Renewable Energy Communities: An Urban Capability-Based Approach to Evaluate Differential Participation in Cities

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Abstract. Renewable Energy Communities (RECs) are deemed to be capable of providing several benefits to their members, as well as to the area in where such associations operate. In this sense they could be considered as capable of expanding the Capability set of the inhabitants of a city to improve their individual and collective well-being. In this contribution, the Urban Capability approach is applied to the EU-introduced concept of RECs to evaluate the preference of different socio-demographic groups in translating RECs from capabilities to functionings. The proposed methodology aims to learn the preference model of individuals depending on their socio-demographic characteristics and geographical location, and to determine the correspondence between preference towards the performance of possible alternative RECs configurations across the city, and the performance thresholds set by inhabitants towards participation. The contribution also presents the questionnaire designed to operationalize the methodology and collect the necessary structured data to build a Machine Learning model able to learn individual preferences. Such structured data will also be used to enrich statistical data from census surveys to "spatialize" preferences related to socio-demographic characteristics of the population. Such types of data could have implications for policy makers in terms of allocation of resources and the evaluation of different levers to better support a wider and fairer participation of inhabitants to energy transition, while, at the same time, removing the barriers to achieve higher level of individual and collective well-being.

Keywords: Energy communities · Urban capabilities · Multi-Attribute Value Theory · Preference learning · Synthetic population

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1 Introduction

In Europe, the building sector is responsible for about 36% of energy related CO_2 emissions, and of 40% of its primary energy consumption [1]. Especially in residential sector, then, energy demand reduction by means of the application of energy-efficiency measures coupled with renewable sourced energy supply represent a major decarbonisation potential of energy uses [2, 3]. In such a context, civic participation is paramount in the achievement of the complex and challenging goal of contemporary society [4].

Among the citizen-led bottom-up initiatives, Energy Communities (EC) [5] are gathering more and more attention due to their capacity to integrate citizens as active actors in decentralized renewable energy generation [6–8], as well as in supporting more conscious way of consuming energy [9]. The aggregation of consumers in participatory schemes aims to take advantages of different building typologies as well as different shapes of consumption curves [10, 11] reducing the temporal mismatch between energy use and generation [12, 13].

At the European level, the Energy Community concept has been recently formalized in two distinct legal entities by the Renewable Energy Directive recast (REDII) [14], and the Internal Electricity Market Directive (IEMD) [15], both being part of the Clean Energy Package [16]; these two legal entities are the Renewable Energy Communities (RECs) and Citizens Energy Communities (CECs). Both concepts focus on the empowerment of the civil society in the energy market by allowing activities such as the production, storage, share and selling of energy produced by the members of such entities, with the former specifically bounded to the prescription of producing energy exclusively by using renewable sources. For such reason, this chapter focuses on this specific declination of possible Energy Communities.

Despite the European policy effort to integrate the civil society in the energy transition, currently, the transition towards the use of clean energy at the urban scale remains slow [17]. To evaluate the possible participation of individuals to the energy transition in the urban context and specifically through the deployment of RECs, this contribution will frame the participation to RECs within the Urban capability approach, viewing such participation as a particular state of functioning of individuals in cities.

Urban capability approach [18, 19] is used to study complex phenomena such as poverty and quality of life, to construct and evaluate public policies [20, 21], as well as to choose among possible feasible alternatives [18].

The capability approach identifies two fundamental aspects: functionings, and capabilities; the former being observable state of being (what a person is and do with her/his resources), and the latter the set of possible functionings that a person has access to. Specifically declined in the city context, urban functioning is what a person does or decide to be in the city, among the possible options (urban capabilities) at her/his disposal [22–25].

Furthermore, the set of available capabilities is determined by the interaction among individual capability (her/his intrinsic abilities) to be and to do, and the external condition (context) in which the individual operates [26]. As stated by Chiappero-Marinetti [20], the transformation of means in actual states is not a mechanistic process, but it is rather influenced by the plurality of intrinsic and extrinsic conditions; with the space being

a potential conditioning factor. In this sense the Capability approach imply the necessity to describe the real opportunities an individual has to use the city and to function autonomously and freely [27].

