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Analysing the potential of citizen-financed community renewable energy to drive Europe's low-carbon energy transition.

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Abstract

In 2018, the real amount invested in the European Union's energy transition fell short of the funding level required to reach the 2030 climate and energy targets by €179 billion. Citizen-led finance in renewable energy development emerges as an innovative tool to bridge this investment gap. However, in spite of the European Union's ambition to involve local communities for co-driving the low-carbon energy transition, there is no comprehensive analysis quantifying citizens' potential to co-finance and participate in community renewable energy initiatives. We address this knowledge gap through a representative choice experiment survey that collected responses to 389,640 hypothetical investment options on renewable energy schemes across all European Union Member States, and estimate the social potential of European citizens to participate and invest in community-administered wind farms. Results from a novel survey-based social simulation indicate that €176 billion could be obtained from citizen-led finance in community-administered wind farm developments, enough to halve the investment gap to achieve a 32% RES share by 2030. Reaching this potential would lead to the deployment of 91GW of installed wind power capacity, generate up to 196 TWh of renewable energy annually across Europe, and trigger an average increase of 8.3% in final renewable energy consumption. This would lead to the abatement of over 103 MtCO_2eq annually and result in a 2.4% annual reduction in greenhouse gas emissions from 2018 levels. Our analysis substantiates the case for easily accessible, risk-insured community investment options across Europe to unlock citizens' social potential for investing in community renewable energy.

Highlights

- Citizens emerge as a legitimate actor for co-driving Europe's energy transition.
- Over €176 billion potentially available to co-finance community-based wind energy.
- Citizen-financed wind energy to trigger 8.3% increase in EU's final RE consumption.
- Impacts include a +2.4% annual reduction in GHG emissions from 2018 levels.
- Novel 'survey-based social simulation' (SBSS) used on choice experiment responses.
- Risk-insured community investment options needed to unlock citizens' social potential.

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Keywords

Community renewable energy, social potential, energy transition, citizen finance, survey-based social simulation.

Word count

8,005 words

Abbreviations

CE	Choice experiment
CO_2	Carbon dioxide
CRE	Community renewable energy
EU	European Union
EU-28	European Union's 28 Member States
GDP	Gross Domestic Product
GHG	Greenhouse gas
GtCO2	Gigatonnes of carbon dioxide
GW	Gigawatt
GWh	Gigawatt hour
MNL	Multinomial logit
MS	Member State
MtCO2-eq	Million tonnes of carbon dioxide equivalent
MW	Megawatt
MWh	Megawatt hour
NECP	National Energy and Climate Plan
RE	Renewable energy
RES	Renewable energy sources
tCO2-eq	Tonnes of carbon dioxide equivalent
TWh	Terawatt hour

1. Introduction

Launched in 2015, the Energy Union is the EU's largest and most ambitious climate and energy legislative effort to fully decarbonise Europe's energy system by 2050, with a set of intermediate energy and climate targets for 2020 and 2030. These now reflect a 32% share of RE in final energy consumption, a 32.5% improvement in energy efficiency, and a 40% reduction in greenhouse gas (GHG) emissions from 1990 baseline levels [1]. However, tangible policy instruments and implementation mechanisms foreseen under current National Energy and Climate Plans (NECPs) for the period 2021-2030 remain elusive and inadequate for reaching the abovementioned targets [2], [3]. In light of insufficient efforts, a viable pathway for decarbonisation at the extent necessary to reach climate neutrality by mid-century remains elusive. EU Member States (MSs) must therefore explore viable GHG emission reduction measures to successfully decarbonise their economies and realise an increasingly steep emissions reduction pathway to operate within an EU carbon budget of around 96 $GtCO_2$ for the period 2010-2050 [4].

The investment requirements to realise such emission reductions are substantial and currently not being met [5]. Estimates indicate that about €380 billion are required annually over the next 10 years in order to achieve the EU's 2030 climate and energy targets, nearly double the 2018 investment level of €201 billion [5]–[7]. This resulted in an investment gap of €179 billion for 2018. Estimates further project that no less than 9% of the foreseen annual investments, at least €34 billion per year, will have to finance the deployment of renewable generation capacity to reach a 32% share of the EU's final energy consumption by 2030 [5]. This translates into a cumulative investment of €340 billion in RE capacity over the 2019-2030 period.

The EU aims to bridge the resulting investment gap through market-driven strategies that place citizens at the core of the Energy Union by having them "[…]take ownership of the energy transition, benefit from new technologies to reduce their bills, [and] participate actively in the market" [8, p. 2]. In that respect, citizen participation in community-based RE (CRE) generation through collective investment and shared ownership schemes, emerges as an innovative tool to unlock citizens' *social potential* to contribute in bridging the existing investment gap, as well as their GHG emission abatement potential through the co-generation and local sourcing of clean energy. This positions CRE as an important vehicle through which bottom-up, community-based climate mitigation actions can occur, and can thereby empower individual citizens to contribute towards Europe's objective of carbon neutrality by mid-century.

Furthermore, CRE schemes can generate ancillary benefits for its owners and surrounding communities and thereby contribute in increasing social acceptance of clean energy alternatives [9]–[18]. Ancillary benefits may include additional sources of income from electricity sales or through dividends from the ownership of shares and/or land rent [12], [19]–[21], lower energy costs derived from local or self-consumption [22], enhanced social cohesion and sense of community [23]–[25], and increased environmental awareness and stewardship [26], among others.

Importantly, CRE schemes can have an additional positive characteristic above self-ownership schemes. Firstly, by distributing the initial capital investment needed throughout a large group of small-scale investors, collective investment schemes in CRE lower the required investment amount for individuals vis-a-vis a fully self-owned system [13], [17], [18], [27], [28]. This can allow for under-privileged groups, such as lower income households or those who lack the proper infrastructure for a self-owned RE installation, to participate in RE generation. Along with this added benefit, citizen participation in CRE decreases social indifference and uncertainty towards new RE installations, an effect that can increase the social acceptance for new RE developments [29]–[33] and therefore expedite the low-carbon energy transition.

However, despite the documented socio-economic benefits attributed to CRE, no efforts have been conducted to quantify – yet alone monetise – individual citizens' potential contribution to financially participate in CRE initiatives. Furthermore, no research has yet aimed to translate different levels of financial participation in CRE into GHG emission reductions. The only attempt to approach such a quantification comes from [34], who use country-level data for estimating the potential number of RE prosumers (consumers and producers of RE) in Europe across a broad base of arrangements including self-ownership, CRE, public ownership and firm adoption. Assuming a 100% RE scenario, the authors estimate that about 113 million households could become prosumers across the EU by 2050. However, the study does not fully consider the participation decisions of households to either adopt or not a RE technology, and further assumes that a hypothetical financial investment per household is a function of average savings rates alone[1].

[1] [34]state their estimation method as follows: "The Eurobarometer contains statistics on which topics concern citizens the most. By selecting the relevant topics, the share of households that will want to invest in renewable energy is estimated. The total amount this group can invest is limited by multiplying their normalized average savings rate between 1995 and 2015 with an estimated minimal and maximum amount each household will invest yearly" (p.13). No further information on this methodology is given in their report.

This study aims build on the work of [34] by investigating the optimal combination of different financial attributes and operational configurations that maximise individual citizen investments in community-based RE generation schemes. We quantify the resulting investment volumes and aggregate them across the EU-28 to estimate European citizens' aggregated financial participation in CRE, defined as the social potential. We then assess the extent by which the EU's social potential can effectively finance the EU's 2030 RE target, and estimate the volume of RE generated and GHG emissions reductions stemming from it.

In order to do so, we use data from a choice experiment conducted across all EU-28 where respondents are presented with different investment options to co-finance RE schemes with different characteristics and varying attributes. Using imputed choice probabilities derived from multinomial logit estimates on the choice experiment data, we compute the social potential as the expected investment from the representative citizen of each EU MSs; we call this process Survey-Based Social Simulation (SBSS).

Section 2 introduces the choice experiment as our main data collection tool. Section 3 describes the development of the SBSS methodology. In section 4 we present the results stemming from our analytical procedure and assess the potential of our estimated citizen financial participation in CRE to effectively bridge the current investment gap for financing the RE capacity needed to reach the EU's 2030 RE target. We then contextualise our results within the EU's broader climate action commitments by translating our estimated social potential into GHG emission reductions; and close by highlighting limitations and caveats to our methodology. In section 5, we explore the effects of existing RE subsidies on our estimated social potential, and reflect on the policy implications of our results. Section 6 concludes.

