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Developing a Business Case for a Renewable Energy Community in a Public Housing Settlement in Greece—The Case of a Student Housing and Its Challenges, Prospects and Barriers

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Abstract: Democritus University of Thrace (DUTh) has formed, under the European Project Renaissance (Renewable Integration & Sustainability in Energy Communities, HORIZON 2020, GA 824342), a virtual Renewable Energy Community (REC) in Greece located nearby Kimmeria at the northeast of the city of Xanthi, at the North-eastern Greece. The REC formed is the first energy community designed in a public housing settlement in Greece and its members are: (a) the Democritus University of Thrace, (b) the Municipality of Xanthi and (c) a local industry. DUTh's main objective is to explore, leverage and mobilize stakeholders to apply schemes for a social group of end users (i.e., students from low-income families) in order to participate in the operation and management of a local renewable energy community, gaining also non-financial benefits. This paper presents the business case scenario and the market players evolving at an Energy Community which includes a public establishment of student residences in Greece.

Keywords: renewable energy community; social housing; smart contract

1. Introduction

As renewable energy (RE) technologies become cheaper and more efficient and hence theoretically more attractive to be adopted, conditions for negotiation occur as households and communities become both producers and consumers [1–5]. The participation of citizens and communities as active players in energy projects is transforming the energy system. Community energy initiatives offer new opportunities for citizens to get actively involved in energy matters. Evolving from this phenomenon, a number of diverse and innovative community ownership arrangements have emerged. "Community energy" or "community-owned renewable energy" (CRE) is one such novel development. Many of the groups which produce and consume CRE have goals embedded within local and immediate needs, often beyond environmental aspirations and towards broader social justice goals [1,6]. CRE can potentially play a transformative role in shaping controlled energy systems more democratically [7], varying from traditional arrangements (based primarily on capitalistic relationships), and creating an active "prosumer" energy public [8,9]. Although, due to cost issues, there are strong trade-offs between ensuring sustainable and affordable living situations, particularly for low-income groups. Community energy can foster citizens' participation and control over decision-making in renewable energy. On the other hand, public housing provision recognizes housing as an integral right, aimed at those unable to enter the traditional housing market [10]. Low-income housing associations provide a unique opportunity for renewable energy installation, not only through potential scale of implementation sites, but also in reducing social and financial costs to tenants [10–14]. Community's energy social innovation potential also resides in the ability to integrate consumers independently of their income and access to capital, ensuring that the benefits of decentralization are also shared with those that cannot participate, releasing the creative forces of social innovation and sustainable lifestyles across different social groups, alleviating their energy poverty.

However, research has rarely combined the two concepts of CRE and public housing, despite a growing interest in the prospective merits of applying energy strategies to social housing arrangements (including both generation technologies and energy efficiency retrofitting), and the facilitatory role that community engagement techniques (both the social housing tenant community and broader community) can play in shaping the success of such energy strategies [15–17]. The aim of the current research is to: (a) explore the challenges, prospects and barriers of implementing an energy community in the context of public housing in Greece, (b) design an incentivization scheme for promoting and maximizing the utilization of RES and (c) develop business case scenarios for the various players involved in the energy community. The following sections, an overview of the approaches that prevail in the creation of an energy community in a public housing at global, European and especially national (Greece) level is attempted, pointing out the opportunities, prospects and barriers that arise on a case-by-case basis. At the end with the conclusions of the current work an attempt is made to inform and identify paths for future policy implications and research initiatives.

2. Social Housing and Renewable Energy Community

2.1. An Overview of the Current State

One of the first officially recorded attempts to form a cooperative took place back in 1844 in Rochdale, United Kingdom. The initiative of the "Rochdale Pioneers" [18] was the trigger for the creation of the International Alliance of Cooperatives (ICA) in 1895 which continues its work to this day. The concept of the cooperative is defined as on the ICA website [19]: "a cooperative is an autonomous association of persons united voluntarily to meet their common economic, social, and cultural needs and aspirations through a jointly owned and democratically-controlled enterprise" and is governed by seven principles: a. Voluntary and Open Membership, b. Democratic Member Control, c. Member Economic Participation, f. Autonomy and Independence, e. Education, Training, and Information, f. Cooperation among Cooperatives, g. Concern for Community. Since then and until today the idea of the cooperative has been applied in various sectors of society and more recently in the case of energy communities, which is the focus of this article, along with its relevance to social housing conditions.

Social housing became an important issue for European countries after World War II. Over the years, social housing took a different meaning and was approached in various ways by European countries. Several studies [1,2,10,20,21], show that the most common type of social housing is the social rental type. Denmark and Sweden make it possible for almost all of their citizens to have access to quality social housing. The UK and the Netherlands are also highly engaged in providing social housing in a large number of their citizens and have been for the past years the "study case" of many researchers. There is also the type of social housing that was provided by the former socialist countries. The social housing stock consisted of large blocks of flats and was solely governed by the state. In the present years this social housing system is undergoing a transition. Lastly, there are countries like Belgium and Norway where housing is mostly individually/privately owned, countries like Germany and Switzerland where there is mostly private renting and Mediterranean countries where homeownership was promoted even for social housing by means of subsidies.