In the process of translating urban capabilities into urban functionings, we could argue that a fundamental aspect to be considered might be the actual system of value that an individual applies to determine what she/he considers as worth being [18, 28], considering individuals as fundamental agents in the transformation processes [29].

Finally, the Urban Capability approach might be of use to understand and describe those situations in which the interaction between city and inhabitants is suboptimal or expression of just a portion of the urban population [24, 27].

Being the participation to RECs able to generate different types of benefits (environmental, economic, social) to both its members and the areas in which these legal entities operate [14], such configurations represent a possibility for the inhabitants to expand their capability set, and increase the level of individual, as well as community well-being (Fig. 1).

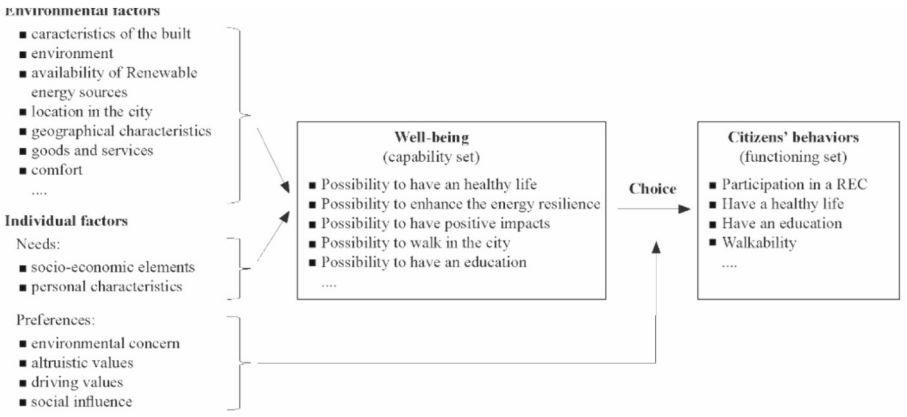


Fig. 1. Participation in a REC as an expansion of capability set (adapted from [28])

Considering the participation of the inhabitants of the city to RECs as possible functioning among the set of available conditions of individuals, this contribution aims at presenting a methodological framework to evaluate the willingness of civil society to participate in such associations as expression of their system of value, and, consequently, to evaluate the extent to which it could be expected that these configuration might be deployed in the urban context. Furthermore, such type of analysis might disclose asymmetrical and differential concretization of the REC concept within the urban fabric, exacerbating possible forms of peripheralization [30] and consequently the suboptimal achievement of the economic, environmental, and social benefits envisaged by the wide participation in RECs [14].

The rest of this contribution is structured as follows: In Sect. 2 the proposed methodology to evaluate civic participation as a declination of Urban Capability approach is

depicted, while in Sect. 3, its operationalization by means of a questionnaire to be distributed to city inhabitants is presented, together with the desired logical structure of the data to be gathered. Finally, in Sect. 4 some policy implications are discussed, while in Sect. 5, conclusions are drawn, as well as future applications of the proposed analysis.

2 Method

As stated, aim of this contribution is to set forth a methodological framework to evaluate the differential degree of civic society's participation in RECs, both spatially (in terms of spatial distribution of the willingness to transform the set of urban capabilities provided by different urban opportunities), and intrinsically, intended as the different inclination that specific group of individuals have toward the constitution of RECs. In order to do so, the proposed methodology is composed by three main parts. The first step (Preference analysis) is to evaluate individuals' system of value and thresholds in deciding either to participate or not in RECs based on socio-demographic characteristics. The second step (Synthetic Population) is meant to distribute the groups of individuals' system of values across the urban fabric by matching the socio-demographic composition of the parts of the city. Finally, by spatializing the socio-demographic groups' system of values (Spatialization) it would be possible to evaluate the likelihood of constitution of different possible configurations of RECs. The following of the section presents the different steps of the methodology in greater details, as well as the theoretical background supporting it.