2. Data collection

The main data utilised for this study was obtained from the responses to a Choice Experiment (CE) conducted as part of an international online survey with private citizens across 31 countries (EU-28, Norway, Switzerland, and Turkey). The internet-based survey was distributed to about 600 respondents in each country through a random sampling procedure that relied on email panels, with a total final sample of 16,235 respondents. Respondents were recruited using a compensation mechanism of at least €5 per person to incentive participation and ensure that not only people with energy interests made up the sample. As shown in table A.1 (see Appendix), quotas were set from national sociodemographic indicators pertaining to age, gender, and income levels in order to ensure the representability of the samples for all 31 countries. To frame our study in the context of EU climate and energy targets, we drop sample responses from Norway, Switzerland and Turkey.

The purpose of the CE was to identify respondents' levels of interest in participating in a community-based investment scheme to finance solar or wind projects, and to investigate what specific set of investment attributes of RE initiatives, including financial and operational conditions, drive citizen participation. Survey respondents were presented with eight different choice scenarios, each one displaying a total of three options to choose from: two hypothetical investment opportunities (option A, option B), and a third "opt-out" option (option C) provided in the case where a respondent had no interest to invest. Respondents were asked to choose which of these three options they would prefer if confronted with the same situation in real life. The choice scenarios were built following a D-efficiency criteria [35], and organized into three blocks of eight scenarios. Each respondent was presented the scenarios from a randomly selected block in a random order[2], and asked to pick one option for each of the eight different choice scenarios. This resulted in eight different choices per respondent and a final sample of 129,880 choice responses selected from 389,640 different choice options available.

As illustrated in figure 1 and specified in table 1 below, each choice scenario included two scenario-specific characteristics that applied to all three choice options (A, B, and C) within a given scenario. In addition, the choice scenarios included four option-specific attributes that varied between choice options A and B, with option C as the default opt-out option where all attribute variables are set to zero. Figure A.1 in the Appendix offers an example of one of the eight choice scenarios utilised in the CE and as shown to English-speaking survey respondents, along with a descriptive script introducing the CE exercise and explaining the scenario and premise of the investment options.

[2] For a full description of the choice experiment design, testing and results please see [27].

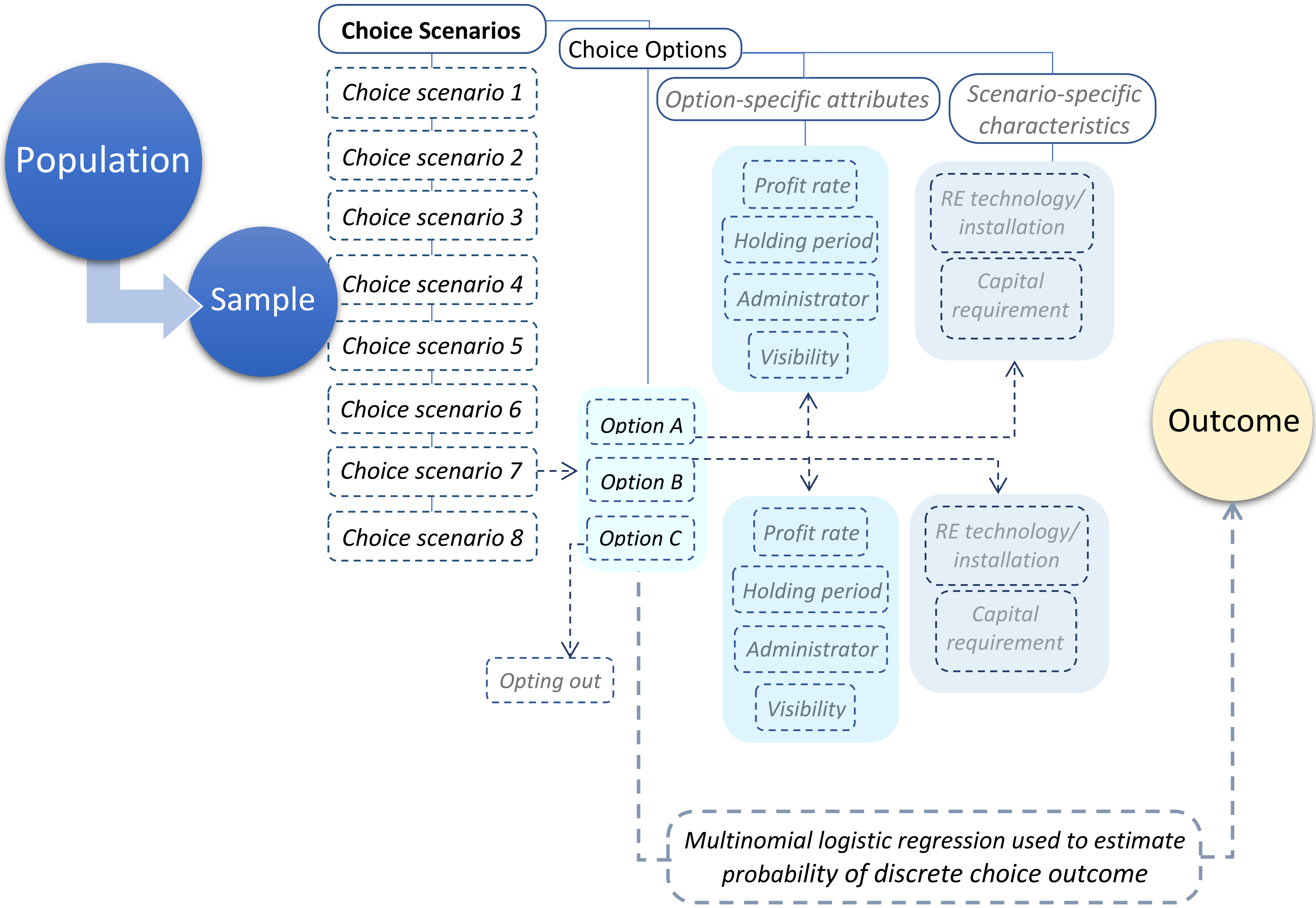

Figure 1. Schematic display of Choice Experiment design, including the conceptual purpose of the alternative specific multinomial logit as an analytical tool to statistically estimate probability of choosing an investment option.

Table 1. Scenario-specific and option-specific attributes, along with their descriptions and range of values.

Investment & operational attributes	Description	Values
RE installation	The type of renewable energy project the respondent is investing in.	• Wind farm • Solar park
Capital requirement	A randomly assigned, risk-free investment amount the respondent has to pay to join any of the investment opportunities being offered.	• €50 • €100 • €1,000 • €2,000 • €5,000

Profit rate	A one-time lump sum payment to the respondent at the conclusion of the holding period, when the RE project is finalised. Displayed as a real rate of return on the initial investment that already accounts for inflation[3].	• 0% • 10% • 20% • 50%
Holding period	The number of years elapsed until the respondent's initial investment and the profit generated from it are both repaid.	• 5 years • 10 years • 15 years
Visibility	Whether or not the RE installation is visible from the respondent's home.	• Visible • Not visible
Administrator	The legal entity overseeing the respondent's investment and in charge of building and administering the RE installation.	• Community organisation (e.g. energy cooperative) • Private utility company • Government entity (e.g. municipality)

Table 2 below showcases the distribution of responses obtained from CE participants. The left column indicates the share of respondents who chose an investment option (A or B) at least once throughout the CE, while the right column specifies the total share (percentage) of investment options selected by respondents in each EU MS.

Table 2. Descriptive statistics of responses to investment options in the EU-28.

Country	Pct. of respondents selecting at least one investment option	Total pct. of investment options selected	Number of respondents
Austria	82%	57%	604
Belgium	71%	48%	604
Bulgaria	88%	64%	605
Croatia	95%	80%	603
Cyprus	82%	60%	251
Czech Rep.	80%	56%	602
Denmark	64%	44%	604
Estonia	91%	84%	605
Finland	74%	46%	604
France	71%	48%	604
Germany	74%	49%	603
Greece	88%	62%	604
Hungary	84%	60%	600
Ireland	81%	51%	624

[3] The CE defined "investments" as lump sum money transfers that are to be fully repaid at the conclusion of the holding period. This specificity allowed to disentangle the profit rate from the holding period and avoided the necessity to consider compounded interest, thereby simplifying the set of considerations that respondents had to account for when evaluating the profitability and, by extension, the preferred choice option.

