (EPCs). In parallel, the effects of climate change that are nowadays more visible than ever as well as other energy-crisis provoking events such as the recent war in Ukraine, the aforementioned need even more imminent. As a response, various organizations, including the European Commission (EC), have emphasized the importance of improving EPC schemes and propose the adoption of a common, homogenous scale of energy classes ranging from A to G. The European Green Deal (EGD)[1] announced by the European Commission in 2019 provides a roadmap to cope with climate change and reduce the greenhouse gas (GHG) released into the atmosphere. The goal is to achieve a reduction of 55% on carbon emissions (compared to 1990 levels) by 2030 and achieve carbon neutrality by 2050 [2,3]

Recently, EC proposed to integrate the rules regarding the energy performance of buildings within the EGD. Buildings are the largest energy consumer in Europe as they account of an approximate of 40% in total consumption[4]. As fossil

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fuels are the primary power source for buildings, the Commission proposes that all new buildings must be zero-emission by 2030.

To accomplish the goals set for the building sector, it is critical for each member state (MS) to measure and keep track of the energy performance of buildings. Moreover, studies of buildings sector suggest that today's buildings will make up at least 75% of the 2050 available stock. Consequently, each EU MS should keep track of energy performance of buildings not only for new constructions but for renovated buildings as well. A study prepared for European Commission[5] showed the impact of energy renovations for buildings for years 2012 – 2016. Specifically, an average of 9.5% of energy savings in non-residential and 12.3% in residential buildings was calculated for energy renovations across EU-27. However, compliance of the EPC is lower than expected as written on the draft report on the implementation of the Energy Performance of Buildings Directive[6] and in most cases EPC regional data are not even available in centralized manner[7]. Making EPC data accessible is a key step in making it useful for citizens, planning authorities, academia and industry. The openness of EPC data varies immensely across Europe[8]. This causes challenges for national policy makers, and for anyone wanting to access and compare EPCs issued in different parts each country.

In order to accomplish a regional impact, the EPC data acquisition must be harmonized and widely provided. To build regional decarbonization plans that could guide the retrofitting wave of incentives there should be an accurate detection of the building stock metabolism via BIM + EPC regional maps + detection of behavioral changes in consumptions at the aggregated level via operational rating. There is a need for a data economy based on open platforms: open platforms offer rapid development solutions in a cloud environment. A proper combination of open source and proprietary solutions creates a dynamic eco-system in which concepts such as open API can support rapid development and innovation in service provision[9].

In recent years, the field of geoinformatics and Geographic Information Systems (GIS) has witnessed rapid advancements in technology, leading to the development of sophisticated tools and techniques for analyzing and managing spatial distributed data such as EPCs[10]. These advancements have also opened up new opportunities for improving the monitoring of building energy consumption and the extraction of statistics based on energy performance certificates (EPCs). However even in the EU GIS technologies and information are either partially used or not used at all in the process of the EPC calculation, monitoring and verification (figure 1).

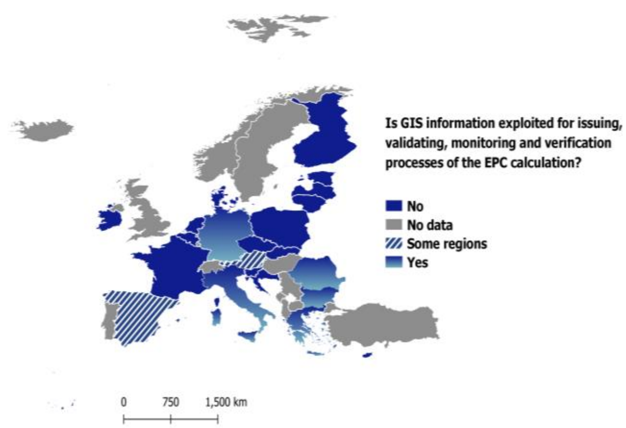

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Figure 1: Use of GIS information for issuing, validating, monitoring and verification processes of the EPC calculation across Europe

The use of GIS and geoinformatics in building energy management can provide a wealth of benefits, by visualizing and analyzing spatial data related to building energy consumption and thus producing added value information such as energy consumption patterns, thermal performance, and energy demand. Additionally, by providing a detailed spatial analysis of building energy consumption, GIS and geoinformatics can help identify areas of inefficiency and prioritize energy-related measures and relevant funding[11]. On one hand, a description of a building project in deep geometrical and attributive details is given by BIM, and on the other hand, a geographic information system (GIS) contributes as the most important tool to describe a digital city in multi-rate, multi-scale, and space-time dimensions[12].

