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A tool-chain to foster a new business model for photovoltaic systems integration exploiting an Energy Community approach

Lorenzo Bottaccioli*, Edoardo Patti*, Andrea Acquaviva*, Enrico Macii*, Matteo Jarre§, Michel Noussan§
*Dept. of Control and Computer Engineering, §Dept. of Energy. Politecnico di Torino, Italy
name.surname@polito.it

***Abstract*—New approaches and business models for the development of renewable sources are needed as an alternative to feed-in tariffs. In this work, we present a tool-chain based on a distributed infrastructure for planning renewable energy systems deployment. This solution aims at fostering new services and business models by promoting energy community actions. Such tool-chain is able to: *i)* evaluate the photovoltaic potential of the rooftops of a community; *ii)* perform economic assessments of distributed photovoltaic system plants considering a "community based business model". As case study, we considered a foothill community in north-west of Italy in which the tool-chain performed economic and energetic analyses. In order to integrate the proposed business model in the Italian regulatory framework, we analysed the Italian laws for electricity distribution and operation, highlighting the limitations in integrating such community approach.**

Keywords*—*Energy Community, Business models, Photovoltaic, Regulatory Framework, Smart Grid

I. INTRODUCTION

Nowadays energy systems are installed and managed at the level of the individual customer or by regional/national utilities. In the last years, a flourishing of community energy infrastructures has appeared [1]. This *"new"* trend is in the context of sustainable energy and carbon reduction programs. Such initiatives can be readily identified in many different countries around the world and many authors have seen this as a form of grass-roots innovation to provide alternative models for generating and supplying electricity and heat to dwellings, small businesses, and community buildings [1]–[9]. These types of innovations are radically different from centralized grid infrastructures that dominate advanced economies as reported by [7]. Indeed, building sustainable communities means creating a collaborative network for collective actions among different stakeholders [8]. Especially municipalities are key actors in relation to the design and implementation of future energy systems [4]. Using local energy production strategies can speed up the proliferation of renewable energy plants faster than waiting for complex, large-scale energy supply systems to catch up [5]. In addition to technical and/or economic issues, the community scale approach affects also on social aspects about energy autonomy [6].

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The rest of the paper is organized as follows. Section II presents the proposed tool-chain to estimate the photovoltaic potential for energy communities. Section III introduces the case study and the results are discussed in Section IV. Finally, Section V provides the concluding remarks.

II. TOOL-CHAIN FOR FOSTERING RENEWABLE ENERGY COMMUNITY

The proposed *Estimation of Photovoltaic Potential for Energy Communities* (EPPEC) is a tool-chain for providing energetic and economic analysis to local actors for promoting energy community actions (see Figure 1). It leverages a middleware presented in our previous works [10], [11], which is a peer-to-peer distributed software infrastructure to allow the access of multiple and authorized actors to information from power systems for providing new services. The EPPEC tool-chain exploits GIS data to evaluate the solar potential of the rooftops in a specific geographic area. Finally, it estimates the consumption and Photovoltaic (PV) production load profile of a community taking advantage of third-party data-sources, such as PVGIS, and data retrieved by the middleware before providing energetic and economic assessments. In the following we analyse each block of the proposed tool-chain.

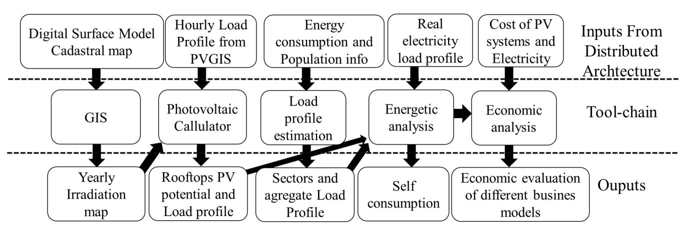

Fig. 1. Estimation of Photovoltaic Potential for Energy Communities tool-chain

A. Solar maps, PV potential and Load profile

Figure 1 shows the whole EPPEC tool-chain. The *GIS* block calculates the *Yearly Irradiation Map* of the community area exploiting the *r.sun* module of GRASS-GIS, which receives in input the Digital Surface Model of the selected geographic area. Data about rooftop solar potential is passed through the cadastral shape file to the *Photovoltaic Calculator* module that estimates the rooftops PV potential with the formula:

$$E_{PV} = H_g \cdot S_{AV} \cdot \eta_{stc} \cdot PR \tag{1}$$

where H_g is the Global Irradiation, S_{AV} is the available surface, η_{stc} is the rated efficiency of PV modules and PR is the Performance Ratio. The efficiency η_{stc} is assumed equal to 0.18 and the PR equal to 0.78, both are referred to a typical mono-crystalline PV panel. The available surface is obtained with correction coefficients in order to take into account the obstacles such as chimneys, dormers, or existing photovoltaic systems as discussed in [12]. In addition, the *Photovoltaic Calculator* module simulates the PV hourly load profiles in the selected geographic area as described in the following. Through the hourly irradiation data retrieved from PVGIS [13] the daily profiles for each month are simulated. The quota in percentage of every interval is calculated as:

$$\%_{Irr_i} = \frac{Irr_i}{\sum Irr} \cdot 100 \tag{2}$$

where Irr_i is the global irradiation at the i interval and ΣIrr represents the daily global irradiation. Then, the global irradiation values per square meter incident on the PV system are retrieved again from PVGIS to calculate the percentage of the monthly contribution $\%_{month}$. The energy production of each month is calculated as

$$E_{month} = P_{PV}[kW] \cdot h_{eq}[\frac{kWh}{kW}] \cdot \%_{month} \tag{3}$$

where P_{PV} is the power of the PV arrays. h_{eq} represents the value of equivalent hours. Finally, the resulting Hourly Load profiles are achieved by multiplying E_{moth} with $\%_i rr$.

B. Electricity consumption and load profiles estimation

In small areas, such as community scale areas, real hourly load profiles often are not provided by local Distribution System Operators (DSO), hence the *Load Profile Estimation* module can evaluate them. It needs the number of inhabitants for dwelling as input to simulate the residential load profile exploiting a probabilistic approach algorithm as the one described in [14]. The aggregated load profile of the whole residential sector is the sum of each appliance load profile per user. Whereas, the estimation of load profiles for Service and Industrial users exploit a standard normalized load profile [15] and electricity consumption of commercial and industrial activities. The street lighting working hours are defined by the National Authority for Electric Energy and Gas (AEEG) [16], and such information is considered to estimate its load profile. Finally, the aggregated load profile of the whole geographic area is achieved by adding each sector load profile for every season and day type.

C. Community model approach

The community model approach is based on the involvement of different actors: citizens, Public Administrators, Enterprises and the local DSO. Normally community-owned energy systems are small and the produced/consumed energy is not managed by the community itself. In this paper, a large installation of PV systems owned and managed by the local community is presented. Similar to experimented community ownership models in wind farms, like in north European countries, the investments for PV systems are done by the community as a unique subject where different stakeholders join together [17]. Exploiting the Low Voltage grid, the produced energy will firstly supply the local community needs. Then, the energy surplus, if any, will be fed into the national grid and sold. For this reason in evaluating the community savings achieved with energy self-consumption, the fees paid to DSO are not taken into account, while the economic savings consider energy costs and system fees.

The *Economic Analysis* module compares different business models and provides the results to stakeholders. In order to produce this comparison the *Economic Analysis* module needs information about: i) energy production, ii) energy consumption, iii) electricity and PV systems costs. Information on energy production and consumption are provided and performed by the *Energetic analysis* module. The comparisons are done between: i) Classic Energy Operator VS Community Operator and ii) Single user system VS Community system. The Community Operator is considered as an user aggregator. In this scenario, two cases are evaluated: i) the Community Operator buys energy in the market at the Unique National Price (UNP); ii) the Community Operator buys energy from a wholesaler at UNP average price plus an additional commission for the wholesaler itself [18].

III. Case Study

As case study, we selected a community located in a foothill area of the Western Alps in Italy. This community involves five municipalities: Cantalupa, Cumiana, Frossasco, Piscina and Roletto. The overall population is about $19,000$ inhabitants and around $1,700$ activities among industrial and service sectors are present in the whole area.

A. Electricity price in Italy

The Italian Electricity bill consists of four categories: i) *Electricity Cost*; ii) *Grid Charges*; iii) *System Charges*; iv) *VAT and Regional Taxes*.

The *Electricity Cost* is the direct cost of delivered energy. *Grid charges* are paid to local DSO and Transmission System Operator. *Systems Charges* are related to operational costs of the national system and include many voices such as incentives for renewable sources. Figure 2 reports the trends of each component of Electric bill for Protected Customers [19]. During the last years, the *Electricity Cost* decreased and reasonably it will continue along this direction. While, *System Charges* have strongly increased due to the growth of the incentives for renewable sources.

