SOCIALENERGY: A Gaming and Social Network Platform for Evolving Energy Markets' Operation and Educating Virtual Energy Communities

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Abstract— **Technology transfer of gamification assets to non-leisure contexts such as the energy efficiency sector has become the "holy grail" of today's research and industrial efforts towards a more sustainable energy system. In the liberalized retail market context, electric utilities are gradually adopting new business models towards transitioning their conventional energy supply business to a more service-oriented model. This paper presents the H2020-funded SOCIALENERGY project, which develops a gaming and social network platform for educating energy consumers and virtual energy communities towards evolving EU energy markets' operation. The proposed S/W platform is modular by design and facilitates the easy, rich and deep communication among involved stakeholders from individual energy consumers and virtual energy communities, to utilities, policy makers, and even other indirect stakeholders (such as electric appliance retailers and building renovators) that will allow them to: i) discover each other, ii) educate themselves in order understand the difficulties and challenges that each one faces, and iii) finally interact and trade among. A serious game for energy efficiency, advanced research algorithms and data analytics as well as a novel competence-based education framework complement the SOCIALENERGY project's innovations.**

Keywords—virtual energy communities; behavioral change; green social network; demand response; digital electric utilities

I. INTRODUCTION

The integration of Information and Communication Technologies (ICTs) in the energy sector is currently boosting the transition from an asset-centric sector to a consumer-centric one, by enabling new business models, services and processes. At the retail energy market side, electric utility companies are gradually following the 'digitization' path towards providing more and innovative energy services to their clients [1] [2]. This digitization trend is expected to enhance the active participation of consumers along the energy value chain, thus changing the nature of consumer engagement across the customer life cycle. Whether to educate consumers, sell a variety of customized energy programs and products, encourage self-service or create value with new services, digitization should be considered as part of every progressive utility's initiative [3].

Disruption in the energy sector becomes a reality, when the confluence of three main forces, namely the: 1) regulatory and policy shifts, 2) changing market demand, and 3) technological innovation, undermine long-standing value chains. In particular, technologies that can slice through pre-existing layers of regulatory processes and business models to directly connect customers to the goods and services they seek are gaining traction across global markets. The utility industry currently faces a perfect storm of all these three forces [4].

Regarding (1), new rules for the retail electricity markets include the following: a) consumers will be provided with detailed information about their energy consumption and their costs through clear electricity bills, b) switching conditions will be made easier, while all switching related charges will be prohibited, except for early termination fees on fixed term contracts, c) consumers and communities will be empowered to actively participate in the electricity market, d) every consumer will be able to offer demand response (DR) and receive remuneration, directly or through DR aggregators. Dynamic electricity price contracts reflecting the changing prices on the spot or day-ahead markets will allow consumers to respond to price signals and actively manage their consumption, e) future electricity markets will be able to send clear price signals and will be free of any public intervention, unless with duly justified exceptions, notably to protect vulnerable and energy poor consumers, for example through the use of social tariffs [5].

As of (2), utility business models are gradually being transformed from supply- to service-based. Rather than

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focusing purely on the delivery of grid-sourced power, energy service providers (ESPs) offer personalized products and services to suit their customers' specific needs. These services include DR and dynamic pricing programs, energy efficiency initiatives, gamification/user engagement/educational features, which will be offered to the end user via a user-friendly web interface and/or transactive energy (TE) platforms [6].

Finally, regarding the technological innovation force, the resulting new business models require new IT infrastructure that relies heavily on the analysis of huge volumes of data. As a result, sophisticated research algorithms (i.e. artificial intelligence, IoT, etc.), data analytics (i.e. advanced profiling, recommendation, etc.) and online optimization tools need to be integrated in the novel S/W platforms mentioned above.

A. State-of-the-art on utility's behavior change programs

Nowadays, utilities and regulators increasingly rely on behavior change programs as essential parts of their demand-side management portfolios. In [7], three major categories of utility's behavior change programs are identified, namely: 1) information-based, 2) social interaction-based, and 3) education-based.