The European Union (EU) in order to promote the use of energy from renewable sources issued in 2009 the Renewable Energy Directive 2009/28/EC [22]. More recently, recognizing that citizens and communities have the right to play an active role in producing energy, issued in 2018 the Revised Renewable Energy Directive 2018/2001/EC [23]. In this Directive energy communities are defined and referred to as "Renewable Energy Communities" (RECs). According to the Directive, 'renewable energy community' is defined as a legal entity (a) which, in accordance with the applicable national law, is based on open and voluntary participation, is autonomous, and is effectively controlled by shareholders or members that are located in the proximity of the renewable energy projects that are owned and developed by that legal entity; (b) the shareholders or members of which are natural persons, SMEs or local authorities, including municipalities; and (c) the primary purpose of which is to provide environmental, economic and/or social community benefits for its shareholders or members or for the local areas where it operates, rather than financial profits. There is one more form of energy community that is introduced and defined in the Revised Internal Electricity Market Directive 2019/944/EC [24], the "Citizen Energy Community" (CEC). According to this Directive 'citizen energy community' is defined as a legal entity that: (a) is based on voluntary and open participation and is effectively controlled by members or shareholders that are natural persons, local authorities, including municipalities, or small enterprises; (b) has for its primary purpose to provide environmental, economic or social community benefits to its members or shareholders or to the local areas where it operates rather than to generate financial profits; and (c) may engage in generation, including from renewable sources, distribution, supply, consumption, aggregation, energy storage, energy efficiency services or charging services for electric vehicles or provide other energy services to its members or shareholders. In support of the above, the European Commission's Clean Energy for All Europeans Package confirms the prominent role prosumers, and their collective forms will play in the future energy system. The legal structures that energy communities possibly have are:

- Energy cooperatives
- Limited partnerships
- Community trusts and foundations
- Housing associations
- Non-profit customer-owned enterprises
- Public-private partnerships
- Public utility companies

2.2. Benefits, Challenges and Prospects

Renewable Energy Communities (RECs) including Social housing (SH) is gaining the interest of energy researchers because of the affordability and the increased efficiency of renewable energy technologies [2]. Renewable Energy Communities (RECs) formed with social housing end users can reduce energy costs but can also systematically generate surplus energy that can be traded in the energy markets. Other motivational factors for installing RE in social housing establishments include the increase of environmental sustainability and controllability of the energy use [25], as well as the enhancement of the comfort and living conditions of residents [26]. RECs are also realizing the decentralization of energy generation, as energy is produced and distributed locally according to local energy demands -as opposed to the "traditional" way of a central production and distribution energy grid. That also means less costs for energy distribution and so less cost for the end user.

Another benefit is the users' controllability of their own energy systems as a higher level of autonomy in the use of energy is achieved through customizing their day-to-day consumption/production of energy according to their specific needs.

RECs, approach energy consumption in a sustainable way, aiming to reduce the amount of energy required to meet the daily needs of a household by incorporating techniques (e.g., insulating buildings), appropriate appliances and so forth that contribute to energy saving and improvement of energy efficiency (i.e. BEMS). However, success of the application of renewable energy and related schemes in SH requires increased awareness and education of residents. Either because the users are not adequately informed about the new technologies that can be applied or because the information provided is complicated, they show reluctance to engage and adopt the novel energy technologies. Training, especially to residents of lower income housing establishments, facilitates understanding on how the systems can perform in an optimum and most efficient way while it encourages a behavioral change in the consumption patterns [27]. In order for the residents to become more familiar with the RE technologies and their use and thus choose to use them over traditional energy sources, they sometimes need to be incentivized. The behavioral change depends on the age, level of education and perception of users.

Financial support is also seen as mitigating the perceived risk of replacing fossil-based energy systems, especially when novel technologies are installed [28]. At the same time when revenues from energy generation is planned with participation to DR (Demand-Response) schemes and the offer of flexibility services, then payback time becomes more attractive for residents [29]. Trust in construction professionals and technical support in decision making especially concerning the technologies to be installed is another factor that improves acceptance for renewable energy systems in SH [30], while institutional and policy frameworks that encourage the aggregation of small projects can achieve economies of scale and provide more attractive incentives [5].

The application of renewable energy sources in SH although creates benefits, it also faces certain barriers. These barriers include the reluctance of the residents to change their consumption patterns especially if not engaged with the process of the transformation of the energy systems [4] or if the monitoring and control mechanisms are too complicated [31]. In addition, both the providers and the residents of social dwellings are often skeptical about the costs of using Renewable Energy technologies. For the providers it means additional cost for the implementation and for the tenants, possible increase of the rent. In some cases, using new/innovative technologies for the first time has a difficulty factor to organize, manage and ultimately implement those. The use of innovative technologies is characterized as positive or negative rather subjectively as it is related to the personal perception of the user of how big or small is the inconvenience caused by the transition from the conventional to the innovative method used.