2.1 Preference Analysis

Formally, the preference model of a user can be expressed by means of binary relations [31]. A binary relation $\succ_x$ among two elements of a set determines the preferability of one element over the other for a specific individual x. A binary relation on a set of elements Σ is a partial order if it is asymmetric

$$(a \succ b \Rightarrow \neg b \succ a),$$

and transitive

$$(a \succ b \wedge b \succ c \Rightarrow a \succ c).$$

A partially ordered set in which for every two elements of the set it exists a binary relation

$$(\forall u, v \in \Sigma : u \succ v \vee v \succ u)$$

is called totally ordered set [32]. The task of inducing a preference model that would result in the prediction of the order that the user would give to the elements of the set is called Label Ranking and has been particularly used to determine covariance between preferences and socio-economic information [33] in case of similarities among users [34].

In label ranking, given an instance x of an instance space X, and a finite set of labels $Y = \{y_1, y_2, \ldots y_k\}$, the aim is to learn a function that maps each instance x to a ranking $\succ_x$ over the set Y, where $y_i \succ_x y_j$ means that instance x (an individual) prefers label y_i to y_j. A ranking over the set of labels Y can be expressed as a permutation τ of {1, 2,…, c}, where $\tau(i)$ represents the position of label y_i in the ranking [35].

The order induced by the preference of x over Y could be explained in the framework of Multi-Attribute Value Theory (MAVT) developed by Keeney and Raiffa [36]. MAVT represents alternatives in a decision problem as composed by a set of attributes and interprets preferences by means of value functions associated with these attributes. The total value of an alternative is given by the sum of the marginal values for the attributes the alternative is composed of. Therefore, by means of aggregation criteria such as the additive one, it is possible to express the total value of the alternative u_y (1):

$$u_y(x) = \sum_{\beta=1}^{n} p_\beta u_\beta(x) \tag{1}$$

where u_β are marginal value functions associated to each attribute β that describe the alternatives, normalized between 0 and 1, and p_β represents the trade-offs among the attributes. In this way, we can define the preference of individual x over two objects as (2):

$$y_i \succ_x y_j \leftrightarrow \sum_{\beta=1}^{n} p_\beta u_\beta(x) >_x \sum_{\beta=1}^{n} p_\beta u_\beta(x) \tag{2}$$

Meaning that, the preference order expressed by x holds true if the total value of the most preferred alternative is greater than the total value of the less preferred one. To evaluate the preferences of individuals it becomes paramount, then, to estimate the shape of the value functions that the specific individual assign to each attribute that describes the different alternatives at his/her disposal.

In the operational research and artificial intelligence communities, the interest around learning and predicting preferences has grown [34], and, in recent years, Preference Learning (PL) has emerged as a branch of ML referring to the task of learning the preferences of individuals or classes of individuals from information about a set of items [37]. Roughly speaking, PL aims to induce preference models from data regarding explicit preference information [38], with a common attempt being to approximate the utility function of a decision maker in multi-criteria and multi-attribute settings.

PL has been widely used in several fields of applications (Fig. 2) such as prediction of customer design choices [39], travel modal choices [40], logistics, information retrieval, collaborative filtering [38]. Among the available methods, Additive Utility Functions (UTA) methods [41] take global statements upon set of alternatives, and subsequently infer the value functions that better fit such statements [28]. Based on linear programming, UTA method approximate value functions by minimizing the errors between the given preference structure over the set of alternatives, and the one computed by calculating the total values of alternatives given by the estimated value functions.