Italy	83%	61%	602
Latvia	68%	44%	600
Lithuania	80%	58%	601
Luxembourg	83%	62%	605
Malta	90%	64%	263
Poland	76%	55%	602
Portugal	81%	59%	603
Romania	86%	67%	603
Slovakia	80%	55%	603
Slovenia	82%	63%	606
Spain	75%	49%	600
Sweden	64%	44%	603
Netherlands	76%	58%	604
UK	73%	46%	623
EU-28	**79%**	**57%**	**16,235**

Overall, CE responses indicate a substantial interest expressed by respondents for participating in CRE developments via collective finance and co-ownership schemes: 79% of respondents selected at least one investment option, and further chose to invest in almost 60% of all available options. While this implies a high interest for CRE alternatives as a social innovation in energy financing, it is important to note that our experimental design assumes full (albeit imperfect) access to robust market information and risk-free community investment options operationalised through a trustworthy and straightforward financial vehicle. These facts, along with the availability of multiple investment options, offer a plausible explanation for the high acceptance manifested for the investment offerings. We note specifically that 19 MSs sampled in the CE have the majority of their respondents choosing an investment option in over half of all choice scenarios presented to them, while only 9 MSs host majorities choosing not to invest in more than half of choice scenarios.

Interestingly, survey countries with a higher observed interest in joining CRE initiatives (e.g. Bulgaria, Croatia, Romania, Slovenia, Hungary, Estonia) correlate with lower installed wind power capacities per capita, while countries expressing a lower interest (e.g. Denmark, Sweden, Germany, United Kingdom, Spain, Finland) have higher wind capacity installations per capita (correlation coefficient = -0.942, based on [36], [37])[4]. This initial assessment points toward a potential trade-off between installed capacity and investor acceptance levels (as manifested by a

[4] Correlation coefficient obtained by first dividing EU-28's installed wind power capacities [36] by their corresponding national populations [37]. The resulting figures (installed wind power capacity per capita for every EU-28) were then correlated with the figures listed in column 3 from table 2 (Total pct. of investment options selected).

lower willingness to co-invest in CRE initiatives), indicating an inversely proportional relationship between both variables.

It further suggests that collective investments on RE initiatives are seen favourably as viable financial instruments in nations where public acceptance issues accompanying new energy infrastructure are not yet strongly rooted [38]. Alternatively, countries manifesting low interest may be illustrating small-scale energy investment constraints due to prohibitive capital investment requirements [39], [40]. This may be further exacerbated by a combination of stricter spatial planning criteria [39], [41], lengthy permitting procedures and legal disputes [42], [43], and increasingly stringent RE compensation mechanisms [44], particularly in countries with long-standing traditions on cooperative association such as Denmark and Germany.

3. Methodology

CEs are a well-suited data generation method for modelling and interpreting respondents' choice dynamics using probability-based discrete choice models to account for people's preferences and decision-making processes [45]–[49]. CEs are grounded in economic random utility theory, which assumes that the utility level person *n* experiences from choice option *i* can be separated into one observable *V*(.) and a random $\acute{\varepsilon}$(.) component [46]. In our analysis, both components are a function of the option-specific attributes Z_{in}, and the scenario-specific characteristics S_n (both illustrated in figure 1 and described in table 1). As such, the latent utility U_{in} from any choice option can be expressed as:

$$U_{in} = V(Z_{in}, S_n) + \acute{\varepsilon}(Z_{in}, S_n) \qquad (1)$$

Based on equation (1), we can assume that any choice option *i* will be preferred/selected over some other choice options *k*, if individual *n*'s utility for *i* (U_{in}) is bigger than the utility assigned to all other competing choice options *k* ($U_{in} > U_{kn}$). Thus, by relating the observed choices to the choice option attributes in table 1, we are able to estimate the preferences of respondents for specific attribute levels via choice modelling techniques.

Following the theoretically-grounded rationale of random utility, we develop a methodologically-structured, three-step probabilistic simulation technique called 'Survey-Based Social Simulation' (SBSS) to estimate European nations *social potential* to collectively finance and co-participate in CRE initiatives. Our aim is to identify the maximum possible capital offering available to be invested in CRE generation schemes by the representative individual citizen in each EU MS under an ideal configuration of the financial and operational attributes outlined in table 1.

Mathematically, we define this individual (per person) social potential as π_N in (2). In what follows we substitute the subscript n for N, as we calibrate the SBSS method on the representative individual of each nation N, as opposed to individual respondents (n).

In order to calculate the individual social potential (π_N) we first impute the probability (P_N) that the representative individual in country N chooses an investment option and then multiply this value by the capital requirement (b_N) that the individual is asked to contribute to for co-financing an RE installation. This yields the expected investment per citizen of country N as expressed in (2).

$$\pi_N = P_N b_N \quad (2)$$

Equation (3) defines the probability P_N that the representative individual of country N will invest in an option with a capital requirement b_N as a result of he/she ascribing a higher utility U to any one investment option (A or B) than to opting-out (option C).

$$P_N = Prob(U_{AN} > U_{CN} | U_{BN} > U_{CN}) \quad (3)$$

The computation of choice probabilities, P_N, is accomplished by imputing the average probability of choosing option A or B from discrete choice multinomial logit (MNL) models estimated on the CE data. The imputations are based on a choice option with the feasible, preferred configuration of attributes defined in Step 1 below. Country-specific social potentials provide the main building block to then proceed to the second stage of our analytical exercise, where we quantify the RE generation and GHG abatement potential stemming from citizen-financed CRE schemes across the EU.

3.1. Estimating the social potential

Employing the SBSS entails the use of choice model parameter estimates to impute choice probabilities given the effects of different combinations between option-specific attributes and scenario-specific characteristics, and maximizing some objective function subject to these imputed probabilities. This allows us to estimate both the probability that any one specific option under any given scenario is selected instead of competing options, and the changes in this probability given some specified modifications in the design settings. Assuming the latent utility in (1) is linear with respect to the explanatory variables and that the error term ϵ_{in} takes a Gumbel extreme value distribution, leads us to the adoption of the alternative specific multinomial logit model (MNL) in (4) – the common workhorse model for discrete choice frameworks.

$$U_{in} = Z_{in}\boldsymbol{\beta} + S_n\boldsymbol{\alpha}_i + \epsilon_{in} \quad (4)$$

As illustrated in the conceptual design of our CE (figure 1), the MNL models the probability of a discrete choice outcome as a function of the option-specific set of attributes Z_{in} and the scenario-specific characteristics S_n. The effects of the variables within Z_{in} and S_n on the latent utility levels U_{in} of individual respondent n are represented by the vectors $\boldsymbol{\beta}$ and $\boldsymbol{\alpha}_i$. Since we are interested in the decision to invest vs. not invest, we set option C (opting out) as the base alternative, and assign a value of zero to its corresponding coefficient vector $\boldsymbol{\alpha}_i$. This allows to more easily interpret the output of the MNL as the effects ($\boldsymbol{\beta}$ and $\boldsymbol{\alpha}_i$) that the different variables from option and scenario-specific attributes (Z_{in}, U_{in}) have on the probability of opting-out from an investment option (A or B) presented in the choice scenario.

3.1.1. Step 1: Estimating the effects of choice attribute variables on choice probabilities

Equation (4) is estimated via maximum likelihood estimation of the full dataset from the entire CE sample in order to estimate the parameters of $\boldsymbol{\beta}$ and $\boldsymbol{\alpha}_i$, as the average effects of the attribute variables in table 1 over the representative individual respondent in every country sampled and across the EU-28. Specifically, the 'option-specific attributes' listed in table 1 are contained in Z_{in}, with the 'visibility' attribute represented as a dummy variable (= 1 if the installation is visible from the respondent's home, 0 otherwise), and the 'administrator' attribute represented as two dummy variables, one representing community-administered installations and one representing government-administered developments with utility company installations serving as the omitted variable. The 'RE technology' attribute within S_n is represented by a dummy variable that takes a value of one if the choice scenario references a solar farm, while the 'capital requirement' attribute contains the Euro value that the respondent was required to pay to join the hypothetical investment. Additionally, within S_n we include option-specific constants for options A and B (with option C as the omitted category), and in the full sample model we include country-level fixed effects, together these variables control for any systematic response biases due to unobserved factors at the country (e.g. financial culture) or choice option (e.g. ordering of options)[5].