RECs involve novel technologies, so novel that the contractors and their crews who are involved in their application/installation have little to none experience in them thus, generating organizational problems both in the phase of construction and the face of use of the technologies. Lack of knowledge and information combined with the novelty of the technologies and the lack of technical support after the implementation is completed, becomes a barrier in the energy transition. There is also the issue of trust between social house providers and external contractors or other intermediary organizations. The social house providers are usually the ones who bear the costs of retrofitting while local authorities make decisions based in political goals and contractors have business profit in mind. These differences of concerns cause distrust between them.

Another hindering factor is the lack of financial support and risk of implementation especially when financial return is low and long term [32] or there is a "split incentive" between the housing owner who has to undertake the financial risk for the RE systems to be installed and the end user who is left mainly with the benefits [30]. Therefore, lack of incentives and national funding and also gaps in legislation are reasons that make the users reluctant. Even if the users understand the benefits of using RES and of being members of a REC, the initial cost of installations is a major obstacle to putting their conviction into practice. In many cases, users are at first, persuaded to switch to renewable energy, from funding or grants which, however, either they do not cover the full cost of the work required or do not last long enough to complete the switch or are discontinued altogether.

Although EU and some member state has stablished new directives and initial regulations concerning RECs, Table 1, detailed and well defined policy barriers can also hinder the adoption and installation of RE in social housing when there is lack of institutional support, incentives or building regulations for energy efficiency requirements [33].

Table 1. European Member States Energy Communities regulatory frameworks summarized according to [1,34].

Member States	Summary of Regulatory Framework
Belgium	No official framework is established in this country, yet the government is opening projects to the citizens for investing.The concept of REC was defined in the Decree 30 April 2019 as "communautés energie renouvelable". This decree permits CSC and users pay special tariffs for network use, taxes and surcharges.
Germany	The Renewable Energy Sources Act (EEG by its German acronym Erneuerbare-Energien-Gesetz) defines citizens' energy companies. Citizen' energy companies are formed by at least ten natural persons, that have the right to vote of which at least address 51% have a permanent dwelling in the administrative area of the project place. There is also another restriction where no member or shareholder can have more than 10% of the voting rights.
Denmark	The concept itself of energy community or collective self-consumption is not recognized by the law. However, the ownership of citizens is fostered, where the residents nearby a new commercial windfarm can opt until 20% of ownership of the RES plant. The citizens in a radius of 4.5 km can own until 50% of the plant.
Spain	In Spain, "local energy community" term is accepted by the Ministry of Ecologic transition. Furthermore, in this country CSC is permitted by the Royal decree 244/2019 whenever the RES installation can be located in more than a residential building and consumers are within 500 m or either the same PCC, can benefit from the energy generated.
France	CSC is recognized as "communautés energie nebouvelable", whose owners can be enterprises and natural persons. The enterprises are restricted to those whose primary activity is not the participation in this community. Natural persons are SMEs, local authorities or groups nearby the installation. These communities have access to all markets by themselves or by a representant (aggregator). The Energy Transition Law permits a public-private business model for fostering energy communities.
Netherlands	Energy associations and cooperatives are recognized by the law, where the operation of a local microgrid composed of households is possible (80% must be end-consumers). This microgrids cannot be managed by TSOs/DSOs or legal persons that produce or supply electricity directly or indirectly.
Poland	In Poland energy clusters are recognized by the law, which are civil agreements between the participants without any legality. They can be composed by natural persons, local government units, entrepreneurs, research institutes and universities. The aim of this figure is to contribute the local economy within a DN < 110 kV
Sweden	CSC is only possible at building scale, only if all the apartments have the same grid connection.
United Kingdom	The regulator of the country, Ofgem, permits the testing of predicts, services and business models. Thereby, in the UK, albeit some concepts are not regularized, they can be in trial.
Slovenia	CSC is permitted in multi-apartment buildings. The RES must be installed in the same LV network as the building users for sharing the energy.
Greece	In 2018 a law on energy communities entered in force, which goal pursued the partned social and solidarity of citizens. The members can be natural persons, legal persons (ether private or public) and local governments.
Portugal	There is no law concerning CSC, however, the research interest in this country is big.

Finally, innovation in RE technologies may result in higher up-front cost which can further hinder the investment decision. The complexity associated with the technology installation and use in combination with lack of professional expertise also becomes a significant barrier to overcome [35].

The literature also identifies some practical recommendations for promoting RE in social housing, which include: (a) ongoing engagement of residents, easy access to energy data and control and clear communication of the benefits according to demographic characteristics and skill levels; (b) ensure awareness of investment costs and responsibilities for both owners and tenants, and highlight the payback time. Barriers notwithstanding, renewable energy investments in social housing can distribute the generation in an energy justice way contributing to various social equity goals [10].

Renewable Energy Communities (REC) can be potential dynamic players/factors in the development of the Renewable Energy sector, in terms of their wider acceptance and use as well as in social and economic aspects. As they evolve and progress, they promote their social, environmental and economic benefits and thus, make the integration of RES in newly built social housing important.