In this paper we introduce a novel webGIS scheme for the purposes of visualizing and analyzing EPC generated data in a regional level. The development of this application has been carried out under the research and innovation project D^2EPC[13] which introduces a comprehensive approach to next-generation Energy Performance Certificates and deployed as a subcomponent of the overall digital platform[14] – namely the D^2EPC digital platform. Our solution offers advanced analytical tools, querying, and visualization functionalities, which include mapping and comparison of EPC statistics across various geographical scales, attribute and geographical querying, and 3D visualization through the integration of Building Information Models.

2. METHODOLOGICAL APPROACH

2.1 Data and methods

In this section the general scope, case studies and utilised data are briefly presented. The main objective of this work is the development of a framework for the provision of regional level EPC statistics to third party stakeholders via a seamless online procedure. The list of interested parties for such a solution contains several stakeholders related with the energy sector such as governmental authorities / registries /public bodies, Energy Service Companies (ESCOs), real estate agencies, the building services industry, researchers or academia, environmental organizations and standardization bodies among others. Consequently, the proposed webGIS scheme mostly addresses the aforementioned third-party stakeholders, aiming to provide regional-level information related to EPC statistics, as well as added-value information such as construction materials and other important energy- and building-related statistics.

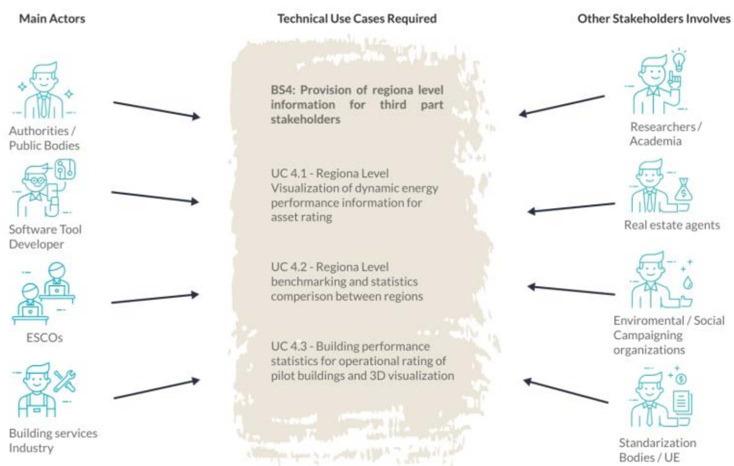

Figure 2: Conceptual graph of the main business scenario of the webGIS tool

As a whole our solution could potentially address the following technical use cases that have been identified as current gaps, as also illustrated in figure 2 above:

- **Regional Level Visualization of dynamic (aspect of time) energy performance information for asset-based EPCs.**

  In order for all data handling and processes to be GDPR compatible data visualisation on the WebGIS concerns only fully anonymised aggregated over regions data for statistics extraction. The constant update of the EPC registries as well as the newly inserted BIM models can provide a continuously updated version of the regional statistics.

- **Regional Level benchmarking and statistics comparison between regions**

A comparison and benchmarking use case is been addressed in order to identify the overperforming and underperforming regions in terms of EPC score. Such information can be critical for a more direct and targeted fundings and subsides (e.g. renovations).

- **Building performance statistics for operational rating of pilot buildings and 3d visualization**

  The capability to visualize the 3D model of the building/dwelling and receive information about its specific characteristics, construction materials and any other energy-related information that can be stored inside a BIM file. Interested stakeholders such as owners, EPC assessors and engineers could make use of such a use case as verified users through a dedicated authentication procedure.

WebGIS technologies have been used to enhance the efficiency and accessibility of EPC data. Web-based platforms have been used to facilitate the analysis and visualization of EPC data at the city scale, enabling policymakers and stakeholders to identify areas with high energy consumption and prioritize energy-saving measures[15]. In another study[16] a webGIS tool visualize the amount and location of waste heat leaving homes and communities across residences in Canada.