The outcome stemming from this initial estimation allows us to identify the most preferred set of variables expressed by the average individual respondent from our full sample model. These

[5] There is no need to include additional scenario-specific variables in *S* (such as age, household income levels, gender, etc.); since at this stage we are primarily interested in aggregating results at the country-level, and generic country-level trends and characteristics are captured by country-level fixed effects.

variables are bundled together and used as the most preferred investment configuration that maximizes the probability of accepting an investment option by the average, representative individual for funding a CRE scheme, for each sampled country *N*.

Important to note that for the other two option-specific attributes in Z_{in} (holding period and profit rate) we select values reflecting the real market conditions and energy productivity ratings related to wind power technology of all EU-28 MSs. Therefore, the holding period is set at a conservative value of 20 years for all countries, as this reflects the working lifespan of wind turbines and the point at which they might get dismounted and either disassembled or refurbished [50]. The profit rate differs from country to country depending on variations of prevailing energy market conditions and different national wind energy productivity ratings. As shown in table A.2 (see Appendix), the calculation of the profit rates is thus conducted using country-specific values through the following process:

1) Firstly, the EU's total investments on wind energy for 2017 (€ 22.3 billion) are divided by its corresponding installed wind power capacity (11.5 GW) for that same year. The resulting figure (€ 1,939.13/kW) illustrates the European average of total installed generation capacity costs for wind energy[6], and used as the default value for all EU-28.
2) To obtain the country-specific productivity ratings of installed wind power capacity, the values from the wind energy generated (GWh) by each MS in 2017 are taken and divided by the country's installed wind power capacity (GW) for that same year.
3) The 2018 average spot electricity price (€/GWh) for each MS is then taken from the different electricity markets servicing the corresponding countries.
4) Taking the information obtained in steps 2-3, we calculate each country's average annual revenue (expressed in EUR) from the generation and sale of energy per GW of installed wind power capacity.
5) With this information, the market profit rates for each country are calculated as follows:

$$profit = \frac{avg.\, annual\; revenue - installed\; capacity\; costs}{installed\; capacity\; costs} \times 20\; years\; \times 100$$

Adding the 'holding period' and 'profit rate' variables to the most preferred investment configuration by the average individual CE participant results in: *a 20-year investment into a*

[6] Our resulting figure reflects IRENA's [83] own value for the total installed costs for onshore wind projects in Europe during 2018.

visible wind farm managed by a community administrator and with a market-determined profit rate.

3.1.2. Step 2: Imputing the probability of accepting an investment option

Following from step 1, we input the most preferred attribute levels identified and defined in Step 1 into equation (4), and compute the probability P_N of accepting the most preferred investment configuration outlined above. Important to note that up until this stage we have not yet considered the other critical quantity for estimating the individual social potential (π_N); that is, the average capital invested per person (b_N). We show this formally in equation (5) by expressing P_N *as* a linear function of the capital requirement b_N of the selected investment option and the market-determined profit rate r offered along with b_N.

$$P_N = \widehat{F_N} + \hat{\gamma}_{1N} b_N + \hat{\gamma}_{2N}(b_N r_N) \quad (5)$$

$$P_N = \widehat{F_N} + b_N(\hat{\gamma}_{1N} + \hat{\gamma}_{2N} r_N)$$

We estimate $\hat{F}_N$ as imputed choice probabilities under the preferred investment configuration defined under Step 1 using parameter estimates from country-specific MNL models that contain variables of all the attributes listed in table 1. In the imputation of choice probabilities the option-specific variables Z_{in} and scenario-specific variables S_n are set as to make equation (5) true even when there is a capital requirement asked for of $b_N = 0$. Therefore, $\hat{F}_N$ depicts the imputed probability of choosing option A or B under the most preferred investment configuration defined in Step 1 and a capital requirement of zero. Thus, we account for feasible values of all attributes from table 1 except for the capital requirement – which we allow to vary under a two-variable maximization framework described in Step 3. For this application, the settings for imputing $\hat{F}_N$ illustrate a visible wind farm with a 20-year holding period, managed by a community administrator and with an initial capital requirement of zero. We re-estimate equation (4) 28 times (one for each country N in the sample), imputing $\hat{F}_N$ in each case and estimating $\hat{\gamma}_{1N}$ and $\hat{\gamma}_{2N}$, the estimated marginal effects on the probability of choosing option A or B for a unit increase in capital requirement and profit rate, respectively.

3.1.3. Step 3: Maximising the expected funds collected per country

The outcome of step 2 above allows to now calculate the optimal investment requirement to ask from the representative individual in each nation N based on the most preferred variables inputted in the simulation of the MNL model. We thus define $\tilde{\pi}_N$ as the country N's 'social potential' for investing and participating in community-administered wind farm cooperatives, with pop_N indicating country *N*'s population with a reasonable expectation to invest (ages 25-64)[7].

$$\tilde{\pi}_N = (P_N b_N)\ pop_N \tag{6}$$

In spite of our goal to maximise $\tilde{\pi}_N$, for now we ignore the population component and return to π_N from (2), which considers only the representative individual from each sampled nation. We thus face a two-variable maximization problem, where we aim to maximise (2) with respect to the representative probability P_N and capital requirement $b_{N,}$ yet constrained by the relationship in (5). Substituting (5) into (2) we arrive at (7):

$$\pi_N = b_N\left[\hat{F}_N + b_N(\hat{\gamma}_{1N} + \hat{\gamma}_{2N} r_N)\right] \tag{7}$$

Taking the first derivative of (7) with respect to b_n we obtain (8):

$$\frac{\alpha\pi}{\alpha b} = \hat{F}_N + 2b_N(\hat{\gamma}_{1N} + \hat{\gamma}_{2N} r_N) \tag{8}$$

By setting (8) equal to zero and solving for b_N we obtain an analytical solution for the optimal capital requirement (expressed as b_N^*) that maximises the expected capital offering $\tilde{\pi}_N$ that the representative individual from country *N* is willing to provide[8]:

$$b_N^* = \frac{-\hat{F}_N}{2(\hat{\gamma}_{1N} + \hat{\gamma}_{2N} r_N)}$$

The optimal capital requirement b_N^* is input back into equation (5) and solved in order to obtain the probability P_N^* that a representative citizen of country *N* chooses to invests capital level b_n^* into a community-administered wind farm, with a 20-year holding period and a market-based profit rate. Inputting b_N^* and P_N^* into (6) and solving results in the final estimation of the social potential ($\tilde{\pi}_N$) for investing and participating in community-administered wind farms in each nation *N*.

3.2. Quantifying the RE generation and GHG abatement potentials

The second stage in our analytical procedure utilises the calculated social potential of each MS as the starting point to quantify the GHG abatement potential of individual citizens across the EU. In order to do so, we first quantify the installed wind power capacity (GW) that could be bought with the social potential of each MS derived from the total volume of individually

[7] For the purposes of this research, all individuals between 25-64 years of age were taken as the representative population with a reasonable expectation to invest for all 28 EU MSs sampled in the CE. Numbers were calculated based on national demographic data obtained from [37], [62].

[8] The $\pi_n(b_n)$ functions are concave down for each nation *N*, verifying that the analysis gives maximum values of these functions.

committed investments in community-administered wind farms. This is done by dividing the expected volume of funds collected per country (the social potential) by the European averaged total installed generation capacity costs for wind power technology (for this, we use €1,939.13/kW as the value derived from market data described in Step 1). With this, we obtain the installed wind power capacity (in MW) that could be purchased with the funds collected from the social potentials of each MS under current market conditions.

Country-specific wind power capacities are then combined with national energy productivity ratings to quantify the RE generated annually from the installed wind power capacity obtained for each MS and across the EU. Building on this calculation, we then input the RE generated into each country's 2017 gross final energy consumption serviced by RES in order to quantify the (percentage) increase in the share of RE consumption within each country's total gross final energy consumption (see Table A.5 in Appendix for details). This allows for quantifying the impact that the energy generated from citizen-financed CRE schemes would have, not only for increasing the share of RES within each country's total gross final energy consumption, but also for reaching national and EU-wide 2020 and 2030 RES targets (see figure 3 below).

Finally, country-specific annual RE generation profiles are combined with country-specific carbon intensities[9]. These are obtained by taking the aggregated emission factors of the fuel mixes of national energy portfolios and subtracting the carbon intensity derived from wind energy generation. The resulting *net* carbon intensities of national energy portfolios are then multiplied by their corresponding annual RE generation profiles derived from the total social potential for CRE investments in each MS. This results in the GHG emissions that could potentially be abated[10] annually through the generation of wind energy collectively financed by individual citizens in each MS – assuming that the RE produced offsets the electricity consumption derived from conventional fuels within the fuel mix of national energy generation portfolios.