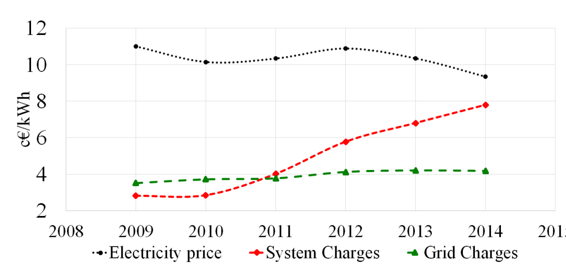

Fig. 2. Electricity Price Trends

The electricity prices in €/MWh for Industrial and Services are collected by [20]. Whereas the electricity prices for residential sectors are provided by AEEG and they are referred to Protected Customers in the 4th trimester of 2013 [19].

B. PV system cost analysis

The price of photovoltaic systems of $20kW$ ($1380€/kW$) and $3kW$ ($2090€/kW$) has been estimated with the use of commercial prices list. This has been done in order to compare the community approach with single user systems. Such costs for both, multiple $20kW$ and single $3kW$ systems, are in line with [21].

C. Incentives on PV systems in Italy

Nowadays in Italy the incentives for PV systems are: *i)* Tax deductions for residential plants; *ii)* Energy Efficiency Credit (EEC) for plants smaller than $20kW$. It is worth noting that feed-in tariffs are not any more available for new plants.

EEC for PV panels is calculated following the directives provided by the authority in [22]. The minimum amount of EEC that a subject has to own for selling them in the market is 20 EEC. The most suitable facilitation for a community action appears to be the EEC because: i) the tax deduction is applicable to persons only and it is released in 10 years; ii) the community approach can easily bypass the obstacle of minimum amount of EEC for selling them in the market.

D. Regulatory framework of electric grid in Italy

The current Italian regulatory framework does not include the definition of Energy Community. The most similar categories are the *Closed Distribution System* (CDS) [23]–[25] and the *Simple Systems of Production and Consumption* (SSPC). Table I and Table II report a summary of their limitations and the share of system and grid charges that each sub-category of CDS and SSPC has to respect.

TABLE I. CDS CATEGORY SUMMARY [23]

CDS	User Internal Grid	Other Private Grids
Constraints	Time (15/8/09) and just industrial customers	Industrial and Commercial customers (households customers just with AEEG exception)
System and Grid charges	Just on energy taken from the grid	Whole energy consumed

TABLE II. SSPC CATEGORY SUMMARY [25]

SSPC	Efficient User System	Other systems of self-production	Historical cooperatives
Constraints	Unique Producer, Unique Customer, Same Location	At least 70% of energy consumed in self-supply	Must be established before 1960
System and Grid charges	On energy taken from the grid and 5% on self-supply	Whole energy consumed	Just on energy taken from the grid

In CDS, only industrial users can participate. This is the main limitation for all CDS sub-categories with the exception of *Other Private Grids*. However, in the *Other Private Grids* sub-category, system and grid charges must be paid for all the consumed energy, even for the self-supplied, and this is not favourable from the economic viewpoint. Among the SSPC sub-categories the most suitable from the economic viewpoint are the *Historical cooperatives* and the *Efficient User System*. However, they are not exploitable by an Energy community due to time constrains and limitations on the same location between consumption and production units. Finally, the *Other systems of self-production* category is not favourable for the same reasons described for the *Other Private Grids*.

IV. RESULTS

A. Energetic analysis

The electricity consumed by the whole area chosen as case study (see Section III) is around 63 GWh/Year and the maximum estimated PV potential for producing energy is around 140 GWh/Year. Given the lack of load profiles real data, EPPEC provides the simulation of the residential, industrial, service and photovoltaic load profiles. The simulation of

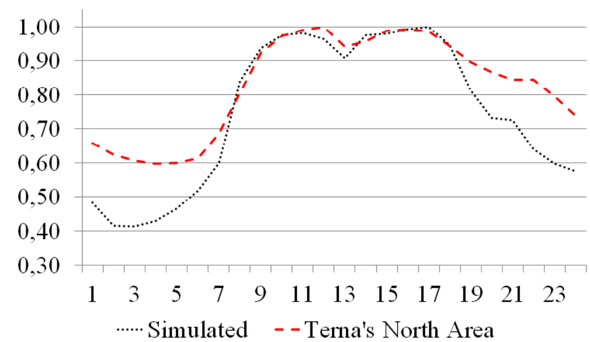

Fig. 3. Summer working day load profile

the aggregated load profile (see Section II) is compared with the load profile registered by TERNA (National Transmission System Operator) for the North area in Italy, as shown in Figure 3. The main differences are observed during the night mainly due to the lack of $24h$ working industries in the area under analysis. Figure 4 reports the summer working day load profile for each sector and for a distributed photovoltaic system of around $8.4MW$. This is the actual power installed in the area which satisfies the 12% of the electricity demand. The comparison between consumption and production allows the evaluation of the level of self-supply for various PV systems sizes.