When referring to social housing, research [24] shows that community support and active engagement, is crucial to the success of the implementation of RE technologies. REC members/groups could promote to communities as an opportunity for local development. As mentioned above, they offer social, economic and environmental benefits but also include innovative technologies in their implementation. These characteristics can contribute to the development of the areas in which they operate, draw attention to them and make them appealing to investors and new residents. Both during the construction/organization phase of the community and during its operation, there are opportunities to create new jobs that will specifically cover these activities.

Also, by providing information about RE technologies it could be key to raising awareness within the social housing sector. The use of new technologies in households, exposes more people to them and brings greater familiarity. Putting RE technologies in good use in the context of Energy Communities, people have the chance to observe, appreciate and hopefully adopt good practices and behavior. Last but not least, RECs can have a very important role in the alleviation of energy poverty [36]. Either as a vulnerable individual/group or as a pro-active energy user, REC members have the opportunity to produce, store, use and generally manage energy in a way that its distribution becomes more accessible and socially just.

In Table 2 a summary the internal and external factors that influence the development course of a renewable energy community (REC) in a social housing is presented.

Table 2. Summary of internal and external factors.

INTERNAL FACTORS		**INTERNAL FACTORS**	
Strengths (+)		Weaknesses (−)	
1	Decentralization of energy generation	1	Residents' awareness/motivation schemes
2	Positive environmental impact	2	Residents' fears for additional costs
3	Residents control their own energy systems	3	Residents' training
4	RE contribute to sustainability of buildings	4	Lack of residents' engagement
5	Enhancing comfort and living conditions of residents	5	Demography of residents within social housing
6	Empowerment of end-user	6	Lack of initial financial capital or/and ongoing capacity to fund a project
EXTERNAL FACTORS		**EXTERNAL FACTORS**	
Opportunities (+)		Threats (−)	
1	Addressing energy demands	1	Recovery of fossil fuel support policies
2	Reducing energy costs for residents	2	Tariffs for reducing payback periods for RE applications
3	Improving energy efficiency	3	Trust between social house providers and external contractors or other intermediary organizations
4	Monetary savings	4	Organizational barriers due to the novelty of the projects
5	Visibility of the new installed technologies	5	Complexity of the new technologies
6	Requirements of new-built social housing developments to integrate RE	6	Split incentives among providers and users
7	Reducing energy poverty	7	Lack of supporting policies for low income housings
8	Promoting good practices		
9	Local development		
10	Job creation		

2.3. Social Housing and Energy Communities in Greece

In an attempt to face energy poverty, following the 2008 turmoil, and to meet EU's energy efficiency targets, Greece's Ministry of Environment and Energy, on January 2018, presented L.4513/2018, on energy communities (EC) [36]. The Ministry's proposed law, was voted by a majority decision and its main purpose was to establish the legal foundation for a civil cooperative on the energy sector, especially regarding local production and consumption of energy [37,38]. The importance of L.4513/2018 lies upon two major introductions/corrections: the acceptance of participation of local authorities to the cooperatives (previously forbidden) and the decrease of the minimum number of legal entities to form an energy community (at least 2–5 entities—or 10 in cases of islands with less than 3100 habitants) [38]. However, the structure and exact terminology used in the legislation, shapes the future of the local energy sector, creating both challenges and prospects.

The insertion of the term "energy community" in the legislation, which L. 4513/2018 dictates, is considered ambiguous by a portion of the scientific community, because it relates with the European directive on renewable energy communities without following the exact terminology [38,39]. By omitting the term "renewable" the recently voted law, infers that a cooperative may be formed where a transaction of energy occurs, without control on the origin of that energy, renewable or otherwise. As far as the EC's legal activities, L. 4513/2018 states that the cooperative cannot act on any other sector except the energy sector, implying the exertion of the community of activities outside the boarders of the EC [37]. Ar. 2.3 of L. 4513/2018, stipulates that the members of an EC, must be legal entities legal persons or companies—who either own property in the district or are permanent residents in it (for the companies' participation, the article stipulates that the respective headquarters must be inside the district in which the EC will act upon) [37]. The latter, prohibits companies outside the district, to participate in the cooperative, whose headquarters are placed elsewhere and citizens who rent or have no ownership in the district [37].

One of the key aspects of an EC is the distribution of goods, as referred in European directive on renewable energy communities [39]. Ar. 6 of L.4513/2018, designates that ECs entirely formed by local authorities, may distribute surplus of goods (fuels, raw materials etc.) to local activities of the energy sector. On the contrary, ECs formed from a majority of physical members, can only distribute their surplus between the members and not outside the EC's derestriction [37,38]. Additionally, not-for-profit ECs may not distribute the surpluses amongst the members, but instead the surpluses should be allocated to an indivisible fund [37]. As far as for-profit ECs are concerned, they have no restriction regarding the allocation of surpluses (ar.6.4 L. 4513/2018). The end-of-life scenario of an EC is also stipulated in L. 4513/2018. Specifically, after dissolution/liquidation of the capital, the distribution of the funds should be allocated to non-profit authorities within the community's district and not to the members of the EC [37]. There are no legislation additions regarding the allocation of these funds, resulting in confusion at the dissolution stage of the cooperative [38].