TABLE I. CATEGORIZATION OF BEHAVIOR CHANGE PROGRAMS

Category	Program	Description
Information-based	Home energy reports	Periodically sent to residential customers with feedback about energy use, tips, rewards, etc.
	Real-time feedback	About real-time energy use via dashboards, web interfaces, etc.
	Energy audits	Done online or in person (personalized evaluation of energy use in a home)
	Persuasive messaging	Written communications that use behavioral insights
Social interaction-based	Games/ competition	Try to achieve the highest rank compared with other individuals/ groups or reach game goals by reducing energy consumption
	Community based	Community-based social marketing, innovative community outreach strategies
	In-person strategies	Opinion leader, foot-in-the-door technique, public commitment, goal setting, guided group discussion, etc.
Education-based	Strategic energy mng	Train building managers, energy experts, etc.
	Training	Vocational, non-school-based education/training, etc.
	School/ university	K-12, college, campus, education of students on energy efficiency

In table I, a brief description of all today's behavior change programs for utilities is provided. The vision of the proposed SOCIALENERGY S/W platform is to use most of the above-mentioned state-of-the-art practices towards delivering a complete and really innovative framework for developing behavioral change programs for progressive utilities of the future.

B. Contribution points

The contribution points of the proposed SOCIAL-ENERGY system can be summarized as follows:

- A Green Social Response Network (GSRN) concept and S/W platform is proposed, which is able to integrate almost all of the state-of-the-art behavior change programs (i.e. information, social, education) in a user-friendly way.
- A hybrid DR strategy is adopted (i.e. combination of price-based and incentive-based DR) via the use of advanced user engagement and incentivization techniques.
- Behavioral economics' models are adopted for the creation, dynamic adaptation and management of virtual energy communities (VECs).
- The self-evolving SOCIALENERGY game integrates all mathematical modeling and algorithms' intelligence and is customizable by design to emulate the conditions of a real residential home as close as possible.
- A competence based educational (CBE) framework is introduced aiming to create the best 'individual learning plan' (ILP) for each individual SOCIALENERGY user and subsequently guide him/her through the whole online learning process.

The residual paper is organized as follows: Section II analyzes the requirements of an innovative S/W platform operated by an ESP with respect to its high-level business objectives. Moreover, the perpetual information flow and lifecycle of the proposed system is explained. Section III presents the SOCIALENERGY architecture, while in Section IV, the novelty features of all S/W components are described. Finally, Section V concludes by providing some interesting R&I insights for future work.

II. REQUIREMENTS' ANALYSIS OF AN INNOVATIVE S/W PLATFORM OPERATED BY AN ENERGY SERVICE PROVIDER

Retail markets suffer from persistently low levels of competition and consumer engagement. Despite technical innovation such as smart grids, smart homes, self-generation and storage, consumers are not sufficiently informed nor incentivized to actively participate in electricity markets. It thus prevents consumers from controlling and managing their energy consumption, while saving on their bills and improving their comfort.

The high-level business strategy objectives of a progressive ESP can be summarized as follows [2] [3] [5]:

- Obj. #1: Build and strengthen a strong core of digital trust ensuring that customers view the ESP/utility as trusted advisor (not just de facto bill sender), which creates a

deeper relationship with the customer that, in turn, increases customer satisfaction and minimizes churn rate.

- Obj. #2: Move from services to experiences with a cohesive personalization strategy (e.g. game, gamification, personalized e-learning, etc.).
- Obj. #3: Personalize at scale via the use of advanced research algorithms. Combine the best of both worlds, i.e.: a proven data analytics platform with a tailored customer experience (i.e. not only automatic or manual processes but a hybrid approach according to the context).
- Obj. #4: Exploit the deep insight into energy use consumption to engage customers on cross-sell options that fit their needs, resulting in new revenue streams (e.g. this can be achieved with strategic collaborations with other energy service companies or companies mainly active in other business sectors).
- Obj. #5: Use rapid prototyping (i.e. modular and customizable S/W platform) to cope with the various, diverse, volatile and dynamically changing needs of the liberalized energy market.

