The EVIDENT Platform: Leveraging Crowdsourcing Approaches for Assessing Consumers Behavior

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Abstract—**Energy efficiency lies at the very core of policy interventions for energy security, energy poverty and climate change, while it also is promoted by technological innovations and investments. However, it seems that these technologies are not adopted by consumers at least to the extent that the assumption of rational behavior would predict. The EVIDENT project aims to study individuals' decision-making process on energy consumption decisions, understand their habits and based on the research's insight propose novel energy policy frameworks. This work aims to present the EVIDENT platform, which is being developed in the context of the project. The platform provides a series of crowdsourcing tools, such as polls, questionnaires, and serious games, trying to understand the behaviour of EU citizens on energy consumption issues and how their behavioural patterns correlate with their financial literacy level.**

Index Terms—**Architecture, climate-neutral economy, crowdsourcing, energy consumption, energy policy, gamification, software design**

I. INTRODUCTION

The record-high energy prices at the end of 2021 and the beginning of 2022 decreased the purchasing power of consumers but without increasing their ecological awareness. The goal of a European Union (EU) climate-neutral economy requires the adoption of new habits and routines from the EU citizens, which are both more eco-friendly and financial-wise. Reducing household energy consumption is one major step towards a climate-neutral economy since the household sector consumes about 25% of the total energy consumption [1]. EU citizens have a crucial role in this objective thus it is important to understand the reasoning behind their preferences and assess the role of behavioural insights regarding their relevant decisions in the energy efficiency spectrum [2], [3].

Under this main concept, the EVIDENT project aims to leverage a wide range of case studies, experiments, surveys, crowdsourcing tools, and randomised control trials (RCTs) in conjunction with state-of-the-art econometric methods and big-data analytics by considering participants' characteristics

to create behavioural models that can interpret consumers' behaviour [4], [5]. By exploiting these behavioural models, along with state of-the-art econometric models [6], [7], EVIDENT will contribute to generating robust estimates and subsequent policy measures for effective policy interventions [8].

A. State-of-Art Overview and Contributions

Crowdsourcing tools, questionnaires, trials, and surveys have been widely integrated into several research projects focused on evaluating the consumers' financial literacy and examining their behaviour with respect to energy efficiency. In more detail, the PROFIT[1] project platform hosts crowdsourcing tools that process financial data and extract and present knowledge to the end user. alsom the plaftorm hosts a number of educational courses and learning material. Moreover, the Start2act[2] platform provides interactive educational material, quizzes, and tools that offer great potential for energy saving. The online platform facilitates a large knowledge base in which visitors may obtain information and tips on energy savings, while also a dedicated forum is deployed where experts address questions regarding energy efficiency. A platform for hosting questionnaires, in which users answer a series of questions related to household appliances, lights, temperature, and behaviour, was developed in the context of the PENNY[3] project. Furthermore, the ENCHANT[4] platform aims to combine the data gathered from implementing various interventions, with a re-analysis of already existing data, in an empirically informed decision tool for impactful campaign design targeting energy efficiency, relevant for a number of public and private actors. Finally, the NUDGE[5] consortium developed a series of smartphone applications designed to

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[1]https://projectprofit.eu/
[2]https://start2act.eu/
[3]https://www.penny-project.eu/
[4]https://enchant-project.eu/
[5]https://www.nudgeproject.eu/

teach users about energy efficiency solutions and provide them with energy savings tips.

Based on the aforementioned descriptions, there are differences among similar existing platforms. However, EVIDENT's strength lies in the highly vast and heterogeneous dataset derived from both field studies and questionnaires, as well as real-time data from smart metering devices. The combination of these two types of datasets is not taken into account in the available platforms when estimating citizens' energy efficiency decisions, which leads to inadequate policy proposals. EVIDENT also involves the addition of other consumer attributes, such as financial literacy, in the analysis. Combining consumer financial literacy with their energy consumption decisions can yield more insights, which can subsequently be used to propose various policy interventions. In this work, we present the design of the EVIDENT platform that was developed within the scope of the EVIDENT research project. In more detail, the contributions of this work are as follows:

- We provide a high-level overview of the EVIDENT component-based architecture and analyze the components.
- We present the entity-relationship model scheme that is used to represent the relationships between the entities of the platform and the flow of information.
- We describe the platform's development and integration process that follows the agile methodology.
- We explain the leverage and exploitation of the platform in the context of the EVIDENT project.