[9] Expressed in tonnes of CO_2 equivalent per megawatt hour (tCO_2-eq/MWh). Taken from [56].
[10] Expressed in tonnes and million tonnes of CO_2 equivalent (t/Mt CO_2-eq).

4. Results

4.1 The most preferred investment attributes

Following from Step 1, we report the results of an initial estimation of the MNL in (4) on the full dataset from all 28 EU MSs. The coefficients of the attribute variables ($\boldsymbol{\beta}$ and $\boldsymbol{\alpha}_i$ effects) are converted into marginal effects and shown in table 3 below.

Table 3. Marginal effect on probability of selecting option C, the opt-out response (i.e. choosing not to invest) across full sample. Variables correspond to the CE attributes in table 1. Model estimated using 389,640 observations from 129,880 choice scenario responses from 16,235 respondents. Model also contains country fixed effects terms. Standard errors are estimated with clustering at the respondent level.

Variable	**Coefficient**	**Std. Err.**	**P-value**
Capital requirement	-0.00006	2.10E-06	0
Profit	0.00027	3.70E-06	0
Holding period	-0.0217	0.0003	0
Visibility	0.0059	0.0019	0.002
Solar farm	-0.0177	0.0019	0
Gov. admin.	-0.0025	0.0026	0.342
Community admin.	0.0315	0.0026	0

Table 3 shows that, on average, European citizens strongly prefer a community-owned legal entity (e.g. energy cooperative) for administering the RE installation they invest in over government or utility company administrators, and slightly prioritise a company-managed RE installation before a government-administered alternative. In spite of high heterogeneity, we observe a slight overall inclination for wind farms over solar parks as the preferred technology to invest in; this is likely highly region-specific as explored in [27]. European citizens are also more willing to invest if they see the RE installation from their household. As expected, higher profit rates make the investments more preferable. Specifically, for every additional €100 obtained as profit, we observe a corresponding 2.7% increase in willingness to invest. Finally, longer holding periods make investment options less attractive: willingness to invest decreases by 2.2% for each added year that the respondent's capital is held.

These attributes represent the most preferred variables that, when combined with the market-derived values obtained for the 'holding period' and 'profit rate' variables, maximise the level of investment collected by the average representative individual citizen in every MS and across the EU. Conclusively, the 'optimal' investment option that maximises the probability the average European citizen co-invests in a CRE initiative showcases a *20-year investment on a community-administered wind farm (e.g. energy cooperative), visible to the investor, and offering* *a country-specific market-based (unsubsidized) annual profit rate* for all cases. Profit rates differ from country to country depending on variations of prevailing energy market conditions and different national wind energy productivity ratings, and are illustrated in table A.2 (see Appendix).

4.2 The social potential for wind farm cooperatives in the EU-28

Estimating CE participants' responses to the optimal investment scenario identified above, and combining these with country-specific profit rates as shown in table A.2 (see Appendix), results in the expected maximum amount of funds that can be collected from each individual in every EU MS. Individually-obtained funds are then multiplied by each country's population with a reasonable expectation to invest (aged between 25-64) to obtain the social potential of each MS. The results obtained at the conclusion of this analytical process and the summations across the entire EU-28 are illustrated in table 4 below.

Table 4. The social potential of the EU-28 under market-based investment profit rates (calculated in table A.2 under Appendix).

Country	Optimal capital requirement* (b_N^*)	Probability of investing (P_N^*)	Expected collection per citizen (π_N)	Pop. expected to invest** (pop_N)	Social potential: total expected funding collected***($\tilde{\pi}_N$)
Austria	€ 3,560.18	21.20%	€ 754.73	4,877,713	€ 3,681.35
Belgium	€ 3,087.35	12.01%	€ 370.94	6,016,415	€ 2,231.73
Bulgaria	€ 4,050.47	22.80%	€ 923.66	3,969,939	€ 3,666.87
Croatia	€ 8,526.89	35.05%	€ 2,988.28	2,268,200	€ 6,778.03
Cyprus	€ 2,797.81	28.93%	€ 809.47	465,867	€ 377.11
Czech Rep.	€ 2,747.61	16.70%	€ 458.86	5,934,718	€ 2,723.21
Denmark	€ 6,383.83	13.53%	€ 863.51	2,949,119	€ 2,546.58
Estonia	€ 5,955.53	34.68%	€ 2,065.57	718,337	€ 1,483.78
Finland	€ 2,466.23	14.28%	€ 352.22	2,828,695	€ 996.32
France	€ 2,774.88	13.47%	€ 373.90	33,896,476	€ 12,674.02
Germany	€ 3,488.24	12.99%	€ 453.20	45,221,866	€ 20,494.59
Greece	€ 3,127.40	27.02%	€ 845.09	5,804,056	€ 4,904.92
Hungary	€ 2,908.52	20.93%	€ 608.66	5,457,241	€ 3,321.61
Ireland	€ 3,110.32	13.99%	€ 435.22	2,545,292	€ 1,107.77
Italy	€ 3,622.99	23.00%	€ 833.32	32,960,658	€ 27,466.93
Latvia	€ 2,740.04	14.73%	€ 403.72	1,070,614	€ 432.23
Lithuania	€ 4,082.34	21.51%	€ 878.10	1,540,716	€ 1,352.90
Luxembourg	€ 3,562.16	26.02%	€ 926.85	340,815	€ 315.88
Malta	€ 3,536.38	18.42%	€ 651.29	254,544	€ 165.78
Poland	€ 4,287.00	18.41%	€ 789.08	21,758,508	€ 17,169.12
Portugal	€ 3,480.66	20.85%	€ 725.77	5,587,789	€ 4,055.46

Romania	€ 6,444.75	30.00%	€ 1,933.45	10,992,372	€ 21,253.21
Slovakia	€ 2,745.70	15.52%	€ 426.25	3,168,805	€ 1,350.69
Slovenia	€ 4,517.52	26.68%	€ 1,205.23	1,171,362	€ 1,411.76
Spain	€ 3,013.60	15.94%	€ 480.38	26,194,723	€ 12,583.30
Sweden	€ 4,248.38	15.19%	€ 645.49	5,087,533	€ 3,283.94
Netherlands	€ 3,729.50	15.07%	€ 562.16	9,036,117	€ 5,079.75
UK	€ 2,724.97	14.35%	€ 391.12	34,154,649	€ 13,358.72
EU-28	**€ 3,847.19**	**20.12%**	**€ 638.02**	**276,273,139**	**€ 176,267.55**

* *wind farm, 20-year holding period, market-based profit rate, visible, community-administered*
** *aged between 25-64*
*** *in millions of EUR*

Results indicate a substantial EU social potential for citizen-led financing of community-administered wind farm cooperatives under current market conditions – that is, without subsidies or any other national support mechanism. We calculate that €176 billion could potentially be harnessed from European citizens to support community-based forms of RE development, and thereby increase the deployment of clean energy and expedite Europe's low-carbon energy transition.

The imputed probability that a given respondent accepts the ideal investment option is of 20% across the entire sample. With the caveat that this average probability is not weighted by country population sizes, this result suggests that about one in five European citizens would be willing to invest in a feasibly configured community-administered wind farm development. We note the heterogeneity in the expected collection per citizen (π_N), where generally nations with lower wind power capacities show higher acceptance rates. This corresponds with the descriptive results obtained from the CE responses (table 2), which we interpret as an increased interest from citizens in EU MSs with low wind power capacities to have access to low-risk, trustworthy investment options in this technology.

4.2.1 Bridging the investment gap

As shown in figure 2 below, current estimates indicate an investment gap of €179 billion annually to achieve the EU's 2030 climate and energy targets [1], [6]. No less than 9% of the foreseen annual investments over the next 10 years (2020-2030) – at least €34 billion annually – will have to finance the deployment of RE generation capacity in order to reach a 32% share of the EU's gross final energy consumption by 2030 [5]. This translates into a cumulative investment of €340 billion over the next decade, and positions the EU's social potential of €176 billion for investing and participating in CRE as a potentially critical resource to bridge the existing financing gap.