A. SOCIALENERGY and GSRN concept and approach

Taking into consideration the above-mentioned objectives, the proposed SOCIALENERGY S/W platform has been designed in such a way that it:

- Is 'modular by design', in order for each ESP/utility to be able to customize its own S/W platform based on the business strategy and the type of its customer portfolio's needs (cf. Obj. #5).
- Can be used by multiple types of users and stakeholders (i.e. end consumers/prosumers, VEC leaders, ESP user, ESCO user, etc.) in order to facilitate the easy, rich and deep interaction among all involved stakeholders.
- Allows the user to be seamlessly educated in the virtual world (i.e. game) and then apply the lessons learned in the real world (cf. Obj. #2).
- Educates the user based on a competence-based education framework that progressively and sustainably engages the user via the use of ILPs.
- Allows users to interact with each other, create VECs with a bottom-up manner, purchase various community energy programs (EPs) and other innovative products at a community level.
- Supports intelligent functionalities for the automation of the various complex processes via the operation of algorithms (e.g. artificial intelligence, dynamic pricing, machine learning, big data analytics, context-aware recommendations, etc.).
- Secures the insight needed to help customers make smart energy use choices and offers new products and services that help customers optimize their bills.
- Combines automation with manual interaction with the user. Therefore, social and behaviour analytics considerations will periodically inform social innovation and guide technology-oriented activities.
- Facilitates a virtual/online marketplace, where a diversified set of products and services can be purchased by the end user. For example, a residential consumer can use his/her SOCIALENERGY credits to purchase a more energy efficient electric appliance or upgrade/renovate his/her home (cf. Obj. #4).
- Is interoperable with a DSO's distribution management system (DMS) taking into consideration the physical underlying network's needs and constraints. It can also be upgraded to a transactive energy (TE) platform for peer-to-peer energy trading in the future.

In Fig. 1, the general idea of the proposed "Green Social Response Network" (GSRN) concept is illustrated. There are three main gamification steps: 1) gamify the user engagement in DR and energy efficiency programs, 2) gamify the process (e.g. VEC management), and 3) gamify the results and feed them back to step (1). As depicted in the figure, there is a perpetual information and knowledge flow among the 3 gamification steps in a way that all types of users (i.e. individual energy consumers, VEC leaders, electric utilities, ESCO users) are continuously educated towards understanding their role in the smart grid market/ecosystem and the needs/interests of all other related market stakeholders in a liberalized electricity market context. The proposed GSRN is "Green", because it facilitates and enables the use of clean energy and good practices on energy efficiency focusing on the residential sector. It is also "Social", because its users are able to participate in virtual/online energy communities and communicate with other peers, who have the same interests or even communicate with other commercial stakeholders understanding better their needs/interests. Finally, GSRN is also "Response Network", because it enables/facilitates efficient DR procedures to take place and motivates the individual energy consumers to change their behavior in the way that they consume energy in their everyday lives. The result of this process will ultimately lead to environment-friendly use of energy resources, the efficient operation of liberalized electricity markets and the realization of new businesses and revenue streams from both new and existing smart grid market stakeholders correspondingly.

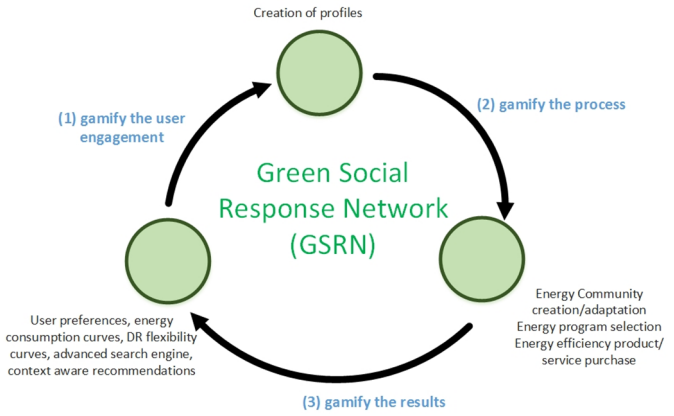

Fig. 1. Green Social Response Network (GSRN) concept

III. SOCIALENERGY ARCHITECTURE

Fig. 2 presents a high-level architecture design of SOCIALENERGY system, which comprises of six S/W components (subsystems), namely: 1) Meter Data Management System (MDMS), 2) the core GSRN S/W platform or else SOCIALENERGY's real world, 3) Energy Efficiency GAME or else SOCIALENERGY's virtual world, 4) Research Algorithms' Toolkit (RAT), 5) Learning Content Management System (LCMS), 6) Energy Information Distribution as a Service (EIDaaS) or else virtual marketplace.