In the specific application that will be presented in Sect. 3, the decision over the participation in a REC has been defined by means of a vector of four attributes among those mostly used in the literature about feasibility analysis of Energy Communities (thus, considering Eq. (1), n = 4): (i) Investment Cost, (ii) Energy bills savings, (iii)

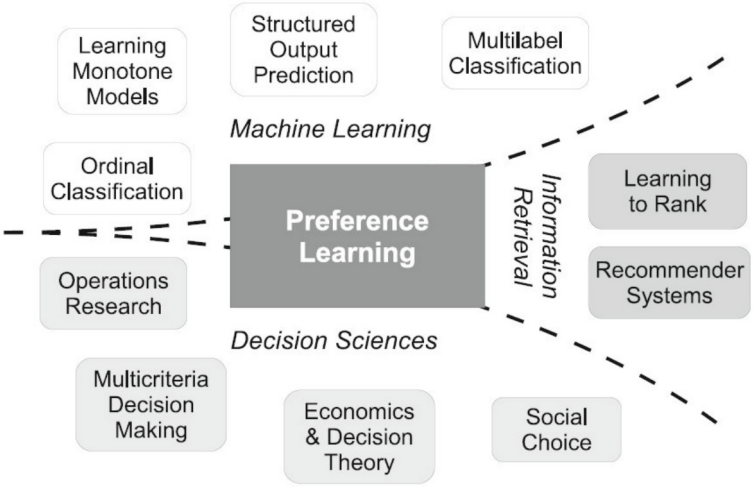


Fig. 2. Fields of applications of Preference Learning (source: [38])

Avoided greenhouse gas emissions, and (iv) Self-sufficiency index. These latter could be calculated relatively easily by means of Urban Building Energy Modelings (UBEMs) tools [42], and, therefore, the individuals' preference learned in this phase could be easily compared with performance data about possible scenarios of application of RECs in different parts of the city. The individuals' preferences are analysed (Sect. 3) by means of a questionnaire, in which the respondent is asked to perform an overall statement by declaring either if she/he is interested in participating in a REC defined by a specific vector of attributes (alternative $y_i \in Y \mid y = \langle \beta_{1i}, \beta_{2i}, \beta_{3i}, \beta_{4i} \rangle$) as well as to specify a complete order over the alternatives. By assigning different value functions (u_β) to the four attributes for each respondent satisfying Eq. (2), it would be possible to infer the preference model of each respondent.

2.2 Synthetic Population

To study the distribution of preferences across the urban environment, the use of population synthesis techniques is envisaged. Popular in the transportation research field, population synthesis refers to the process of creating a simplified microscopic representation of an actual population that matches the aggregated statistical measures of the actual population [43, 44].

To generate a synthetic population, a Population Synthesizer (the software that implement the process) requires two types of input data: disaggregate population samples referred as seeds, and population marginal distributions named as controls or targets [45]. By applying data fusion techniques, the synthetic population is generated expanding the seed sample to match the marginal distribution.

The population marginal distributions represent the constraints for the population synthesis procedure and might include social, demographic, and economic variables useful to describe the population living in a specific area under analysis (Census Block,

Census Tract, Metropolitan Statistical Area, or at any specified geography for which data are available).

The disaggregated data is typically obtained by census and other specific surveys to describe the population according to the goal of the study for which a synthetic population needs to be produced. The seed sample should contain demographic characteristics corresponding to the marginal control variables defined as controlled variables (age, sex, occupation, etc.), while it could also contain further information that are not controlled via the marginal distribution variables. Such variables, termed uncontrolled variables, could store the data enrichment of the seed sample by means of the value functions calculated in the previous step, thus allowing for the association of the preference models evaluated to the synthetic population modelled in each censor track of the urban environment.

Numerous are the software available to generate synthetic populations, among them, PopulationSim [45], is an open-source Python-based tool that is part of the collaborative framework ActivitySim [46]. Besides the seed tables, and the marginal distribution table defined via comma-separated values files, PopulationSim receives a further input (the Controls table) in the form of a logical map that connects the attributes from seed tables to marginal control ones [43].