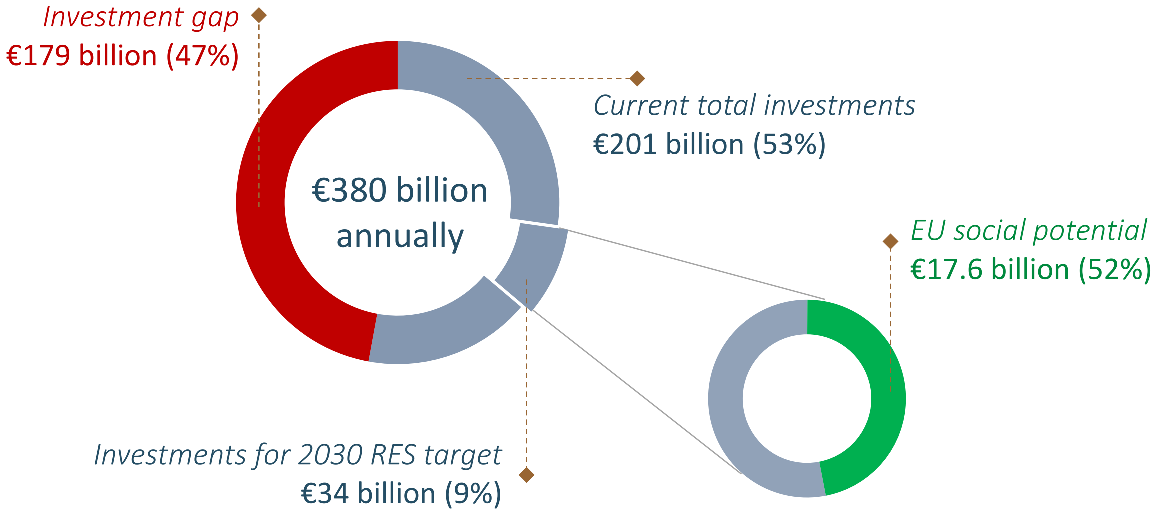

Figure 2. Estimated annual investments between 2019-2030 to achieve EU 2030 climate & energy targets, with specific investment requirements to reach 2030 RES target, plus annual contribution from EU social potential.

As depicted in figure 2 above, the social potential of €176 billion that European citizens could contribute with through collective investment schemes in CRE respond directly to this need. When evenly distributed throughout the 10-year timespan mentioned above, they result in an annual investment of €17.6 billion, enough to halve the investment requirements foreseen to achieve a 32% RES share by 2030. In light of this huge potential, the EU's energy-related carbon mitigation efforts could greatly benefit from the proactive financial participation and involvement of European citizens. Policies that reach out to and unlock this potential are therefore desirable and should be carefully considered for a timely, cost-effective, and participatory implementation of a low-carbon energy system. This is further explored in section 5 below.

4.2.2 GHG abatement potential from citizen-financed wind farms

Following the process outlined in section 3.2, the EU's social potential for co-financing wind farms would be sufficient to "purchase" a total of 90,900 MW of wind power capacity across the entire EU. This represents a larger volume than the national electricity generation capacities of 24 different MSs [51].

When multiplied by their corresponding national wind energy productivity ratings, the installed wind power capacities from each country's social potential yield the final RE (in GWh) generated annually by each MS and across the EU. Building on this initial calculation, the RE generated is input into each country's 2017 gross final energy consumption serviced by RES in order to quantify the increase that the share of RES consumption would experience in each country's total gross final energy consumption if the social potential were realized. This is illustrated in figure 3 below.

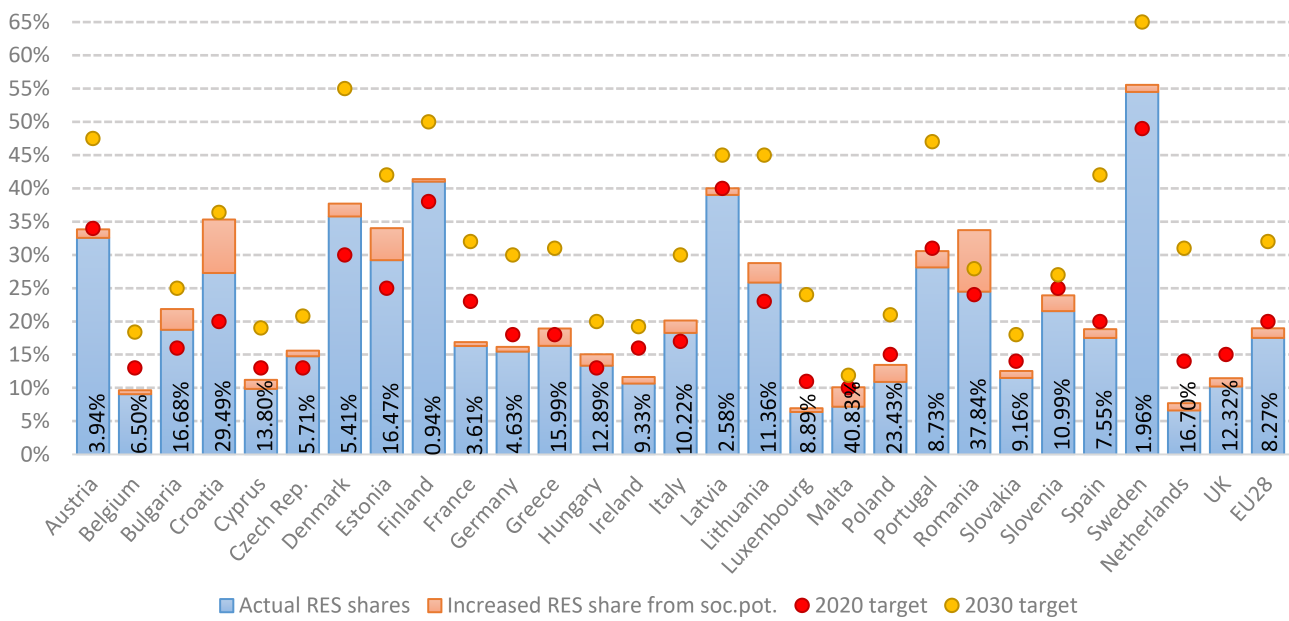

Figure 3. Renewable energy shares (2017) and percentage increase from social potential under current market conditions (subsidy-free) in every Member State and aggregated at EU level; plus 2020 & 2030 national and EU-wide renewable energy targets[11] (own calculations and elaboration based on table 5 figures and [2], [51]–[53]. See Table A.5 in the Appendix for details).

Results indicate an average 8.3% increase in the consumption of RES across the EU when the social potential for co-financing community-administered wind farms is included. As shown in Table A.5 (Appendix), this translates into a total of 196 TWh of additional energy consumed. Assuming such consumption does not add to – but instead substitutes – 196 TWh of energy consumed from conventional energy sources, the GHG emissions that could be potentially abated amount to 103.4 MtCO_2-eq annually (table 5 below). This represents a 2.4% reduction in annual emissions from 2018 EU aggregate levels[12] and over 3% of the GHG emissions stemming from the energy sector in 2018 [54]. While this reduction in emissions is a substantial improvement expediting the projected pace of emission reductions, it is by no means sufficient to put the EU on track to achieve its 2030 GHG reduction target. The EU would still need to abate an additional 274 MtCO2-eq per annum to achieve a 40% reduction by 2030 [55]. The EU should therefore adopt

[11] UK's 2030 RES target not reported in its National Energy and Climate Plan (NECP) nor submitted to the EU.
[12] Excluding international aviation/shipping and LULUCF emissions, including indirect CO_2 emissions.

additional carbon reduction measures in order to successfully decarbonize its economy and realise an emissions reduction pathway sharp enough to operate within an ‘EU carbon budget’ of around 96 $GtCO_2$ per annum [4].

Table 5. Analysis of the annual GHG abatement potential from realizing the social potential for wind-farm cooperatives (own calculations with input data from [56] as described in Section 3.2).