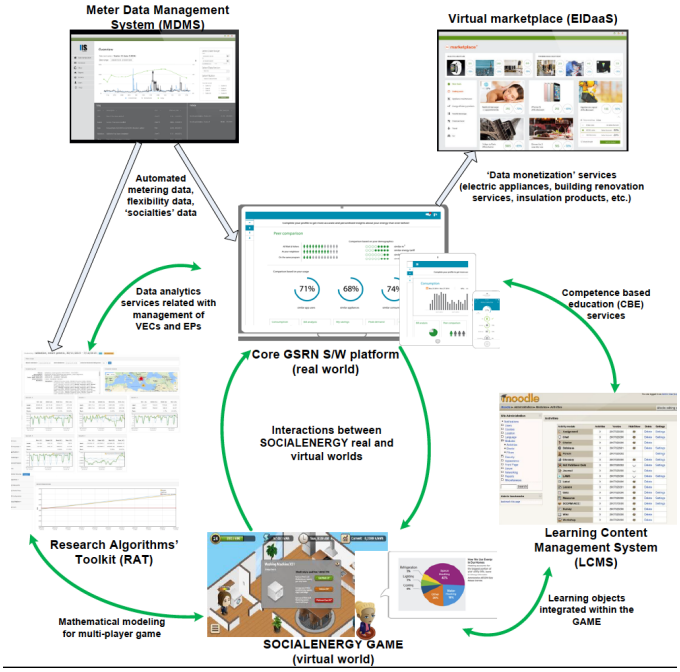

Fig. 2. High-level architecture design of SOCIALENERGY system

In MDMS, all energy consumption related data is collected. MDMS actually serves as SOCIALENERGY's database, where all energy-related data models are also available (e.g. electric appliance consumption models). The datasets that will be used for SOCIALENERGY purposes come from real energy consumers of various types (e.g. residential vs. commercial, high vs. low educational level, different locations/countries, etc.). This energy consumption data is made available in various time granularities.

The GSRN is the core S/W platform of the SOCIALENERGY system, in which all types of SOCIALENERGY users (e.g. individual consumers, VEC leaders/managers, electric utility/retailer user, ESCO user, etc.) are able to log in and visualize/experience many innovative functionalities. GSRN has technical interfaces with all other five (5) subsystems integrating several multi-disciplinary functionalities ranging from the scientific/research sector (cf. RAT) to the gaming/gamification sector (cf. GAME) and the educational sector (cf. LCMS). GSRN is also being fed with real-life energy consumption data from MDMS. It also offers EIDaaS-like services to various targeted stakeholders such as building renovation companies and electric appliance vendors/retailers, who aim at indirectly exploiting SOCIALENERGY system's operation towards realizing new revenue streams for their businesses, too.

The SOCIALENERGY GAME will be played by the user in a range of platforms starting from a basic web-based implementation and possibly being extended to a mobile application, too. After the SOCIALENERGY user (i.e. individual consumer) is logged in the GSRN, s/he uses the same credentials to download the game and start the gameplay. The GAME is an applied game on energy efficiency, combining characteristics by both serious games and classic entertainment industries. The player creates/enters a virtual world (i.e. virtual house) with all electric appliances and tries to maximize the energy efficiency KPIs by striking to find an optimal trade-off between the energy cost and the discomfort incurred through the load shedding and shifting. Via the gameplay, the user is seamlessly educated in best practices about energy efficiency and this is done in an enjoying manner. Furthermore, the users can customize the GAME's settings and create a virtual environment that is similar to their real house. As a result, GAME can also serve as a (near) real-life testbed to help in quantifying user's behaviour change through time, which is very important from both a research and commercial exploitation point of view. It should be noted that the GAME is also interacting with the RAT (by integrating all sophisticated mathematical modeling, which provides the basis for the GAME's long-term success in the market). GAME also incorporates references to educational material (e.g. in the form of small pop-up windows) that the users can find in the LCMS and search for more details therein.

The RAT subsystem is very important for SOCIALENERGY's operation because it provides all the intelligence that is required towards making SOCIALENERGY S/W platform competitive enough and commercially successful in a sustainable manner. It provides "data analytics" services mainly to GSRN, but also to the GAME (by integrating the sophisticated mathematical modeling mainly in the energy pricing and score calculations). Various research algorithms are executed regarding the dynamic pricing models that are adopted in the various innovative Energy Programs (EPs) and the Virtual Energy Communities' (VECs) creation and dynamic adaptation algorithms, which are required for the online management of the virtual energy communities. RAT also provides context-aware recommendations to GSRN and is also a toolkit to be used by the system administrator for business/strategy analysis by running various simulations (i.e. 'what if' scenarios).