The main output of the synthetic population is an artificial population whose distribution is coherent with the actual distribution of the real population living in a specified area (according to the availability of data of the marginal distribution, typically census track boundaries) with individual-level granularity of data according to the variables structure of the seeds.

Once the synthetic population has been generated, and the Value Functions for each socio-demographic group have been estimated with the UTA methods (step 1), it is possible to merge the two pieces of information by means of a data enrichment process. Data enrichment techniques are used when there is the need to enrich data from a dataset (referred to as *target* dataset), with information from another dataset (the *source* dataset) sharing a subset of common attributes. In the specific case, the target dataset to be enriched is represented by the synthetic population dataset generated, while the source dataset is represented by the questionnaire results, with the attribute to enrich the synthetic population with being the Value Function determined in step 1. The procedure used is taken from statistical matching algorithms [47–49]. In particular, a vector of attributes $A_{t,1:N}$ for each (target) observation t of the synthetic population, and one vector $A_{s,1:N}$ for the source dataset are defined, and the matching of the two is evaluated in order to append the Value Function information to the household h of the synthetic population dataset. The specific attribute to define the matching are determined based on the vector of households' socio-demographic attributes that determine the different shapes of Value Functions.

2.3 Spatialization

The third and final step of the methodology involves the evaluation of the matching degree between the performance of alternative RECs that could be established on the territory, and the preference models of the different socio-demographic groups across the urban environment by means of Geographical Information Systems (GIS) [50]. Municipality

GIS-based databases provide access to information regarding the urban fabric, allowing energy consumption evaluations, the assessment of renewable energy production options availability (considering also legal constraints), as well as the evaluation of possible energy efficiency intervention scenarios to be applied in different areas.

In this direction, the performance of possible alternative configuration of RECs across the city is calculated coherently with the range of attributes specified to determine and evaluate the preference model of inhabitants. By comparing the preference model of the enriched synthetic population generated with the performance achieved by different RECs alternatives in specific census tracks, it will be possible to determine the order of preference of the different socio-economic groups over the alternatives, as well as the thresholds posed by individuals to the possible participation in RECs. In Fig. 3 an expected result of this last step of the analysis is showed.

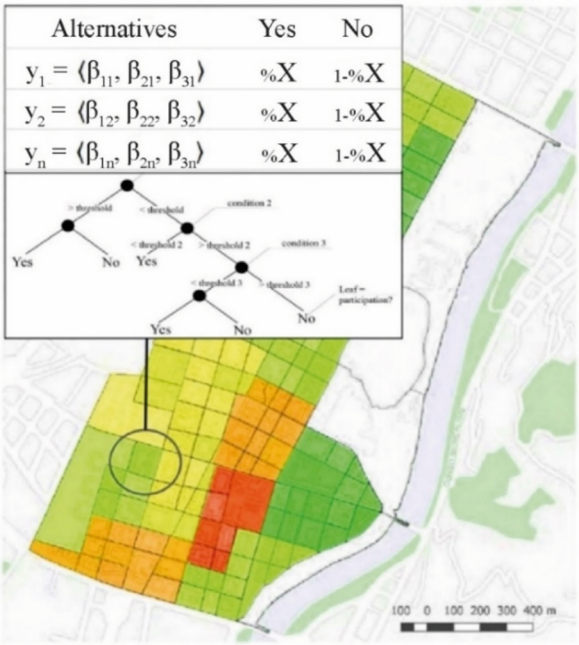


Fig. 3. Expected result of the Spatialization step (adapted from [44])

As showed in Fig. 3, for each census track, the final goal of the analysis is to determine the percentage of local population who, according to the approximated preference model, might be willing to participate in the possible alternative REC configurations *y* described as a vector of attributes β. Such analysis could provide useful information regarding the potential distribution of penetration of RECs in the urban environment depending on the typology and system of values of population that reside in a specific area (intrinsic capabilities), as well as on the contextual factor that might hinder such propensity.