Country	Energy generated annually (GWh)	Net carbon intensities**	Annual GHG abatement potential***
Austria	4,366.03	0.201	877,572
Belgium	2,503.00	0.229	573,187
Bulgaria	3,959.85	0.814	3,223,321
Croatia	6,722.33	0.218	1,465,467
Cyprus	259.73	0.807	209,602
Czech Rep.	2,653.28	0.840	2,228,756
Denmark	3,543.27	0.370	1,311,011
Estonia	1,808.28	2.007	3,629,227
Finland	1,183.14	0.196	231,896
France	10,733.32	0.083	890,866
Germany	18,844.58	0.648	12,211,290
Greece	5,283.09	0.800	4,226,475
Hungary	3,838.02	0.287	1,101,513
Ireland	1,353.30	0.513	694,245
Italy	26,138.47	0.414	10,821,327
Latvia	493.07	0.173	85,302
Lithuania	1,901.10	0.118	224,330
Luxembourg	258.11	0.098	25,295
Malta	181.78	0.992	180,322
Poland	22,002.10	1.080	23,762,265
Portugal	4,774.17	0.358	1,709,154
Romania	26,580.88	0.522	13,875,218
Slovakia	1,393.09	0.231	321,804
Slovenia	1,387.15	0.414	574,281
Spain	13,395.95	0.333	4,460,851
Sweden	4,373.01	0.028	122,444
Netherlands	6,481.12	0.476	3,085,013
UK	19,439.32	0.579	11,255,365
EU28	**195,850.57**	**0.494**	**103,377,398**

*** expressed in tonnes of CO_2 equivalent per megawatt hour (tCO_2-eq/MWh), from [56].*

**** expressed in tonnes of CO_2 equivalent (tCO_2-eq)*

4.2.3 Limitations and caveats

The analytical process and simulation procedure for estimating the social potential is subject to various caveats. Most notably, realizing the social potentials shown in table 4 requires that all citizens have access to community investment options provided by reliable institutions. This is not currently the case in all EU MSs.

Furthermore, the CE is designed to have changing profit rates according to different national market conditions, but the holding period is fixed for every country at 20 years. Switching to a non-fixed holding period for the simulation procedure would provide a more flexible maximization framework that would most likely result in a generalised increase of the estimated social potentials for every sampled country.

The same rationale could be employed when calibrating the ‘RE technology’ variable: based on the responses obtained, the analytical process takes the most preferred RE technology/installation on average across the EU-28, despite the potential for regional heterogeneity in this dimension. The proposed SBSS methodology allows for a more refined analysis by disaggregation in many dimensions, including in the dimension of the preferred RE technology on a country basis to determine whether some countries prefer solar or wind technologies. This might lead, again, to an overall increase of the estimated social potential (albeit only in countries with a strong preference for solar investments). The CE gave each respondent eight choice scenarios, but stipulated that the respondent consider them separately, not as additional investments to those already chosen in the exercise. For this reason, we only consider one RE technology (wind) as the object of investment. Simultaneously considering solar would violate this condition of the CE and in effect ‘double-count’ the willingness of respondents to participate in some CRE schemes.

In the same vein, the optimal capital requirement was calculated to be nation-specific, as our analysis focuses on the representative individual of each sampled country. However, future SBSS work could further disaggregate by income bracket, gender or age. In the present case this would result in a more appealing investment proposition being offered to different groups of citizens and would again likely lead to an overall increase in the estimated social potential.

All these measures, when combined, would likely increase individual respondents’ investment probabilities, as well as the quantities willing to be invested. It would in turn increase countries’ social potentials and, consequently, the GHG abatement potential of individual citizens across the EU. In this regard, the current analysis is considered a conservative estimation.

It is also important to acknowledge the effects that a hypothetical bias may have in respondents' manifested choices according to potential deviations from actual investment behaviours when confronted with a similar investment proposition in a real-life situation. This might lead to an over-estimation of the social potentials of each MS, and therefore inaccurately depict the real level of interest and willingness to invest of the average individual respondent.

In an attempt to account for the effect of hypothetical bias in the CE, the survey asked respondents if they would like to share their email to receive information on actual investment options from companies that offer CRE investments. This exercise exposed respondents to a small real-world 'cost' of sifting through future emails, and served to measure the sincerity of their interest in the CRE investments options. Almost half (48%) of CE participants explicitly stated their interest in receiving such information periodically and allowed access to their email addresses. Although the high proportion of respondents sharing their email suggests a sincere interest in real-world CRE schemes, we detected some responses that were at odds with choice behaviour. In particular, 1,963 respondents who chose to invest in all eight choice scenarios but then did not give their email for follow-up; and 697 respondents who chose not to invest in all scenarios but then gave their email. We consider these two groups of respondents to be candidates for hypothetical bias. As a robustness check, we drop all 2,660 respondents from the sample and re-run the SBSS procedure detailed in section 3.1. The full results of this exercise are not reported for brevity (available upon request), but the final EU-28 social potential is estimated at €151 billion when the potentially biased responses are removed. This is a 14% decrease from the original €176 billion estimated in table 4, yet would still represent a substantial contribution for financing next decade's €340 billion required investment in RE capacity.

5. Discussion

It is important to note that the experimental design of the research presented herein assumes that all citizens have access to market information and community investment options provided by reliable institutions. Most notably, it guarantees a risk-free investment operationalised through a trustworthy and straightforward financial vehicle. These facts, along with the availability of multiple investment options, offers a plausible explanation for the substantial social potential and high acceptance rates expressed for the investment offerings. Therefore, the results outlined above substantiate the need to ensure that easily accessible, trustworthy, and risk-insured community investment options are available across EU MSs to unlock their social potentials for investing in

CRE. This section presents policy-relevant insights that would help move towards a risk-minimised regulatory environment for citizen-led RE finance and thus help satisfy the main policy recommendation that flows from our empirical analysis.

5.1 The effect of RE subsidies on the estimated social potential

In line with previous research on the role of financial participation in the social acceptance of RE [29], [31]–[33], the findings presented in this research suggest a tangible relationship between financial participation and co-ownership, and increased acceptance for localised forms of RE generation from European citizens.

It is important to highlight that the empirical analysis presented in this study estimates the EU's social potential for collectively investing in community-administered wind farm cooperatives *under current market conditions* – that is, without capital subsidies or any other national support mechanism for RE development such as feed-in policies, investment/production tax credits, or other fiscal incentives. Our results therefore stem from a conservative estimation and reflect a *subsidy-free* social potential. However, national support schemes to RE generation are commonly employed throughout the EU-28. In order to understand the potential of subsidy schemes to influence citizens' willingness to co-invest in a community-administered wind farm development, we perform a scenario analysis using the SBSS process.

In order to do so, we take current national RE subsidies [57] and use these to re-calculate the profit rates for wind energy generation, as explained in section 3.1 (see Table A.3. in Appendix for details). We then re-conduct the SBSS analytical procedure to assess the changes in each country's average respondent's probability of accepting the most-preferred investment option incorporating a subsidised (as opposed to market-based) profit rate for their investment, and quantify the resulting social potential stemming from those probability changes (see Table A.4 in Appendix for details).

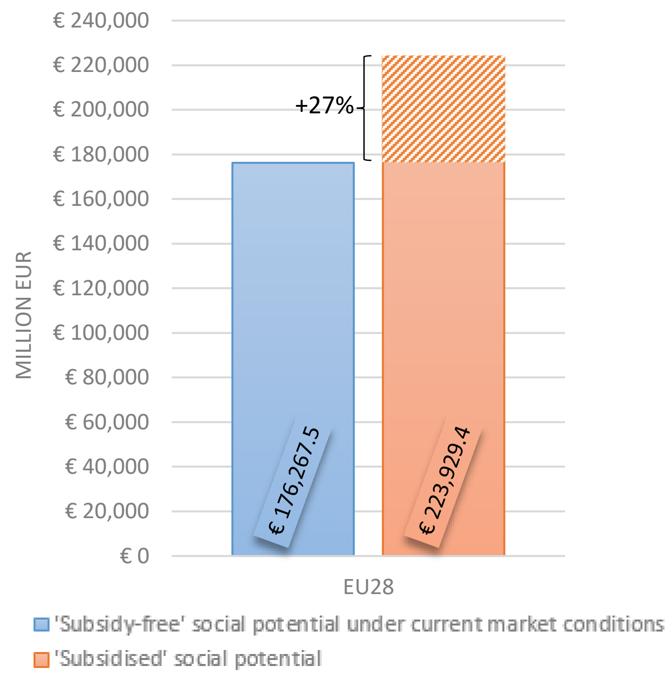

Figure 4. EU-wide estimated social potentials for funding CRE wind generation under current market conditions (subsidy-free) and with added 2016 national subsidies to support community renewable energy (own elaboration based on CE data and [37], [57]).

The results stemming at the conclusion of this analytical procedure indicate that a *subsidised* social potential would yield a 27% increase in the expected volume of citizen investments collected across the EU, and reach a total volume of €224 billion (figure 4). This equates to 1.3% of the EU's GDP in 2018. Thus, our social simulation results suggest that subsidies can play a role in increasing the total volume of CRE wind capacity realized. Though this result is still subject to the caveat discussed above, namely that citizens have access to, and awareness of, CRE investment options, policy strategies to make this a reality are discussed in the following sub-sections.