According to Hagen H., the omission of the terminology "cooperative" along with "energy community", results in ambiguous legislative regime when referring to ECs "If it is to regulate the activity of the cooperative sector, it will be part of public economic law and should include, besides rules on the formation, structure, operations and dissolution of cooperatives, also rules on the establishment, the set-up and the powers of a supervisory authority. If, on the other hand, it is to only propose to potential cooperators a mode of organization which will permit them to develop their activities in an autonomous manner, then it will be part of private law". This ambiguity, creates the opportunity, ECs, regardless of the similarities they present with the cooperatives, to include them in public law, as they may be cooperating with authorities and legal entities [40].

Another significant aspect of the new legislation is the decrease of the minimum number of entities who can form an energy community to 2–5 members [38]. As stated in numerous occasions, previous attempts to increase the minimum number of members, resulted in discouragement from the participant's side in Greece's situation [38]. Regarding the introduction of local authorities as potential members of an EC, the context of L. 4513/2018 motivates them to participate as long as they use the service produced (energy). The bedrock of this motivation lies on the fact that (1) energy is a common good, (2) cooperatives may benefit from the cash flow and capital investment the authority has to offer [37,38]. The last but not least prospect of the new law, is the addition of specific subsections in the legislation which promote the formation of ECs in remote islands. Another interesting aspect of these subsections, is the participation of ECs in the community welfare by providing services or surpluses to vulnerable members of the district [38]. While funding schemes are still ambiguous, many attempts have been made by communities to form an EC. The vast majority of applications are still pending and there is only limited information, but there are cases which published either their vision or they presented results of the creation of such communities, as presented in the next section.

An increasing number of new applications for ECs is currently undergoing, in northern Greece 30 ECs are expecting approval by HEDNO (Greece's Public Authority managing the transportation of the electrical energy), 25 are located at central Macedonia (Epanomi, Trilopho, Thermi, Scholariou, Vasillikon are the most advanced regarding the application approval stage) while 5 more are located at eastern Macedonia (Servia, Aliakmonas, Limni, Argos and Kelli). The common issue faced by all the ECs is the funding mechanism which is still unknown (state participation, bank loans, private investors etc.).

Despite the renewable energy potential of the Greek territory, many islands (especially remote) still cover their energy demands via fossil fuels [41]. Renewable energy sources (RES) in the insular areas of the country are mostly solar and wind energy. The average wind speed in those areas is 10 m/s while the average solar irradiance is over 1900 kW/m^2, the exploitation of which has not yet reached the desired potential [41–43]. An attempt to utilize the available primary energy has been made by some presented examples, which are, to the best knowledge of the authors, the ones with the greatest degree of detail regarding planning, infrastructure (both installed and to-be installed), financial research, funding mechanism (either found or in progress of search) and published material about the EC.

3. The Case of Democritus University of Thrace Student Housing, in Greece

DUTh has installed a variety of RES systems at the student residences in Kimmeria, in order to reduce energy bills and carbon emissions, while it is in the process of identifying ways for optimizing the installed systems' operation and maximize self-consumption and flexibility offering. New systems that is, an ORC turbine and PCM thermal batteries will further support the already installed RES systems and innovative smart contracts for social housing will be deployed for incentivizing the end-users that is, students changing their consumption patterns. DUTh main objective is to explore, leverage and mobilize stakeholders to apply schemes for a social group of end users (i.e. students from low income families) in order to participate in the operation and management of a local renewable energy community, gaining also non-financial benefits.

3.1. The Technical Profile of the DUTh Renewable Energy Community

Democritus University of Thrace (DUTh) has formed, under the European Project Renaissance (Renewable Integration & Sustainability in Energy Communities, HORIZON 2020, GA 824342), a virtual Renewable Energy Community in Greece located nearby Kimmeria at the northeast of the city of Xanthi, at the North-eastern Greece [44]. The REC formed is the first energy community designed in a public housing settlement in Greece and its members are: (a) the Democritus University of Thrace, (b) the Municipality of Xanthi and (c) a local industry. The DUTh REC at Kimmeria has a social character, since its end users are mainly students, who are allowed to enter the student accommodation based on low-income criteria. Accommodation for students at the Democritus University of Thrace is provided free of charge. The total occupants of residences are approximately 630 and the residence's contracts are renewed every year.

The total built area at DUTh residences is 14.819 m2 and consists of eight (8) student residence buildings, an amphitheater, a restaurant and a building used for all the electromechanical equipment of the building complex. The DUTh REC at Kimmeria, has a variety of RES assets installed, presented in Table 3. Within the framework of the Renaissance program an ORC engine, two thermal batteries and twenty smart meters will further be installed. The existing equipment currently covers the thermal energy demand for the 8 student residence buildings [44]. The cooling energy produced is provided only to the amphitheater, which hosts the university big events throughout the year. The annual consumption for thermal energy of the community is 2337 MWh_{th} and the annual electrical energy consumption is 2317.2 MWh_e.

Table 3. Installed renewable energy sources (RES) Assets at the Democritus University of Thrace (DUTh) Energy Community.