LCMS is the subsystem, where the user/player educates herself/himself both online and offline to consolidate the new knowledge about good practices on energy efficiency. LCMS interacts with GSRN. Thus, the latter can provide recommendation services to the user according to the educational content that is mostly keen on watching next based on her/his current educational profile and experiences in both SOCIALENERGY's real and virtual worlds. The role of the LCMS is important because it provides the user the opportunity to better comprehend the new concepts in the liberalized smart grid markets and inter-relate the "lessons learned" from the

GAME with the real-life conditions in order to be able to efficiently interact with her/his electric utility/retailer.

Finally, via the EIDaaS S/W component, SOCIALENERGY bridges the gap between energy consumers and companies as well as among multiple other stakeholders related to the energy efficiency sector. Using the SOCIALENERGY platform, the profile of each energy consumer is created (e.g. energy consumption history, social networking activities, commercial actions' history, etc.). This profiling information could be exploited from stakeholders in order to: i) design energy efficiency products and services more appealing to their audience, ii) allow VECs to participate in the design by giving their opinions, iii) exploit VECs as cells within which they will enable group trading, and iv) generally sell Energy Information Distribution as a Service (EIDaaS) to whom it may concern in the long-term future. SOCIALENERGY has created an API through which it can commercialize this idea of "data monetization" service. Moreover, the virtual marketplace module can host products and services from electric appliance vendors/retailers, building renovation companies, etc., so the user can have an end-to-end experience towards achieving his/her energy efficiency targets.

IV. FUNCTIONALITIES PER SUBSYSTEM

In Table II, the main innovation points per SOCIALENERGY subsystem are presented. In the following subsections, the basic S/W modules and respective functionalities of each major SOCIAENERGY subsystem are described.

A. Core GSRN S/W Platform

GSRN includes the following S/W modules: a) e-learning/training, b) rewarding mechanism module, c) data analytics/visualization module, d) energy module, e) user profiling, f) gaming profile module, and g) 'socialties' module.

'E-learning/training' module is responsible for the integration and visualization of all educational material and relevant interactions coming from the GSRN-LCMS API. The rewarding mechanism works at the backend and computes the individual points for all users' activity in the GSRN. It also connects to the GAME-API in order to feed the *'User Profiling'* module with game leader-board and relevant points from the user's game performance. The mechanism will be flexible to the administrator to set up the point system and the redeemable points, based on users' stage, points and performance. Points will have two categories: Actual points and Experience points, indicating activity engagement and knowledge engagement.

GSRN's '*Data Analytics*' module visualizes all RAT-API outputs and provides a visualized KPIs' dashboard to the users to check their overall performance. *'Energy module'* is connected to the MDM-API and RAT-API in order to visualize real energy consumption from users' meters and billing information respectively. *'Gaming profile'* module connects directly to the GAME-API and gets all relevant details from the game, regarding each specific user. User will get badges, leader board, performance, stages, points and all available GAME-API inputs. Finally, *'Socialties'* module is also working at the backend and is used to get user's social network information, as the user logs in the system. It is also combined with all other modules to provide personalization and further analytics.

B. SOCIALENERGY Game

The Game exchanges data with all other subsystems through GSRN. It receives user profile data, recommendations and dynamic pricing models. Then, it processes them for player login and gameplay and produces statistics and game results. The statistics and results of gameplay are made available to all other subsystems via RESTful APIs. The *'Game Loop (GL)'* module is the game as such. It includes the game interface, gameplay and controls. It gets the gaming profile from the *'Gaming Profile Administrator'*, prices from *'Price Administrator'* and learning content from *'Learning Manager'*. GL is also responsible for processing the information about the appearance of user's virtual house.

C. Research Algorithms' Toolkit (RAT)

From the GSRN S/W platform's web interface, the utility/ESCO user (i.e. system administrator) is able to select the "RAT" tab and then a new window navigates him/her to the RAT's functionalities. As already described above, RAT includes all the SOCIALENERGY's intelligence, which is realized via the GSRN-RAT interface. In particular, there is a RESTful API, from which the RAT gets the GSRN and LCMS score for each individual user and/or VEC either instantly or periodically. Historical data can also be acquired at various time granularities and timeframes. Via the GSRN-RAT interface, RAT receives all social, demographic and personal preferences data for each user and energy community. Moreover, the LCMS-related score is also acquired by RAT. Then, the VECs' creation algorithms module is able to create and possibly adapt the structure of the VECs when needed. Regarding the RAT-GSRN interface, the GSRN gets the energy costs, energy/money savings per user according to EP involved to be used for GSRN credits' distribution policies.