The rest of the paper is organized as follows: Section II presents the EVIDENT platform, while Section III discusses its development and integration process. Furthermore, Section IV explains the utilization of the platform in the scope of the EVIDENT project and, finally, Section V concludes this work.

II. THE EVIDENT PLATFORM

A. Component-based Architecture

The EVIDENT platform aims to provide a unified endpoint (system-as-a-whole) for the resources, services, and tools that will be developed through the project's lifetime. The development of such services requires examining current solutions, identifying the existing needs, and defining the different user roles and their behaviour on different use cases.

Figure 1 presents the architecture that is followed for the development of the EVIDENT platform. It illustrates the flow of information and the connection between the different software components.

The EVIDENT platform follows the modular architecture paradigm, allowing the addition of new features if it is requested, and it has been designed to have two types of users: organisations and participants. The former set up a lab experiment using the services of the platform (questionnaires, polls, etc.) and the latter participate in these lab experiments. The users that desire to organise a lab experiment and use the services of the crowdsource component are authorised by the EVIDENT consortium to act as organisations, after the related request with a short justification via email.
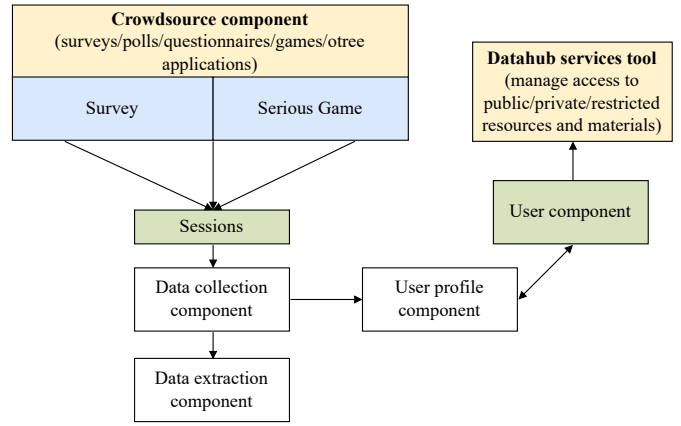

Fig. 1. EVIDENT Platform Architecture

A component-based architecture was selected for the EVIDENT platform, enabling the potential expansion of functionalities in order to host additional services. The architecture consists of five components each one offering a specific service to the end-users, as follows:

- Crowdsource component collects information from the visitors to the platform. It includes the survey subcomponent and the serious game.
- Data collection component compiles the information given from the users, proceeds in their anonymisation, and provides the interfaces for the external use of the collected data.
- Data extraction component processes the collected data and produces useful insights that are used for both commercial and research purposes.
- User component covers all the functionalities that are provided to the platform's users to interact with its services.
- Datahub services provide a repository for all the datasets that are used in the context of the EVIDENT project and for future projects in the field of financial literacy.

The crowdsource component is one of the cornerstone concepts in the EVIDENT architecture, extracting visitors' current behavioural biases on energy consumption habits via surveys, polls, questionnaires, and serious games. The crowdsource component consists of two subcomponents, namely the survey and serious game subcomponents. Through the survey subcomponent, users registered as an organisation can create and edit surveys that can be used within the lab experiments. If published, the new survey can be selected as a distinct step in the context of a lab experiment. The SurveyJS library is used to develop the survey feature in the platform providing an integrated survey creator for in-house data storage. The organisation users will be able to leverage the full functionalities of the SurveyJS library creating dynamic surveys and using them in their lab experiments. Similarly, the organisations can use the serious games subcomponent to upload and edit serious games as a web app in the context of

a lab experiment both as a website and a mobile application.