3 Operationalization and Results

To operationalize the methodological architecture proposed in the previous section, a questionnaire has been constructed to gather the data necessary to define the individuals' preference model and the relevant socio-demographic variables that will be than used for the generation of the synthetic population. The following section is devoted to the presentation of the questionnaire and to show the structure of the output results from a pilot test run before its application to an Italian case study in the city of Turin (Northern Italy).

The proposed questionnaire has been constructed using the online survey tool limesurvey [50], and is composed by three main sections: (i) an introductory part devoted to a general set of questions based on a 4-point Likert scale on the themes of the research, in order to gather some introductory data regarding respondent's inclination toward RECs and their possible economic, environmental, and social benefits [14]; (ii) a second part in which the preference statements over respondent's willingness to participate in RECs are registered by means of a first filtering of possible REC alternatives, and two ranking exercises among the selected options; (iii) and a final part in which the socio-demographic data regarding the respondent and his/her household are collected. In Table 1 the logical structure of the questionnaire is presented.

For each question, the modalities define the available answers for the respondents. In this way, the first section of the questionnaire allows the respondents to specify his/her level of agreement with the specified statement on a 4-Point Likert scale, while the third section present modalities in terms of clusters (i.e., age = {<15, 15–19, 20–24, …, > 75 years old}, sex = {Male, Female, Other}, etc.) according to Italian census data [51].

As previously mentioned, in the second part of the questionnaire the respondent is asked to express a series of overall judgement on the alternative RECs proposed. As mentioned, the respondent is presented with 8 different REC alternatives described by means of four attributes: (i) investment cost, (ii) energy-bill savings, (iii) avoided CO_2 emissions, (iv) energy Self-sufficiency. For each of these alternatives, the respondent is allowed to state either if he/she would be willing or not to participate in the constitution of a REC with such characteristics, or if she/he is uncertain. In Fig. 4, an example of the question is displayed.

After this first filtering, the respondent is then asked to rank the alternatives for which she/he stated the willingness to participate or the uncertainty towards such decision. Hypothesizing a strict preference of the former over the latter, it is possible to extrapolate a complete order of the proposed alternatives for the generic respondent x. In Table 2 the results structure of a pilot test run is shown.

Together with the order of the alternatives useful for the approximation of the value functions by means of the application of the UTA methods, the clustering of alternatives in the "refusal to participate" category (when the respondent states his/her refusal to possible participation), allows to quantify the thresholds and total values of alternatives that determine their exclusion from the desired capability set of the respondent.

Table 1. Logical structure of the questionnaire

Section 1			
Code	Question	Modalities	Condition
1.1	Collaboration between people is essential to reduce energy consumption and all be more sustainable	4-Point Likert scale	
1.2	Reducing energy consumption is necessary to combat climate change	4-Point Likert scale	
1.3	Adopting energy efficiency measures in my home seems expensive to me, and it is not a priority for me	4-Point Likert scale	
1.4	Climate change can worsen social inequalities between people	4-Point Likert scale	
1.5	Promoting the well-being of all individuals is important, even if this may limit individual profit	4-Point Likert scale	
1.6	The State must commit to reducing society's environmental impact, including by introducing taxes to discourage the use of fossil fuels	4-Point Likert scale	
1.7	Are you already member of a REC	Y/N	
1.8a	Participating in the Energy Community has allowed me to reduce my impact on the environment	4-Point Likert scale	If 1.7 = Y
1.9a	Participating in the Energy Community has allowed me to have a positive impact on my quality of life and that of other people as well	4-Point Likert scale	If 1.7 = Y
1.10a	Participating in the Energy Community has allowed me to save on my energy bill	4-Point Likert scale	If 1.7 = Y
1.11a	Participating in the Energy Community has allowed me to be less dependent on changes in the price of energy	4-Point Likert scale	If 1.7 = Y
1.11a	Participating in the Energy Community required a significant initial expense	4-Point Likert scale	If 1.7 = Y
1.8b	I am interested in the social benefits that an Energy Community can guarantee for families in economic difficulty	4-Point Likert scale	If 1.7 = N