Within *'dynamic pricing algorithms'* module, the ESCO/utility user will be able to: 1) Select a specific consumer or VEC and visualize the financial savings comparing all the available EPs. The most beneficial EP could then be recommended to this individual consumer or VEC, 2) Run simulations with various customizable parameters to realize the pros and cons of each EP, 3) Run real-life experiments with users, who have agreed to switch to a more beneficial EP. The basic EPs integrated in RAT are: i) fixed pricing, ii) Time-of-Use pricing, iii) Real-Time Pricing (RTP), iv) Personalized RTP (P-RTP), and v) Community RTP (C-RTP). The user is able to insert inputs such as: cost of energy purchased by ESP in the wholesale market, user's flexibility, and actual Energy Consumption Curve (ECC). Then, the user selects the EP/algorithm to run and finally the main outputs (KPIs) are system's cost of energy, aggregated users' welfare and total welfare.

A pricing scheme has to fulfill several requirements (by achieving an attractive trade-off) that concern: i) the end user's satisfaction (*user's welfare*) [8], ii) the stability of the

energy production/transmission/consumption system (*behavioral efficiency*) [9], and iii) the ESP's financial profit margins (*profit dynamics*) [10].

D. Learning Content Management System (LCMS)

The *'ILP module'* receives the created ILP from GSRN for each individual user. The ILP is based on the SOCIALENERGY competences' framework, realized, fully supported, and served by the LCMS. On the base of the ILP, this S/W module creates a set of learning objects (courses or learning resources/activities), covering the required competences in the learner's ILP, which later on the system will offer to the learner. The *'learning assessment'* module supports various modes of assessment of learner's knowledge and competences like quizzes, tests, tasks, etc. with clear and transparent rules for grading. Competency-based assessment is supported by grading related to activities, where students demonstrate the relevant competencies.

TABLE II. MAIN INNOVATIONS PER SOCIALENERGY SUBSYSTEM

Name	Main Innovation
GSRN	- combination of various external components on a unified dashboard
	- personalized product scoring system
	- context-aware reporting/recommendation
	- virtual marketplace and interaction with many diversified market stakeholders
GAME	- mathematically modeled to emulate real conditions of a liberalized energy market, where an optimal trade-off between energy cost and comfort should be achieved
	- multi-player serious game for virtual energy communities
	- use of self-determination theory to address the satisfaction of basic psychological needs for relatedness, autonomy and competence
	- directly integrated in a utility's digital platform targeting more customers and having a clear target group
RAT	- dynamic pricing algorithms (i.e. personalized real-time pricing, community real time pricing, etc.).
	- Multi-parametric creation, dynamic adaptation and management of VECs
	- advanced data analytics to be used for business analysis and decision making
LCMS	- customization and personalization of the educational content to the end-users' needs
	- competence-based learning is based on ILPs, connecting learning content to relevant competences, needed for an end user, as measurable outputs of the learning process.

V. R&I INSIGHTS AND FUTURE WORK

SOCIALENERGY aims to constitute the platform that will not only mediate the future energy market, but also will harmonize demand and production in it through its very innovative and advanced features like the game, the support of sophisticated research algorithms for dynamic energy pricing and management of VECs, and the development of LCMS, which will guarantee the long-term user engagement and continuous learning of good practices on energy efficiency.

Regarding the further exploitation of SOCIALENERGY's concepts, several research and innovation insights come in the foreground, such as:

- Cyber-physical interaction between the real and virtual worlds may be elaborated via the use of a mixed/ augmented reality application.
- Elaborate more on the advanced variants of P-RTP and C-RTP models to include RES and storage assets as well as enhanced 'peer pressure' models for the social interactions among the VEC members.
- Extend the proposed virtual marketplace module to involve as many stakeholders as possible.

Finally, SOCIALENERGY can be used as a S/W component of a future TE platform by providing built-in analytics and advanced scheduling algorithms that automatically decide the right time for a customer's system to use, export, or store self-generated electricity, depending on current and projected future spot prices as well as the customer's preferences.

ACKNOWLEDGMENT

The work presented in this paper received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 731767 in the context of the SOCIALENERGY project.

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