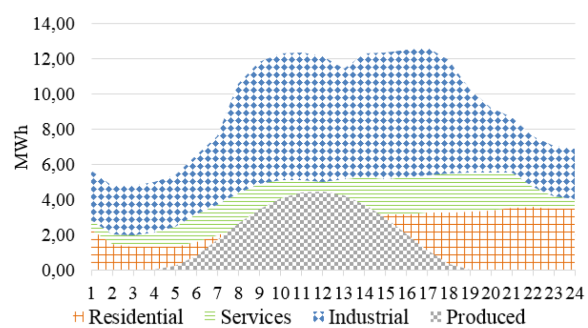

Fig. 4. Summer working day profile

B. Economic results

As discussed in section II, the Community Operator can buy: i) energy in the market at UNP price for each hour, or ii) energy from a wholesaler at UNP average price plus an additional commission for the wholesaler itself. In the first scenario, the evaluation of UNP price at each hour is performed following [18]. In the latter scenario, the UNP average price for the year 2013 is around 63 €/MWh and the commission prices for the wholesalers are assumed to be 10 €/MWh or 20 €/MWh. Figure 5 compares the Pay Back Time (PBT) values for these scenarios applied to a 8,4 MW PV systems. It is worth noting that PBTs also take into account the prices for installing the PV systems.

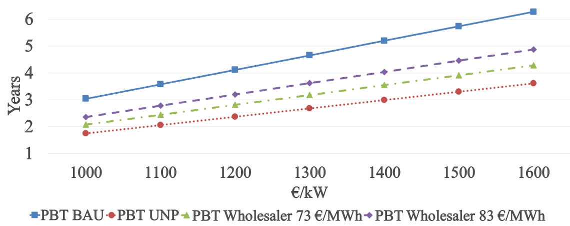

Fig. 5. Pay Back Time with sensitivity on Photovoltaic price

Figure 5 highlights that the community approach is favourable in terms of PBT for deploying the PV systems. Furthermore, aggregating all users in a single entity, the Energy Community, to manage energy consumption and/or production is convenient with respect to *Classic Operator* scenario because buying electricity at UNP price is the most favourable. However, it should take into account the risk of dispatching that is not evaluated. Hence, the most suitable solution consists on buying the electricity from a wholesaler that takes the risk of displacement.

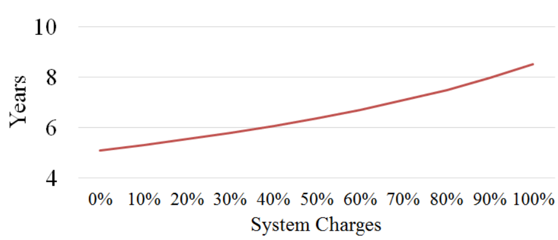

Fig. 6. Pay Back Time variation with respect to system charges

Figure 6 shows the variation of the PBT in function of the quota of system charges paid by the community. The trend is referred to the *Classic Operator* scenario where the cost of system charges strongly affects the PBT. It is not reasonable that the community does not pay them at all because this component is necessary for supporting the national power system. To address this issue the involvement of the Authority, as crucial stakeholder, is required. Indeed with the Authority a compromise between the necessity of the community to ensure a fast return of the investment and the needs of the National System has to be found.

Finally, the comparison between community approach and *Single User* approach confirms that community model is favourable because: i) the unitary price of the 20 kW system is lower than the 3 kW, and ii) the energy produced is completely self-consumed by users of the community and is not fed into the grid.

V. Concluding Remarks

The literature review [**?**], [1]–[4], [6]–[9] and the analysed case study confirm that the community approach provides economic benefits for end users. Furthermore, it is a good driver for fostering Smart-Grids and increasing energy efficiency. The energetic analyses of the photovoltaic production performed by the proposed EPPEC tool-chain demonstrate the importance of adopting the community approach. Finally, the results of the economic and regulatory analysis highlight that the main obstacle for promoting and developing Energy Communities in Italy is primarily due to the regulatory framework.

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