Equipment (# of Items)	**Capacity (Total)**
Solar-thermal collectors (720)	1700 m^2
Heat exchangers (4)	118 m^2
Thermal energy storage tanks (4)	40 m^3
Biomass boiler (1)	1.15 MW_{th}
Absorption chiller (1)	316.52 kW*c*
Economizer (1)	50 kW
Cooling Tower (1)	720.5 kW
Master Geothermal Heat Pump (1)	135 kW_{th}
Slave Geothermal Heat Pump (1)	94.6 kW_{th}
94.6 kW_{th}	55.4 kW_p
OPzS batteries 2 V (72)	3780 Ah (each)

The heating and domestic hot water (DHW) of the buildings is produced locally at the energy center and is distributed through a local piping network. This network serves all students' residences and the amphitheater, while the restaurant has a separate heating and domestic hot water system. The heating network consists of 5 branches. Each student's residence building has a 2500 liters' hot water storage tank in order to cover its domestic hot water demand (DHW). In terms of electricity, the building complex is connected through a substation of 750 kVA with the medium voltage national grid operated by DEDDIE S.A.

DUTh has invested in RES that is, wind turbine, PV, solar thermal collectors, biomass boiler, thermal energy storage and geothermal heat pumps, with the aim to reduce the CO_2 emissions but also benefit from reducing the energy bills. Before the installation of the RES assets, DUTh was paying the total energy consumed in the student housing facilities from its yearly budget that derives from the state accounts. The RES assets managed to reduce the energy costs by 40% for DUTh and also reached social, environmental and economic objectives such as: (a) monitor energy consumption patterns; (b) optimize energy consumption behavior; (c) reduce primary energy consumption and CO_2 emissions; (d) earn benefits as a non-financial support to students, (e) reduce cost of energy for student housing for DUTh, funded by the state; (f) promote social innovation in student housing; (g) Peer-to-Peer energy exchange.

3.2. DUTh Incentivization Scheme

In order to further promote and maximize the utilization of the RES assets an innovative credit-incentive program at the DUTh Energy Community is developed. Each student, resident of the student housing facilities, is credited once entering the facilities every year with a predefined number of energy coins (Initial Energy Coins—IEC). Different pricing will apply for energy coins (representing kWh consumed) depending on which source delivers the energy consumed within the community. The total number of IECs that will be credited at the beginning of each year to each student, is calculated according to a typical student room energy needs and the annual RES production. For the typical room the expected energy consumption considering all energy vectors (i.e. electrical, thermal) is 3660 kWh. This is split into 915 kWh of solar energy and 2745 kWh of thermal energy produced by biomass.

The total IECs to be distributed evenly and equally to the students at the beginning of each academic year will represent 80% of the annual RES production (kWh). The rest 20% will be reserved as a backup to cover excess energy needs when required. The (maximum) number of IECs credited to each student will come from the fraction of the yearly total RES energy in situ production of the energy community, that is the solar thermal/biomass/PV/geothermal and stored energy divided by the total number of tenants in the student accommodation facilities for each academic year. For the distribution of IECs the following conditions shall be considered:

- Each student must have a unique identification password. This password will be used for his/her identification and will be linked to energy consumption behavior of each student room.
- Each student, during each academic year, will be credited with a number of IECs. IECs total credits will be affected by the energy consumption behavior. For example, if a student ends a year with a positive balance of ECs, then she/he will be credited an equal amount of (intermediate Energy Coins) that can only be exchanged for services.

Thresholds linked with KPIs will be set for classifying "very good energy behavior", "moderate energy behavior", "non-adequate energy behavior".

3.3. DUTh Business Model and Services

DUTh's business model includes: (a) the reduction of DUTh energy bills for social energy supply through self-consumption, and (b) enabling the offering of flexibility services through Peer-to-Peer. To achieve this, DUTH plans to incentivize the student community to utilize the RES assets in three different ways: (1) promote the consumption of energy produced in situ from the RES, (2) save energy, by reducing consumption especially when the energy cannot be provided by the RES systems and (3) change the demand profile, with personalized incentivization schemes. DUTh will be responsible to manage the Demand-Response system and incentivization scheme through smart contracts and also trade the excess of energy to the city of Xanthi or to the closest energy intensive industry allowing the energy community to maximize savings in the electricity bills and increase the entire system's performance.

Services that can be exchanged for ECs include: (a) free use for X time of electric bicycles of the community (when purchased), (b) redemption of energy coins with discount coupons exchanged at local businesses (e.g. restaurants, bookstores, etc.) participating in the program, (c) free use of laundry (e.g. amount of time per month equal to ECs value) (d) transfer or exchange Energy coins. It has to be mentioned that all services provided to the students of the dorms are for free. Otherwise, an exchange with monetary value could have also been foreseen.

In this paper, two business scenarios for promoting the utilization of RES produced in the DUTh Energy Community, are detailed:

- Social energy supply
- Peer-to-peer

Social energy supply

The social consumers, that is, the students for the case of DUTh, consume energy that originates either from the RES assets or from the grid. Different pricing applies at the energy coins depending on the source of energy consumed within the community. More specifically:

- If the energy consumed origins from the University RES (case 1), then each kWh equals to 0.7 Energy Coins (ECs). In this case the students will "pay" less for each kWh consumed from the University Energy Community.
- If the consumed energy comes from the Municipality or the local industry (case 2), then each kWh corresponds to 1 Energy Coin.
- If the consumed energy comes from the national grid (case 3), then each kWh corresponds to 1.5 Energy Coins. This means that students will be charged more if they consume from the grid.