In this study,and for the webGIS development purposes, dummy EPC sample data were generated all across Europe. Specifically, thousands of randomly generated georeferenced points with a uniform distribution., populated a dedicated geospatial database, acting as original EPC data (ranging from A to G). The aggregated EPC information derive form this initial input was created based on the following four selected spatial scales: i) NUTS level 0 – countries, ii) NUTS level 1 - major socio-economic regions, iii) NUTS level 2 - basic regions for the application of regional policies, iv) NUTS level 3 - small regions for specific diagnoses and v) Pan-European climatic zones as provided by the D^2EPC project partners. The Nomenclature of Territorial Units for Statistics (NUTS)[17] of Eurostat was selected as the primary geographic unit for the extraction of regional EPC statistics. Its use offers superior data harmonisation, better analysis, and improved comprehension of socio-economic indicators. NUTS is widely used as the geographical baseline for policy-making and thus provides a standardized framework for regional data analysis.

2.2 Integration with the overall platform

Our proposed web-GIS scheme is part of the wider web-based solution that has been developed to facilitate the next generation of EPC issuance. This web platform adopts a holistic approach for the representation of the various EPC results and KPIs, along with information and data derived from the asset's documentation. The utilised framework architecture is divided into four processing layers: the physical layer, the interoperability layer, the service layer, and the representation layer. Each layer includes various components and sub-components. **Error! Reference source not found.**3 provides an overview of the D^2EPC architecture framework as well as the key interconnections and integration dependencies of each sub-component, including the webGIS tool.

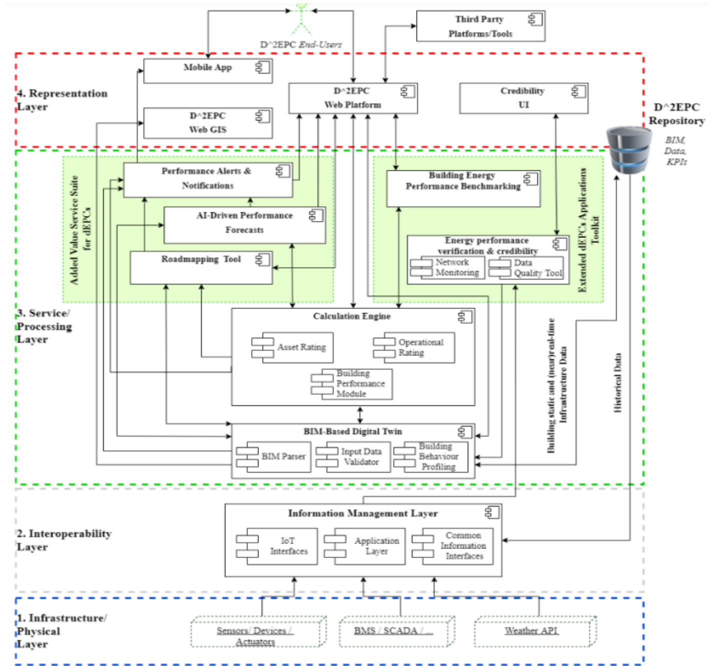

Figure 3: D^2EPC system architecture

The **Physical Layer** includes the required infrastructure for data collection, namely IoT devices; sensors or even systems (e.g. Building Management System or Supervisory Control and Data Acquisition- SCADA). Additionally, this layer includes Application Programming Interfaces (API) used for retrieving the data streams form the deployed sensing/metering devices as well as, data streams from the Web (e.g. weather data). Proceeding to the second level, the **Interoperability Layer** transfers the information from the monitoring system to the framework repository to be accessible from the superior layers. To address the challenge of data interoperability, the framework extends current protocol standards (i.e. IFC4) to achieve data exchange in a commonly accepted format and to store data in the framework's repository.

The third layer constitutes the platform's computational core. The **Service or Processing Layer** is equipped with a variety of components. Starting from the BIM-based Digital Twin, the heterogeneous building information are managed in a uniform way to provide the building's near-real time representation. The Calculation Engine configures the asset's as-designed and as-operated energy performance, while also providing a wide range of indicators in the domains of smart readiness, life cycle analysis and human comfort. The Added Value Services Suite leverages advanced computational techniques (e.g. Artificial Intelligence) to extract renovation and operational recommendations for end-user while the Extended dEPC Applications Toolkit enriches the platform with advanced data verification and building benchmarking capabilities.