The subcomponent "Sessions", which enables users to participate ins and engage with the lab experiments, ensures the platform's primary functionalities run without a hitch. The "Data collection component" is a system for organizing and storing the data obtained from users' participation in the lab experiments. The "Data extraction component" can be used by organisations and visitors to extract the collected data from a session or their participation, respectively. The "User component" includes the actions a user can perform regarding her/his account. Based on use cases, a user might want to extract all her/his data the EVIDENT platform has collected for her/him, update her/his personal data processing consent, etc. The component implements the user dashboard and extends the user profile subcomponent and the data extraction component. The "User profile component" provides the mechanism for the user to edit her/his profile such as personal information, platform password, etc. and to leverage the functionalities of the data extraction component to extract the data collected during her/his participation in a session. The datahub services tool will be used as a hub that will host all the data used for the intervention trials (in anonymised form, without exposing any private user information), the econometric analytical tools that will be developed during the project lifetime, and the reports and insights derived from results.

The EVIDENT platform offers a comprehensive method for planning and executing online lab experiments, as it is built on established technology solutions and resources. While the interconnections between the various subcomponents ensure the consistency of the acquired data, the crowdsourcing component coordinates the primary interactions in the platform acting as a consolidated tool for the organisations. To make it simple for each platform actor to export needed data, all developed apps (surveys, serious games, and sessions) and their acquired data should be organised and securely stored in the central EVIDENT database. For instance, if the session includes a survey and a serious game in addition to two different applications, each participant's behaviour and responses should be identified by their respective unique ID within the lab experiment. The difficulty that comes with the crowdsourcing component is creating a development and integration strategy that will enable the platform to materialise quickly and smoothly.

B. Entity-Relationship Model Scheme

The EVIDENT platform is based on an entity-relationship model (ERD). An ERD is a graphical representation that shows relationships between individuals, things, locations, concepts, or events within an information technology system. An ERD employs data modelling techniques to represent the business processes and prepares the basis for a relational database. It offers a visual starting point for database architecture and depicts the flow of information within the information system.

Figure 2 presents the ERD scheme that was followed for the conceptualisation of the EVIDENT platform and used as a basis for the construction of the models. Each entity represents
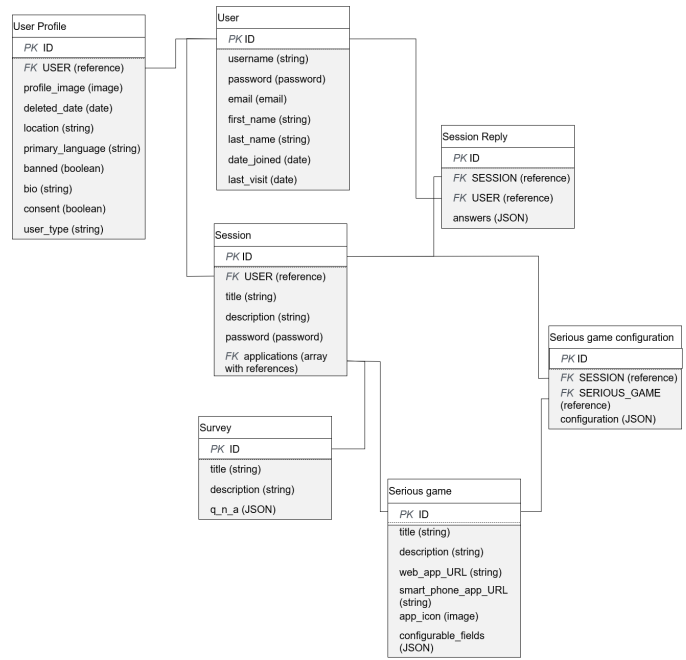

Fig. 2. EVIDENT Platform ERD Scheme

an essential feature for the platform's operation. There are seven main entities as follows:

- User profile – it includes all the fields that are related to the profile of a user such as profile image, deletion date of profile, location, primary language, banned flag, a short bio of the user, consent flag, and user type. It relates to the entity User which has as a foreign key the User's ID.
- User – it is one of the two main entities in the system, and it includes information related to the user. It is connected with the entities User profile, Session Reply, and Session.
- Session – it is the second main entity of the system and is the backbone of the platform. It represents the main functionality of the crowdsource component implementing the lab experiments for the different organisations that are enrolled in the platform. It is connected with the entities User, Session Reply, Survey, Serious game, and Serious game configuration.
- Session reply – it collects the responses for the lab experiments that take place, and it associates them with specific sessions and users.
- Survey – it represents one of the two crowdsourcing applications alongside the serious game. It has four fields: title, description, and q_n_a, and it relates to the entity Session.
- Serious game – it is the second crowdsourcing application, and it is connected with the entities Session and Serious game configuration.
- Serious game configuration – it represents the configurations that every serious game receives on every session. It is connected with the entities Serious game and Session.

III. Development and Integration

The development and integration process follows the agile methodology where the platform is split into several phases for more efficient monitoring allowing constant feedback from the end-users. The core value of the agile methodology is the constant collaboration with stakeholders and continuous improvement at every stage of development. Every development phase includes a process of planning, executing, testing, and integrating into the existing system.

The development of the crowdsource component is the main component of the EVIDENT platform dictating the use of a specific paradigm and programming framework. The different features within the crowdsource component were integrated into the platform without any major issues. However, the datahub and the serious game components are not designed with the same principles as the main platform.

The serious game is a 3D game, designed using Unity, which will help with the research in a more intractable way. The form of the game will be a WebGL (Web Graphics Library) export using Unity and/or an android application. WebGL is a JavaScript application programming interface (API) used for rendering interactive 2D and 3D graphics within any compatible web browser without the use of plug-ins. The WebGL application will run through the EVIDENT platform on the user's browser. The information exchange between the game and the platform come true through JSON files. The communication with the platform is running through HTTP requests and handling HTTP responses. The JSON file's information will initialize the settings of the game, personalizing the game to every user based on his previous answers. Moreover, the user's answers will be saved on a database that will be used for further research.

The EVIDENT team is considering using the Zenodo[6] repository as the primary repository for the data created on the EVIDENT platform. Moreover, Zenodo provides safe archiving and referability, including digital object identifiers (DOIs). The EVIDENT platform will integrate Zenodo to offer the capability to users to develop a set of DOIs corresponding to the Datahub. Likewise, Zenodo has an API and will enable its connection with the EVIDENT Platform. It should also be mentioned that there is a sandbox environment where testing is allowed, and integration tests can be performed during development, where the sandbox environment can be cleaned at any time.

Special focus is given to software testing as a necessary step in software development, and it is defined as the process of evaluating and verifying that a software product or application does what it is supposed to do. Software testing has a twofold aim, first, evaluates the quality and the acceptability of the produced software, and second, discovers problems in the error-prone process of software development. The benefits of designing and implementing a testing plan include the early recognition of bugs, the reduction of development costs, and the improvements in the system's performance.

Each component will be thoroughly unit tested with tools to be defined by the development team. Each subsystem is responsible for updating other subsystems, so after each change, a unit test is developed to ensure the existing system is not affected. The EVIDENT development plan aims to evaluate the functionalities that are developed in each Sprint, minimising the threat of cumulative bugs. The testing process is split into four categories: unit testing, integration testing, system testing, and acceptance testing.

The unit tests allow us to isolate a part of a software application and validate it with no dependencies. Additionally, they don't need access to databases, APIs, or other external information references. They are often executed via code, and they only cover limited aspects of the system. However, giving unit tests isn't always enough to confirm that our program operates successfully. To indicate that all the components of our program work appropriately, communicating and transferring data between them rightly, we use integration tests.

Integration testing validates two or more components of an application at once, including the exchanges between the elements, to specify if they operate as planned. This type of testing expresses weaknesses in the interfaces between disparate components of a part as they gather each other and provide data between themselves. Integration tests are extremely important in service-oriented architectures (SOA) where different components must communicate for the final service to be provided.