It is of increased importance therefore to raise student awareness towards changing their behaviors to consume thermal and electricity when RES is mostly available based on the designed incentivization scheme.

Peer-to-peer

In this scenario, DUTh supervises the Ecoins transactions and imposes the limits and restrictions on these transactions (Ecoins, kWh). Other REC members and also prosumers, for example the Xanthi municipality and the local industry, can provide energy (virtually) to DUTH. This energy can be distributed to the DUTH's internal consumers (students). In the same way excess energy from DUTh can be traded in the peer-to-peer market to the Xanthi municipality and the local industry.

3.4. Market Actors

The related market actors, apart from the members of the REC, include: (a) the distribution system operator, and (b) the retailer, for which their business models do not vary so much. Both the DSO and the retailer roles can be performed by another third-party organization and not necessarily DUTh. For the distribution system operator, the revenue and cost structure remain the same; however, incomes could be potentially reduced due to existence of the Energy Community and its increase in self-consumption. In the case of the retailer, different tariffing ways may appear, depending on the consumption patterns of the energy community. The retailer can also act as a balance for the microgrid, as for example in case, where there is not enough self-consumption, it will supply the electricity that comes from the external grid through the wholesale market. Other market actors include the providers of products and applications for managing the performance of the collective self-consumption and the energy exchange in the energy community, as follows:

- Local energy exchange market platform, that is, the platform provider supports the digital platform and its maintenance and provides the required software updates of the platform.
- User interface service, that is, the user interface application enables the interaction between the platform and the members of the community.
- Consumption and generation service, that is, the agent providing the information about the prediction of energy demand or generation of an individual prosumer/consumer, groups of prosumers/consumers or the global community.
- Smart-meters that is, the supplier of the smart-meters and the IoT devices to the Local Energy Community.
- Laundry service that is, the local community laundry services. The social consumers that is, students can use or exchange the Ecoins to the Local Laundry service provider for using its services.

3.5. DUTH's Social Energy Supply Smart Contracts Logical View

The digital tool that allows the development of the DUTh Social Energy Supply market is the smart-contract. Smart contracts are a new technology emerging with force to automatically execute, control and document important actions according to the terms of a contract or an agreement. It is a kind of a digital agreement in which two or more parties specify agreements with conditions where all parties can view the contract, but it is not possible to change the contract afterwards. In consequence, the parties do not necessarily have to trust each other, as they can rely on the contract and the underlying blockchain technology. That is, the smart contracts are supported by blockchain technologies [45] and cannot be changed or deleted.

The development of blockchain technology [46] and smart contracts provides new opportunities to address security, trust, and transparency issues without the involvement of a third-party [47]. To design the smart-contract 4 + 1 view model [48] is used. In this architecture the logical view is one of the views used where the design and the functionality of the object model is done.

In this section the logical view of the DUTH Social Energy Supply smart contract is presented. In this view a brief description of the interfaces integrated in the smart-contract, Figure 1, are presented.