The **Representation Layer** lays on top of the platforms architecture and it is responsible for the delivery of the results to the end-user via two critical components. The D^2EPC Web-Platform is the component that informs the end user for all the related information on the building-unit level, utilising 3D visualization and visual graphs to enhance user-friendliness and promote the interaction of the end user with the platform. On an aggregated point of view, the D^2EPC WebGIS component provides an elevated view on regional level to assist in optimal policy-making, identification of energy patterns, and compliance with national legislation. More specifically, the tool's interface is accessible through the main D^2EPC Web Platform through a single-sign-on (SSO) mechanism. Users of the latter that are eligible to view the tool's results (e.g. relevant authorities) can be redirected to the WebGIS upon selection. Additionally, the tool collects EPC-related, semantically enhanced information for each building registered in the overall platform through the BIM-Based Digital Twin, contributing to effectively visualizing and calculating the corresponding statistics per region.

2.3 Architecture

Energy performance certificates provide important information about energy consumption and play an important factor in investing, renting, and buying decisions. As proposed by 2025, issued certificates must be based on a common homogenous scale of energy classes ranging from A to G. To this end, the D^2EPC framework mainly focuses on delivering an EU-based platform for issuing EPCs based on a common methodology for buildings across EU MSs. This implementation leads to the construction of a centralized database for storing these dynamic EPCs. Centralized information of EPCs regarding important information such as the energy class/grade, the type of building/dwelling and its exact location can be very useful for data interpretation and further analysis. As mentioned in the previous section, the webGIS tool is part of the representation layer of the overall platform architecture while also presents communication/interactions with the common EPC repository and the web platform.

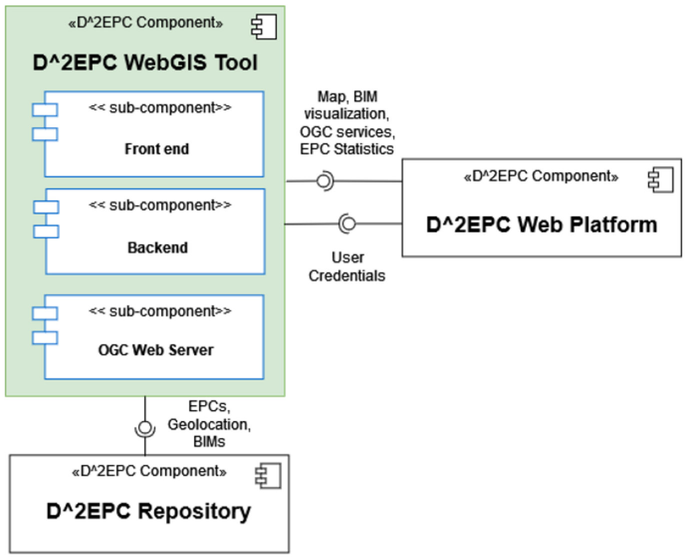

Figure 4: WebGIS Tool functional diagram with its related communication/interactions

The architecture of the designed application consists of three main sub-components namely the a) the Geospatial database server, b) the OGC web server and c) the web server comprised from the back-end and front-end solutions, as illustrated in the provided functional diagram in figure 4.

Geospatial database server

The role of the geospatial database is to store and handle the dynamically generated data regarding spatial information of issued EPCs as well as to enable the spatial functions required for storing, querying and processing spatial features. This database consists mainly of four tables corresponding to the four NUTS levels used and each one of them holds anonymised EPC statistics (asset rating grades) per region.

OGC web server

This server functions as an intermediate channel between the database and the application’s main web server. It delivers the database tables as OGC services (WFS, WMS) to the WebGIS backend providing interoperability by using these standard formats.

Web server (front end and back-end solutions)

The backend of this server is responsible to update the statistics for each region (various NUTS layers) in the application’s geodatabase as soon as a EPC is issued (new building), updated or deleted in the D^2EPC main database. In addition to writing to the database, the backend also retrieves the data from the database and serves them to the frontend via forming proper http requests to the OGC web server. The frontend displays the layers on a map and their corresponding statistics via visualisation tools, the BIM models using 3D graphics and the querying structure for end users to engage with the database