The evaluation of the system as a whole takes place under system testing aiming to identify the desired behaviour of the software. Evaluating a system is closer to our everyday life, for example, evaluating a product or system against our expectations that derive from the description of the product. The tests under the umbrella of system testing cover business scenarios validating the proper integration and cooperation with all software components.

Finally, user acceptance testing takes place on the software in order to verify its smooth operation based on the user's needs. User acceptance tests follow the black-box paradigm validating the execution of the system's different features without any interruptions or crashes, ensuring that the user takes the solution; and software sellers often refer to this as 'beta testing', preceding the production release.

The EVIDENT development plan includes a grey testing process for every feature having an identifier ID, the purpose of the test, a description of the test conditions, the values of the input data that the test had, and the outcomes of the test. It is important to keep the same format throughout all the different tests that take place for readability and accessibility reasons. However, black-box testing often takes place from non-expert users browsing the platform, thus it is not realistic or beneficial to ask them to complete formal testing forms.

IV. Usage Scenarios

The EVIDENT platform implements a role-based access control (RBAC), thus, the user role determines the actions each user can implement on the platform [9]. In this respect, four

different user roles have been defined, namely super-admin, organiser (also referred to as "organisation"), participant, and non-registered user (also referred to as "visitor"). Besides the actions a registered user can perform, non-register users can simply view the platform information and a list of the available sessions.

The EVIDENT platform offers a series of functionalities, aiming to create an ecosystem that satisfies different research needs. Three main concepts fall under the umbrella of the EVIDENT platform: surveys, serious game applications, and datahub services. These three services could be combined enabling researchers to create different lab experiments aimed at different audiences. Lab experiment is a research method by which researchers create controllable environments to test hypotheses.

The first step in the design of the platform is the identification of the users that are anticipated with the release of the platform, and their interactions that are expected to be met. Four different user roles are defined: super-admin, organiser (also referred as "organisation"), participants, and non-registered users.

First, as in every service, there are users with full permission, limited to the specific consortium members that have system administrator knowledge, named super-admins. This type of users monitors the operation of the platform, secures access to the platform, and ensures the smooth operation of the services. The number of super-admin users is limited for security reasons.

The organisers are key personnel from an organisation that want to use the EVIDENT platform to design and implement a series of lab experiments. During the development phase of the platform, only the academic partners of the consortium will have this role of exploring the platform and providing their feedback to the development team. After the completion of the platform, the organisations interested in designing and implementing an experiment will communicate with the consortium and after reviewing the request, the access will be granted. The reviewing process is a necessity for the first releases of the platform because the platform needs to maintain its research orientation aiming at high social impact.

The participants are individuals (e.g., students, consumers) who participate in the experiments that have been created and are managed by the organizations. They participate in the platform to gain knowledge in financial literacy and improve their decision-making process on energy consumption issues. Usually, they belong to a specific pool of people (e.g., urban residents).

The different actors are expected to proceed in specific actions in the platform to achieve their objectives. These actions are called use cases and they are defined as a list of actions or event steps that define the interaction between an actor and a system to achieve a goal. The use cases of the EVIDENT platform are presented in the format of tables providing all the necessary information to be understood, modelled, and eventually implemented.