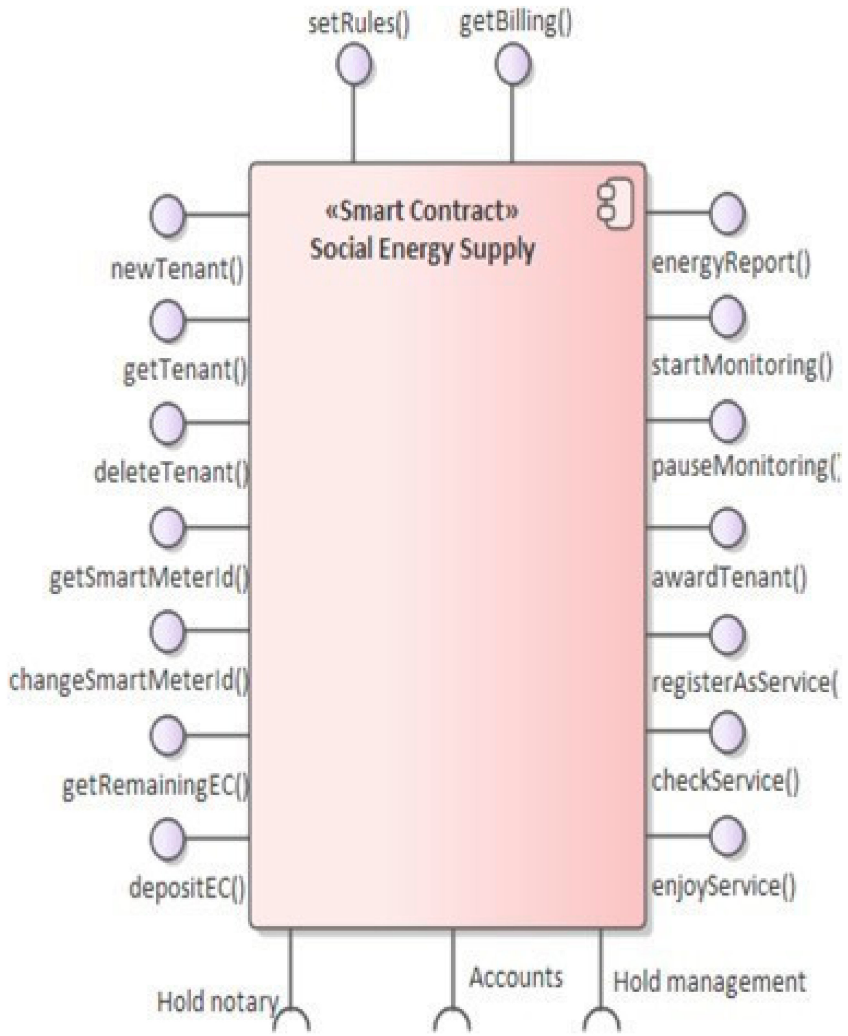

Figure 1. Unified Modeling Language (UML) logical component diagram of Renaissance's Energy Social Supply smart contract illustrating its required and provided interfaces. **setrules():** which is meant to be invoked at the beginning of the smart contract to set how the billing is going to be made. **newTenant()**, **deleteTenant():** which are meant to be invoked to register a new student (tenant) or delete an existing one. **depositEC():** To create a Hold for the student in order to pay for energy. **changeSmartMeterId():** to change the smart meter ID attached to the room assigned to the student. **startMonitoring()**, **pauseMonitoring()**: To start or pause the monitoring period, where energy consumption is monitored and the held amount reduced accordingly. **awardTenant()**: To award the student in case of good behavior. **energyReport()**: Used by the Smart oracle (smart meter database) to inform smart contract about the energy consumption of the student. **registerAsService()**: invoked by the student to register a new service with the energy coins obtained as award for good behavior. **enjoyService()**: invoked by the service provider to check a service as consumed. **getBilling()**, **getTenant()**, **getSmartMEterId()**, **getRemainingEC()**, **checkService():** auxiliary interfaces to inform the student about their status.

In addition, the DUTh's Social Energy Supply smart contract consumes interfaces of the E-Money smart contract to get Accounts and to create, release and execute holds, the latter three encapsulated in the "Hold management" interface. Moreover, this smart contract consumes interfaces of the Smart Oracle Marketplace Holds Notary to register and approve the release and execution of holds, encapsulated in the "Hold notary" interface, that are created in the context of the marketplace's auctions.

4. Conclusions—Further Work

This paper presents the business case scenario and the market players evolving in an Energy Community, which includes a public establishment of student residences in Greece. The residences are offered for occupation to students of the Democritus University of Thrace free of charge if they come from low-income families. The Democritus University of Thrace used to pay the energy costs of the residences by the annual university budget coming from the state accounts. However, in recent years DUTh has invested heavily in the deployment of various renewable energy technologies that increased self-consumption, resulting in reducing the total energy costs for the particular establishments saving the money for other university social initiatives, like buying new equipment/assets for laboratories or facilitate new infrastructures which improve students' experience in the university.

In the case of the DUTh Energy Community, the institution has identified the required resources to proceed with the investment of renewable energy technologies for the purposes of decreasing the budget spent for utility services. However, this case study focuses on a small community and carries a relatively low scale effect because of the particular circumstances that pertain to the student housing accommodation in Greece that is, tenants do not pay for utility services as those expenses are covered by government funds through the academic institution. However, if the specific type of energy community would be implemented within another context of low-income housing then incentivization schemes for landlords or tenants could support the initial investment as well as the provision of post-investment services, monitoring, and maintenance of the utilization of Renewable technologies.

The DUTh's Energy Community is presented along with the business case scenarios for the various market players in the Community including the Municipality of Xanthi and the industry that are involved in the Energy Community. The goals are: (a) to increase the incentivization of students to participate actively in the energy community and contribute to the energy saving by changing their energy consumption patterns and (b) to minimize the discarded energy of the involved stakeholders. The incentives to achieve this goal are designed as certain benefits the students can obtain if they decide to adopt new energy consumption behaviors. The incentivization schemes are deployed and monitored with smart contracts. Further work that is already planned includes the validation of those smart contracts within the community and the refinement of the concepts for increasing the adoption rates of new energy technologies, while maximizing their efficiency because of the behavioral changes of the end-users. The scope is rather more complex than an energy community in which at the end—users can obtain the financial savings themselves. In the social energy community of DUTh the end-users cannot obtain direct financial savings from consuming less energy, but they contribute to the development of other social initiatives caused by changing their consumption patterns, which in turn result to energy savings for the university, and reduction in CO_2 emissions. Future work includes the verification of the business concept and the smooth operation of the market actors identified that could potentially inform other social energy communities with similar context conditions. Similar contexts of social energy communities and related incentives can trigger changes in the consumption patterns that can result to higher adoption rates of renewable and energy efficient technologies.

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