2.4 Functionalities

The WebGIS tool is a web application that has been developed in an appropriate manner to act as an endpoint between end users and the overall system solution providing data in a presentable and useful form. To our knowledge, until today there has not yet been available an operational web-based platform which could comprehensively provide the following set of functionalities:

i) Produce regional EPC related statistics based on the exact geolocation metadata deriving from either an EPC assessor, an official governmental registry or a building's BIM file
ii) Visualize and compare the aforementioned produced statistics with charts and plots
iii) Provide attribute and spatial querying capabillities
iv) Provide an endpoint for data dissemination using OGC (Open Geospatial Consortium) services
v) Visualise BIM models in a 3D manner (.ifc4 file formats)

3. RESULTS AND INTERFACES

3.1 Technologies

During the implementation of the WebGIS application only widely used, free, open-source coding libraries and state-of-the -art technological tools have been prioritized for the development purposes. In figure 5 an overview of our solution's technological stack is illustrated.

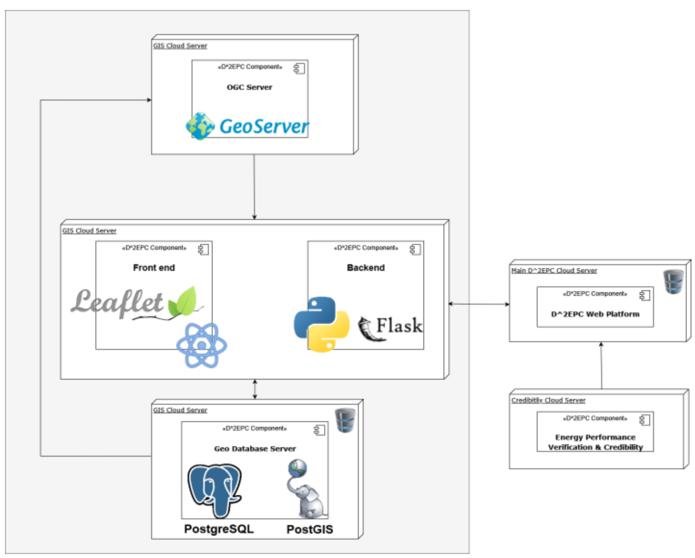

Figure 5: Overview of the deployed technological stack

The application's front-end component is structured using React.js, one of the most popular frontend frameworks, and the viewer map is implemented using Leaflet. Leaflet in an open-source JavaScript library that works efficiently across all major desktop and mobile platforms while also provides numerous third-party plugins covering most mapping features. In parallel, the backend component, which implements the connection of the front end with the PostgreSQL and the Geoserver, was developed using Python programming language and Flask. Flask is a lightweight Web Server

Gateway Interface (WSGI) web application framework with little to no dependencies to external libraries (micro-framework) and can support the creation of both small and bigger commercial websites. For the purposes of the webGIS development, and the interconnection of python to PostgreSQL, additional spatial functions provided by the PostGIS extension such as SQLAlchemy and GeoAlchemy2 have been utilized.

Our application also incorporates the open-source RDBMS PostgreSQL for storing and handling the aforementioned generated data. Moreover, various similar works[18, 19] employ postgres and PostGIS extension for handling the geospatial data. PostGIS is a dedicated spatial database extender that adds support for geographic objects allowing location queries and many other geographic functions to be run in SQL. Additionally, towards optimizing the dissemination and map creation for the data contained in PostgreSQL we explored the usage of the Geoserver web server. Geoserver is a Java-based server that allows users to view and edit geospatial data using open standards set forth by the Open Geospatial Consortium (OGC), and it has been widely used and tested in various other webGIS applications[20, 21]. Here, we apply Geoserver as a middleware application by connecting the WebGIS back and front end with the geospatial database in order to generate OGC services namely WFS, WMS and WMTS for displaying data coming from the PostGIS.

As far as the tool's web component is concerned, the selection of a Nginx Web Server provides additional scalability while it can be also used as a reverse proxy and load balancer. The overall developed solution is deployed using Docker, ensuring the interoperability with any host operating system. Docker Engine is an open-source containerization technology for building and deploying applications that can be easily re-installed and run on any supported system.

