Towards Pro-Social Load Balancing in Energy Communities

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ABSTRACT

Having emerged as a new paradigm to re-structure energy systems around citizens, energy communities have quickly gained the attention of researchers worldwide. Nevertheless, a significant challenge is the lack of datasets and tools to support research developments at scale. As such, this paper presents the PRO-social energy Community SIMulator, an open-source project to support the development and evaluation of pro-social energy management schemes in energy communities.

CCS CONCEPTS

• **Computing methodologies → Simulation tools**; **Multi-agent systems**; • **Hardware → Smart grid**; **Renewable energy**.

KEYWORDS

Energy Communities, Renewable Energy, Load Balancing, Pro-Social, Agent-Based, Simulation

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1 INTRODUCTION

Increasing the amount of energy from Renewable Energy Sources (RES) in the electricity mix is easier said than done. Among the main challenges is the uncertain nature of generation from such sources, particularly when considering solar and wind generation.

In this respect, Renewable Energy Communities (REC) have emerged as a new paradigm to increase the consumption from RESs, and at the same time, contribute to fighting poverty through reduced energy consumption and lower supply tariffs. In straightforward terms, RECs aim to produce or invest in the production of clean energy to meet their own consumption needs, trying to avoid, as much as possible, the use of energy from non-renewable sources [3].

However, despite their potential, RECs are not problem-free. In this regard, two of the most crucial challenges that need to be addressed are: 1) the need to properly balance the demand and supply, hence minimizing the need to acquire energy from outside the community, and 2) guarantee a fair attribution of the community resources, to guarantee the long-term sustainability of the community.

In Brooks et al. [1], the authors propose a pro-social computing approach to solve this problem, in which agents acting on behalf of the REC members accept to perform costly actions for the benefit of the community. More precisely, it is proposed that the scheduling of individual appliances consumption is performed by "social agents" that trade appliance usage time-slots among each other to guarantee the optimal balancing of demand and supply in the REC.

However, and despite the promising initial results, a significant challenge to REC research is the lack of data and tools to evaluate such approaches at scale, as highlighted in a recent survey paper [4].

Against this background, this poster abstract presents the PRO-social energy Community SIMulator (PROCSIM), which enables the simulation of pro-social energy management schemes in energy communities.

Ultimately, using this platform, it will be possible to evaluate and benchmark different load balancing schemes for ECs. In pro-social schemes like the one proposed in [1], it will be possible to assess the relationship between the satisfaction levels of the EC members and the load balancing results. For instance, two important research questions can be addressed: 1) is it possible to have an appropriate load balance and keep the majority of the members satisfied?; 2) how are the overall satisfaction and balancing schemes affected by the size of the community?

2 PROCSIM SIMULATION PLATFORM

The PROCSIM allows the simulation and management of energy communities, taking into consideration the available RES. The current prototype is divided into two main concepts: 1) the community simulation where the community is created and the individual and aggregated energy flows are generated, and 2) the pro-social simulation where the different load balancing schemes are developed and simulated.

An overview of the PROCSIM main concepts and modules is presented in Figure 1. A brief description of the underlying modules is provided next.

2.1 Community Simulation

In the present version, the community simulation is comprised of the following three modules:

The *Community Generator* module provides the tools and mechanisms to create an EC. The user should specify some important data, namely, the number of households, which appliances are available in each house, the number of householders, and the main activities performed by each one. In this module, the users also set the RESs

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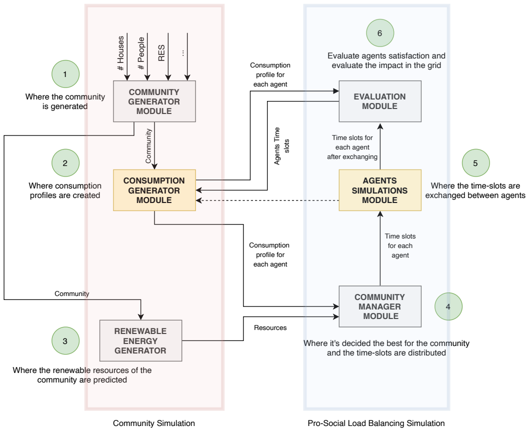

Figure 1: PROCSIM main concepts and modules.

available in the community, e.g., installed kWp, and geographical location.

The *Consumption Generator* is used to generate the consumption profiles of the community based on the information provided in the previous module. More precisely, for each household, the module generates the baseline load and the consumption of each appliance. These are then summed to form the households and community aggregated consumption profiles. The current version of PROCSIM relies on the AMBAL appliance trace generator [2], which generates appliance consumption traces at 1Hz.

The *Renewable Energy Generator* module provides the tools necessary to generate the profiles from RES. In the current version, only PV production is supported, using the PVLib-Python library[1] and weather data from Solcast[2]. This enables the generation of solar PV production profiles with sampling intervals down to 5-minutes when using historical weather data and 30-minutes when using real-time measurements.

2.2 Pro-Social Load Balancing Simulation

The pro-social load balancing simulation is also composed of three modules:

The *Community Manager* module is responsible for identifying the consumption requirements of each EC member (i.e., appliance usage time-slots) and distribute them according to the member needs, the energy available from RES, and other constraints (e.g., peak demand threshold).

Once the appliance usage time slots are distributed to each EC member, the *Agent Simulation* module will enable the exchange of appliance usage time-slots between agents, where each agent acts on behalf of a specific EC member. It should be stressed that a fundamental assumption here is that the community manager will not be able to meet the requirements of all EC members all the time due to grid constraints and/or prediction errors (e.g., attribute a time slot when it is not needed). The present version of PROCSIM extends the Energy Exchange Simulation project[3].

[1]https://github.com/pvlib/pvlib-python
[2]https://solcast.com/
[3]https://github.com/NathanABrooks/ResourceExchangeArena

The *Performance Evaluation* model provides the tools and metrics necessary to assess the performance of the developed load balancing schemes. The performance assessment is made in two different dimensions: 1) the overall EC members satisfaction, which is measured mainly based on the ratio between available and requested time slots (a value of one meaning total satisfaction), and 2) load balancing, which is measured based on metrics such as the ratio between the peak energy after and before the time-slot exchange (a value lower than zero indicating an effective decrease in the peak demand).

3 CONCLUSION AND WAY FORWARD

The PRO-social energy Community SIMulator is currently under heavy development, and the most recent version is publicly available on a GitLab repository[4].

Future developments of this platform will include updates to the different community simulation modules in order to generate ECs that are as realistic as possible. This includes, for example, adding the possibility of generating consumption profiles from existing datasets, some of which are listed in [4], and enabling the addition of renewable energy generation profiles from wind, using, for example, the WindPowerLib[5].

Another aspect that can significantly contribute to generating richer simulations would be incorporating Electric Vehicles (EVs) and EV charging stations. By introducing such elements, it will be possible to simulate scenarios that go beyond the exchange of appliance usage time-slots, introducing, for example, the exchange of the flexibility provided by EVs to accommodate excess production (i.e., charging the EV), or covering the consumption in peak demand periods (i.e., Vehicle to Grid).

On the other hand, changing the Agent Simulation modules will enable the creation of totally different EC management strategies. For example, greedy agents can be introduced in a pro-social simulation to understand to what extent greedy behaviors affect the EC community.

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