TABLE I
USE CASE SCENARIOS

Use case	Brief description
Register as an "organisation"	An organization can register to the EVIDENT platform and use it to design and implement a controlled lab experiment (e.g., universities, energy companies, policy makers etc.)
Register as an "participant"	An individual can register to the EVIDENT platform and participate in active lab experiments.
User login/logout	The user can login/logout to/from the EVIDENT platform and use its services
Manage user profile	The user can update her/his profile
Delete user account	The user can update delete her/his account in the EVIDENT platform
Reset password for user	User can reset her/his password through the "Forgot your password?" option on the login page
Export user profile data	The user can export all her/his profile data, data stored in the EVIDENT's database.
Update user demographics	The user can update essential information about her/his demographics.
Create a new survey	Superadmins and Organisations can create and implement a lab experiment. An experiment can contain one or more "survey" and "serious game" applications. The actor creates a "survey".
Update a survey	The actor updates an existing "survey".
Delete a survey	The actor deletes an existing "survey".
Upload a new serious game	Superadmins and Organisations can create and implement a lab experiment. An experiment can contain one or more "survey" and "serious game" applications. The actor uploads a new "serious game".
Update a serious game	The actor updates an existing "serious game".
Create a new lab experiment	Super-admins and Organisations can create and execute a lab experiment. An experiment can contain one or more "survey" and "serious game" applications. The actor creates a new "lab experiment".
Edit an existing lab experiment	Super-admins and Organisations can create and execute a lab experiment. An experiment can consist of one or more "survey", one or more "serious game". The actor creates a new "lab experiment".

TABLE I
USE CASE SCENARIOS (CONTINUED)

Use case	Brief description
Delete a lab experiment	The actor deletes an existing "lab experiment".
Configure a serious game for a Lab Experiment	The actor configures an existing "serious game".
Participate to a lab experiment	The participant selects a published or protected lab experiment to participate.
See scoreboard	The participant checks the collected points for her/his participation in a serious game.
Inspect participation in a lab experiment	The participant participates in a published or protected lab experiment and after her/his participation she/he selects to inspect her/his answers.
Export user answers from a lab experiment	The participant participates in a published or protected lab experiment and after her/his participation she/he exports her/his answers to a supported format file (CSV/xlsx/JSON, etc.).
Collect answers from a lab experiment	The actor can collect/export all participants' answers from a lab experiment that she/he has created.
Share a lab experiment	Actors can share a lab experiment on social media or via email.

Twenty-four use case scenarios, as listed in Table I, providing the consensus around the use of the platform and assisting in the design and development of the platform. Moreover, the sitemap of the EVIDENT platform is presented in Fig. 3, while Fig. 4 depicts an example of a user's participation in a survey.
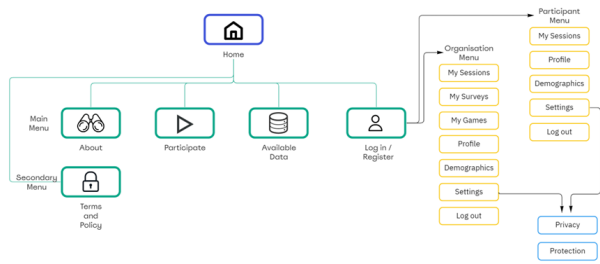

Fig. 3. EVIDENT Platform Sitemap

V. CONCLUSION

In this work, we presented the design of the EVIDENT platform that was developed within the scope of the EVIDENT research project. A component-based approach was adopted
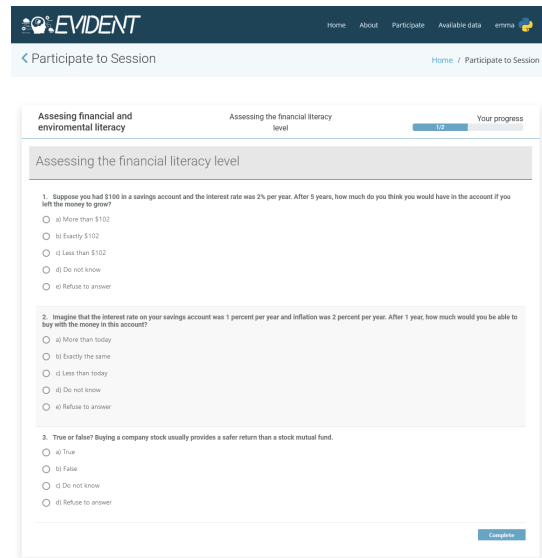

Fig. 4. Example of a user participating in a survey

for the architecture design, while the development and integration of the components followed the agile methodology. The platform hosts a number of crowdsourcing tools aiming to collect large volumes of datasets, which, combined with real-time big data analytics, will generage useful insights that can be levereaged for proposing policy interventions.

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