3.2 Main Interfaces and visualization

In this section we present the main webGIS development results as translated through its main interfaces and sub-modules. In figure 6 the landing page of the webGIS page is presented

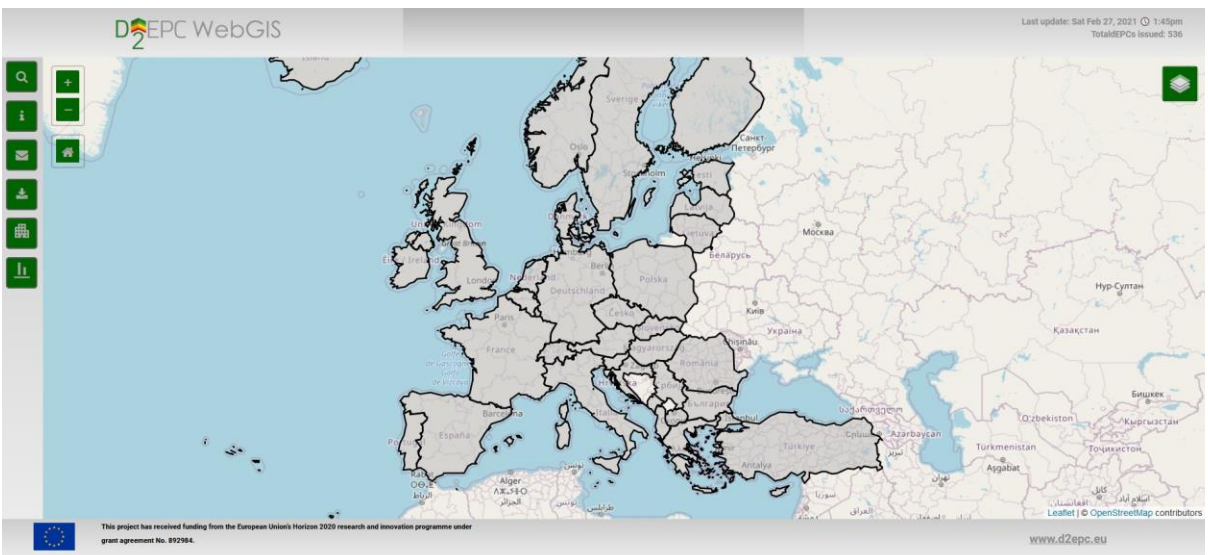

Figure 6: The webGIS landing page

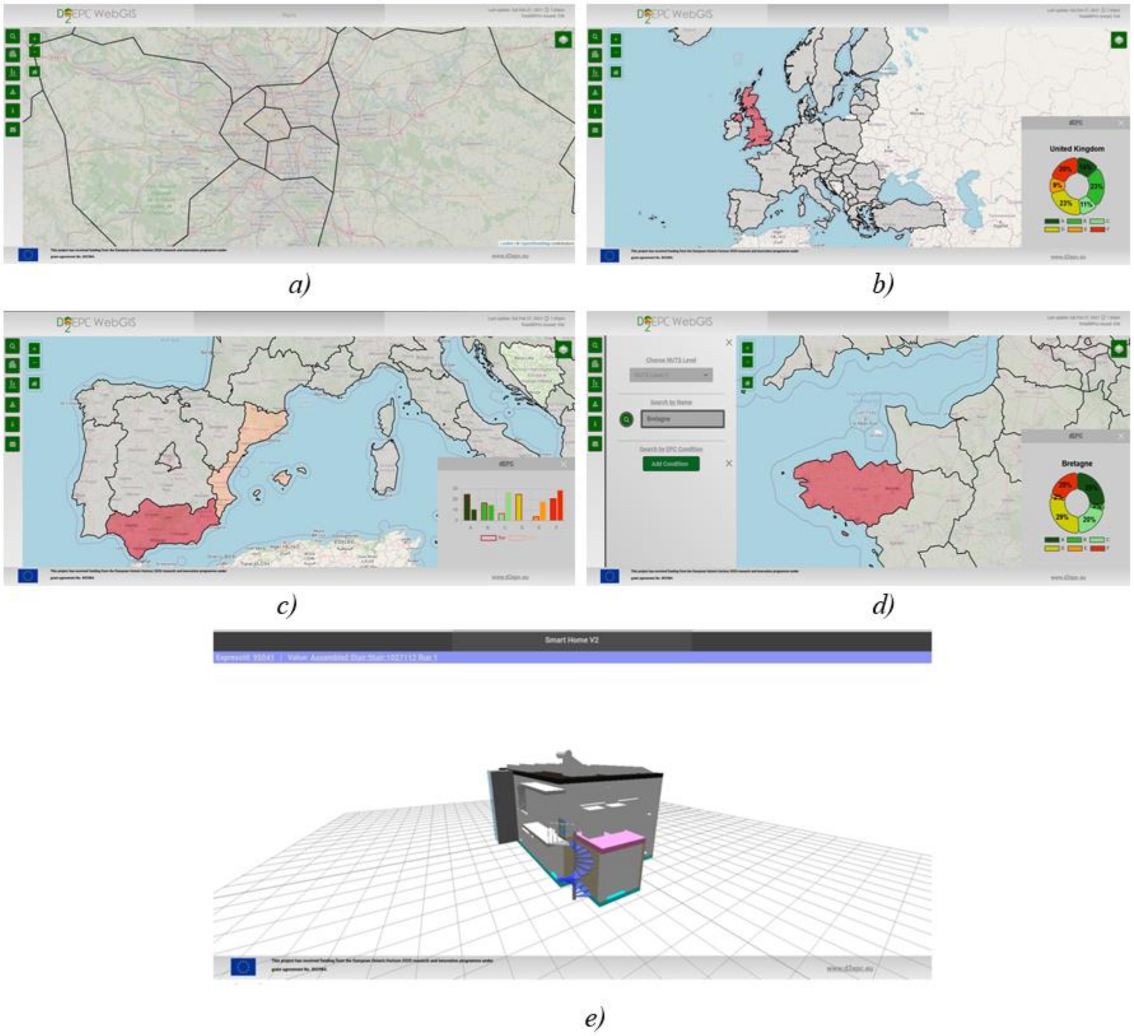

Figure 7: Different instances of the D^2EPC webGIS interfaces and operational modules: a) automatic zoom selector, b) EPC statistics visualization, c) the comparison module, d) spatial and attribute querying and e) 3D BIM visualization

Results - Render Web Map

The most important feature of the application is the view of the calculated statistics in the GIS environment. Firstly, in order to access the tool, end user has to either enter the main D^2EPC Web Platform -insert their credentials for authenticated access- and select choose the WebGIS application or simply access it using the provided URL that is provided for the D^2EPC project purposes. The WebGIS front end retrieves the WFS vector layers containing regions and their corresponding features from the OGC Server which in turn has formed the WFS from the data contained in the geodatabase. This data provision is an asynchronous call to the backend. The WebGIS return the vector layers as well as the rest of the application - WMSs for map base layers and HTML components.

Results – EPC statistics visualisation & querying

Following the rendering of the WebGIS map on the client device the services of visualising the EPC statistics and querying are provided. The data are already provided by the sequence of calls to the backend, OGC server and geodatabase. This improves the user experience as it minimizes the application's response times for accessing the requested data. Querying requests take place in the front end of the application avoiding in this way further data transmitting between client and server. The visualisation of the EPC statistics is provided by front end functions and libraries that display data using plots. Apart from the querying function and provision of EPC statistics per selected region, the WebGIS