(*continued*)

Table 1. (*continued*)

Section 1			
Code	Question	Modalities	Condition
1.9b	I am interested in the savings on my energy bill that an Energy Community can guarantee	4-Point Likert scale	If 1.7 = N
1.10b	I am interested in the reduction of polluting emissions that an Energy Community can guarantee by producing clean energy or reducing consumption	4-Point Likert scale	If 1.7 = N
1.11b	I am interested in the possibility of self-producing part of the energy I consume in order to be more self-sufficient	4-Point Likert scale	If 1.7 = N
1.12b	If I decided to become a member of an Energy Community, I would also be willing to invest money	4-Point Likert scale	If 1.7 = N
Section 2			
code	**Alternative selection**	**Modalities**	**Conditions**
2.1–2.8	Would you participate in a REC option (y)? (With $y \in Y$, and $Y = \{A, B, C,\ldots,H\}$)	Yes/No/Maybe	
	Ranking		
2.9	Rank the options you stated you would agree to participate in	Complete order	$\forall y \in Y, \mid \langle y,\text{Yes}\rangle$
2.10	Rank the options you stated you might agree to participate in	Complete order	$\forall y \in Y, \mid \langle y,\text{Maybe}\rangle$
Section 3			
code	**Question**		**Modalities**
3.1	Sex		2 modalities
3.2	Age group		13 modalities
3.3	Educational level		5 modalities
3.4	Profession		10 modalities
3.5	Citizenship		2 modalities
3.6	Household size		7 modalities

(*continued*)

Table 1. (*continued*)

Section 1			
Code	Question	Modalities	Condition
3.7	Questions 3.1 to 3.5 for each member of the household (as stated in 3.6)		-
3.8	Property regime of the household		2 modalities
3.9	Annual income of the household		5 modalities
3.10	Who has more influence on household decisions		4 modalities
3.11	Household location		Pin on map

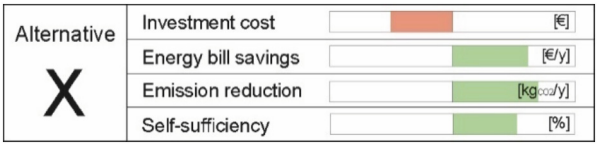


Fig. 4. Example of tabular description of a REC alternative

Table 2. Structural logic of the results of the pilot test

ID	Alternative (0 = No, 1 = Maybe, 2 = Yes)								Order	
	A	B	C	D	E	F	G	H	Yes	Maybe
1	2	2	2	2	2	2	2	2	E, B, D, C, A, H, F, G	
2	0	0	2	0	2	1	1	2	H, C, E	G, F
3	1	0	0	2	0	0	0	0	D	A
4	1	0	2	0	1	0	1	0	C	A, E, G
5	2	2	2	2	2	2	2	0	A, D, E, B, C, F, G	
6	0	1	0	0	0	1	2	0	G	F, B
7	1	0	1	1	1	1	0	0		A, C, D, E, F
8	2	0	0	0	0	0	0	1	A	H
9	2	0	2	0	2	0	0	0	A, C, E	

4 Policy Implications

The academic production on RECs mainly focuses on energy planning aspects related to technical feasibility, often neglecting to consider other mostly social aspects in the evaluation of possible configurations of RECs [52]. This latter aspect reinforces the concept of a difficult integration between energy planning and city planning [53, 54].

Sustaining the necessity to consider the integration of RECs into urban planning as part of the "enabling framework" that the Member States should provide according to European Directive RED II, Gerundo & Marra [55] propose a methodology for the prioritization of areas where the public decision makers could intervene to maximize energy and social benefits with the minimization of constraints on the formation of RECs. Among the social benefits that this methodology aims to maximize, is the one related to energy poverty alleviation [16, 56]. Even though there is no single conceptualization on how to quantify energy poverty, several proxy variables are commonly used to identify this condition, such as poor energy performance of housing, high ratio between energy expenditure and income, and low-income inhabitants [55, 57].