is designed to be switchable to comparison mode where the user can specify two regions to get the correspodning comparison statistics of EPCs. The result is shown using open-source javascript library optimized for such data visualization Lastly, the application provides links to the WFSs coming from the OGC server that can be used for viewing and analyzing data in external GIS tools (e.g. QGIS) and in http client environments.

Results - BIM visualisation

A use-case specific module has been developed with the application, in order to provide the 3D model visualization capability of a selected apartment / dwelling / building (figure 7e). The solution at its current development works with BIM models in. ifcv4 format as it enables the user to 'hover' around the building in a 3D environment.

4. CONCLUSIONS

This paper introduced a novel webGIS concept scheme and briefly presented the different implementation steps for such a tangible operational tool, with minimum open-source and technological dependencies. Several different public organizations and stakeholders could potentially benefit from such a solution. The D^2EPC webGIS offers a generalized, across all EU member states EPC documentation and the functionality of visualizing this information in a uniform manner and on a map, while enabling the extraction of meaningful statistics. EPC registries and governmental institutions could extract significant insights related to building energy consumption and efficiency by analyzing and visualizing spatial data through our solution, while also identify areas of inefficiency, and prioritizing energy-related measures and relevant funding. Our technological solution has been developed exclusively with open-source programming languages and libraries webGIS and presents a diverse set of functionalities ranging from statistics generation and geospatial data handling, to 3D building viewing and BIM files integration

5. ACKNOWLEDGMENTS

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REFERENCES

[1] Sikora, A. European Green Deal – legal and financial challenges of the climate change. ERA Forum 21, 681–697, (2021)

[2] Directive 2010/31/EU, European parliament and of the council of 19 may 2010 on the energy performance of buildings (recast), Official Journal of the European Union, pp. 13–35, (2010)

[3] World Energy Outlook 2022, IEA, Paris, www.iea.org/reports/world-energy-outlook-2022

[4] Magrini, A.,Lentini, G. et al., "From nearly zero energy buildings (NZEB) to positive energy buildings (PEB): The next challenge - The most recent European trends with some notes on the energy analysis of a forerunner PEB example. Developments in the Built Environment", Volume 3**,** 100019, 2020

[5] Hermelink, A. & Schimschar, Sven & Offermann, et al., (2019). “Comprehensive study of building energy renovation activities and the uptake of nearly zero-energy buildings in the EU”. 10.2833/14675, (2019)

[6] A guidebook to European Building Policie: key legislation initiatives. Brussels: BPIE. (2020)

[7] Hong, T., Chen, Y., Lee, S.H., Piette, M.,“CityBES: A Web-based Platform to Support City-Scale Building Energy Efficiency” (2016)

[8] Altmann-Mavaddat, N., Tinkhof, O. M., et al., “Report on Existing Monitoring Initiatives and Databases to Retrofit Action: How European Countries are using Energy Performance Certificate (EPC) Database System”. Retrieved from Deliverable to the REQUEST2ACTION project: https://www.energyagency.at/fileadmin/dam/pdf/projekte/gebaeude/Report_on_existing_monitoring_initiatives_and_databases.pdf (2015)

[9] ETIP-SNET. ETIP SNET Implementation Plan 2021-2024. Brussels: European Technology & Innovation Platforms – Smart Networks for Energy Transition (2020)

[10] Ali, U., Shamsi, M. H., et al.,”A data-driven approach for multi-scale GIS-based building energy modeling for analysis, planning and support decision making. Applied Energy”, 279, 115834 (2020)

[11] Azaza, M., Eskilsson, A., & Wallin, F, “An open-source visualization platform for energy flows mapping and enhanced decision making. Energy Procedia”, 158, 3208-3214 (2019)

[12] Niu, S., Pan, W., & Zhao, Y. “A BIM-GIS Integrated Web-based Visualization System for Low Energy Building Design, Procedia Engineering”, 121, 2184-2192 (2015)

[13] European Commision, CORDIS, Next-generation Dynamic Digital EPCs for Enhanced Quality and User Awareness (31 March 2023) https://cordis.europa.eu/project/id/892984

[14] Koltsios, S, Fokaides, P. et al., “An enhanced framework for next-generation operational buildings energy performance certificates. International Journal of Energy Research. 46. 10.1002/er.8517 (2022)

[15] Kim, S. A., Shin, D., et al.,”Integrated energy monitoring and visualization system for Smart Green City development: Designing a spatial information integrated energy monitoring model in the context of massive data management on a web based platform. Automation in Construction”, 22, 51-59 (2012)

[16] Hay, G.J.; Kyle, C.; Hemachandran, B.; et al.,. “Geospatial Technologies to Improve Urban Energy Efficiency”, Remote Sens. 1380-1405. (2011)

[17] EUROSTAT, NUTS - NOMENCLATURE OF TERRITORIAL UNITS FOR STATISTICS, (31 March 2023) https://ec.europa.eu/eurostat/web/nuts/background

[18] Can, R., Kocaman, S. and Ok, Ali. “A webgis framework for semi-automated geodatabase updating assisted by deep learning”, The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. XLIII-B5-2021. 10.5194, ISPRS, (2021)

[19] Sadoun, B., Al-Bayari, O., Al-Tawara, S., “Open Source GIS Solution: An Overview of the Architecture of Free Open Source Web GIS.”, Jordan Journal of Earth and Environmental sciences, 13(2), pp. 74-81 (2022)

[20] Singh, H., and Bhatia, T. et al., “Web GIS Development using Open Source Leaflet and Geoserver Toolkit”.

9. 29-33 (2018)
[21] La Guardia, M., D'ippolito, F. et al., “Construction of a WebGIS Tool Based on a GIS Semiautomated Processing for the Localization of P2G Plants in Sicily (Italy). International Journal of Geo-Information. 10. 671. 10.3390 (2021)