It has already been stated that an effective strategy for reducing energy poverty is to encourage area-based initiatives, i.e., to intervene where there is greater need [58]. In this direction the overlapping of different layers of information (such as urban plan constrains and areas of low performing residential dwellings as proposed in [55] methodology) could benefit from the integration of two other pieces of information that are considered in the proposed methodology in this contribution. First, the evaluation of potential performance of alternative RECs configurations in different areas will highlight the limitation posed by the actual morphology of the city that individuals interested in distributed generation from renewables and energy efficiency intervention projects will face (considering the specific location in the different part of the city as a potential source of inequality, both from the point of view of capabilities, and intrinsic condition of the urban fabric). Second, the matching degree between the possible achievable outcomes of different RECs configuration and preference models of the population will shed light on the expectable magnitude of bottom-up initiatives that could arise from the territory, and the degree with which these could meet the public goal of reducing greenhouse gases emission from the urban environment.

In light of this level of information, the public authority could consider forms of intervention to increase its support both financially (such as financial schemes to support fragile socio-demographic groups [59]), or by direct intervention by considering entering RECs with public own buildings [60], by easing the extent of constrains posed by the urban planning use of land, or by supporting the participation of third entities such as ESCOs to partner with groups of individuals residing in less wealthy areas.

A further aspect worth considering is the potential effect of energy poverty alleviation and emission reduction on health and well-being of the population, supporting the necessity of providing decision makers with a clear mapping of the areas that, due to the limiting factor highlighted, would not be able to self-sustain a fair ecological transition.

5 Conclusions and Future Perspectives

In this contribution, the Urban Capability approach has been applied to study the possibility for urban inhabitants to participate in Renewable Energy Communities as a potential conversion of the capability set in Urban functionings. In such an effort, to consider the preferences of different socio-demographic groups is paramount to evaluate the system of values that could result in the willingness to participate in such associations, or in the refusal to act in this direction.

The proposed methodology composed in three steps (analysis of different socio-demographic groups preferences, construction of a synthetic population enriched by data regarding people's system of values, and the spatialization across the urban environment) could shed light on the real potential penetration of the REC concept among different strata of the population, and urban geographies depending on intrinsic characteristics of the population, as well as on resource availability of the territorial context.

The methodology will be applied to a real case study in the city of Turin (Italy). The expected results might have several policy implications in the effort toward the energy transition, conceived as an occasion to reduce inequalities in the urban environment. First, the spatialization of the likelihood of RECs constitution might support the public Decision-Maker in defining policies that might aid the more fragile part of the population in embarking in such projects as an attempt to reduce peripheralization effects highlighted by a slacking attention towards the less appealing areas [61, 62] Second, possible suboptimal outcomes in terms of mismatch between the economic oriented private Decision-Maker preferred alternatives and the Public Interest most preferred ones could be highlighted, and corrective measures undertaken. Furthermore, possible spaces for partnerships might be envisage for those areas in which the establishment of a REC might have substantial direct or undirect benefit for the population wellbeing, even though the inhabitants are not interested or uncapable to undergo such types of investments, potentially resulting in a waste of resources (firstly spatial resources in case of distributed renewable energy generation). Finally, in case of areas of low level of interest shown by the living population, these might be targeted by specific participatory processes that the Public Authority might put in place to further examine the reasons behind the population indifference or refusal (or even impossibility) to act.

An additional expansion of the research could be seen in the possibility to replicate the study in different cities: the distribution of the questionnaire in other locations will allow to look for pattern of homogeneity regarding the preference model of socio-demographic groups in different geographic areas and to identify specificities in the potential penetrations of the RECs concept depending on the variation of the intrinsic and extrinsic capabilities in those areas. This latter would represent a source of information for the public Decision-Makers to monitor the effect of the policies supporting the REC strategy to foster the sustainable green transition.

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