5.2 Regulatory risk, market instability and investor confidence

One possible reason for the high levels of interest observed in the CE may be the low-risk, stable framing of the investment options. As such, unlocking the EU's social potential may require a stable regulatory framework that facilitates market access and a level playing field for new market participants. Unstable regulatory frameworks imposing retroactive modifications to previously approved policies and RE support schemes would likely increase regulatory risk and reduce the market acceptance for RE investments. Similarly, uncertain revenue projections stemming from volatile electricity prices and fully exposed investments to market risk would substantially challenge the business case for local scale RE development and likely reduce investor appetite for CRE. Both regulatory and market risks would violate the conditions of the choice experiment and add significant uncertainty to the investment, which has been shown to reduce participation in the case of household RE adoption [59].

Appropriate revenue mechanisms may therefore prove a critical element in creating a risk-contained environment for citizen-led finance in CRE. In that respect, the results from this study substantiate the case for tailoring national RE support mechanisms according to the specific cost structures and unique financial, material and operational capabilities of a more diverse set of market participants involving less-experienced CRE entitites, along with more traditional, larger RE developments. The EU's current climate and energy regulatory framework, NECPs and related set of RE support mechanisms do not address this need successfully [2], [3], [60] and, as such, undermine the ability of European citizens to partake in CRE schemes and co-benefit from Europe's low-carbon energy transition.

5.3 Citizen agency in the energy transition

These insights attempt to contextualize this research into the ongoing transformation that energy markets must undergo for accommodating the transition to a low-carbon energy system with an increasingly diverse set of actors combining traditional players with newly emerging market participants. In that respect, the idea of *social potential* developed through this research may serve as a useful conceptual tool to further explore how the Energy Union's regulatory framework can be operationalised for supporting more inclusive and participatory pathways towards a decarbonised energy future. Collective finance for alternative energy generation schemes shaped by collaborative dynamics around local communities offers a vehicle of collective action leading to such citizen empowerment and the development of shared agency.

Extending the availability and awareness of CRE investment options could be a potentially resourceful approach in promoting the uptake of CRE schemes throughout Europe. Specifically, the provision of easily accessible, trustworthy, and low-risk community investment options and revenue mechanisms may be a viable means to expedite the pace of RES deployment and increase citizen participation through community-based forms of energy generation. The extent of citizenry empowerment and collective agency derived from €176 billion in potential CRE investment may prove a pivotal element for redefining Europe's Energy Union from a political commitment to a citizen endeavour where "citizens take ownership of the energy transition, benefit from new technologies [and] participate actively in the market" [8, p. 2].

6. Conclusion

This study quantifies the social potential for participating in CRE investments to assess the feasibility of citizen-driven financing to bridge the next decade's investment gap for a decarbonised energy system. Using responses obtained from an international survey and choice experiment across all EU-28, a novel Survey-Based Social Simulation (SBSS) quantification method is developed and illustrated. The method relies on estimating the probability that the average representative citizen in each nation would participate in a CRE scheme with optimal investment and operational characteristics. These probabilities are imputed using a probabilistic discrete choice model anchored in economic random utility theory.

The results obtained indicate a substantial social potential of €176 billion that could be harnessed from European citizens willing to co-finance community-administered wind energy cooperatives with market-based rates of return. Realizing this social potential would be enough to halve the investment requirements foreseen to achieve a 32% RES share by 2030, leading to an aggregated energy generation potential of 195,805 GWh every year. This translates into an annual GHG emissions abatement potential of over 103 MtCO2-eq for the entire EU, equalling to a 2.3% annual reduction in EU-28 GHG emissions from 2018 levels. Introducing current RE subsidy schemes in the simulation procedure would result in a 27% increase on the estimated social potential and reach a total volume of €224 billion.

In light of the substantial interest and potential for participation in CRE initiatives, EU energy and climate policy must strive to generate trustworthy financial vehicles, stable regulation, and low-risk market conditions. Such a climate would facilitate the incorporation of more innovative yet risk exposed CRE developers (e.g. energy cooperatives) and help to expedite the increased penetration of RE in the EU.

While the SBSS method is subject to caveats and assumptions discussed above, the development and application of this method herein illustrates its potential for contributing to social research questions as a counterpoint to the rising popularity of agent-based modelling (ABM). SBSS benefits from a standardized theoretical background (random utility theory) and data collection methodology (CE) *vis a vis* ABM. Whereas, ABM exhibits greater scope and flexibility in how research topics are addressed and how human behaviour is modelled. This flexibility also increases computational complexity especially of large-scale (e.g. EU-28) ABM endeavours that can make the problems intractable [61]. For such large-scale problems social scientists may consider applying the SBSS method and corresponding simplifying assumptions.

7. Author Contribution Statement

Cristian Pons-Seres de Brauwer: Conceptualisation, Writing - Original Draft, Formal Analysis, Visualisation, Writing - Review & Editing.

Jed J. Cohen: Methodology, Formal Analysis, Validation, Writing - Review & Editing,

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9. Data Availability

The full dataset and code can be made available upon request or, alternatively, uploaded to the journal's archives.

10. Declaration of Interest

The authors declare no competing interests.

References

[1] European Commission, "2030 climate & energy framework," 2018. [Online]. Accessed on 04/02/19. Available: https://ec.europa.eu/clima/policies/strategies/2030_en.

[2] European Commission, "REPORT FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE, THE COMMITTEE OF THE REGIONS AND THE EUROPEAN INVESTMENT BANK. Fourth report on the State of the Energy Union.," COM(2019) 175 final, 2019.

[3] European Commission, "Technical Note. Results of the EUCO3232.5 scenario on Member States," 2019.

[4] D. L. McCollum *et al.*, "Energy investment needs for fulfilling the Paris Agreement and achieving the Sustainable Development Goals," *Nat. Energy*, vol. 3, no. 7, pp. 589–599, Jul. 2018.

[5] R. Williams, L. Eichler, N. Gottmann, H. Förster, and A. Siemons, "Energy and the MFF," 2018.

[6] European Commission, "COMMISSION STAFF WORKING DOCUMENT IMPACT ASSESSMENT - Accompanying the document Proposal for a Regulation of the European Parliament and of the Council on the establishment of a framework to facilitate sustainable investment and Proposal for a Regulation ," SWD(2018)264/978675, 2018.

[7] European Commission, "IN-DEPTH ANALYSIS IN SUPPORT OF THE COMMISSION COMMUNICATION COM(2018) 773 - A Clean Planet for All: A European long-term strategic vision for a prosperous, modern, competitive, and climate neutral economy," 2018.

[8] European Commission, "ENERGY UNION PACKAGE. COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE, THE COMMITTEE OF THE REGIONS AND THE EUROPEAN INVESTMENT BANK. A Framework Strategy for a Resilient Energy Union w," COM(2015) 80 final, 2015.

[9] A. L. Berka and E. Creamer, "Taking stock of the local impacts of community owned renewable energy: A review and research agenda," *Renew. Sustain. Energy Rev.*, vol. 82, pp. 3400–3419, Feb. 2018.

[10] S. Breukers and M. Wolsink, "Wind power implementation in changing institutional landscapes: An international comparison," *Energy Policy*, vol. 35, no. 5, pp. 2737–2750, May 2007.

[11] P. Devine-Wright, "Local aspects of UK renewable energy development: exploring public beliefs and policy implications," *Local Environ.*, vol. 10, no. 1, pp. 57–69, Feb. 2005.

[12] Entwistle, "blablabla test."

[13] C. Haggett and M. Aitken, "Grassroots Energy Innovations: the Role of Community Ownership and Investment," *Curr. Sustain. Energy Reports*, vol. 2, no. 3, pp. 98–104, Sep. 2015.

[14] S. M. Hoffman and A. High-Pippert, "From private lives to collective action: Recruitment and participation incentives for a community energy program," *Energy Policy*, vol. 38, no. 12, pp. 7567–7574, Dec. 2010.

[15] G. Walker, P. Devine-Wright, S. Hunter, H. High, and B. Evans, "Trust and community: Exploring the meanings, contexts and dynamics of community renewable energy," *Energy Policy*, vol. 38, no. 6, pp. 2655–2663, Jun. 2010.

[16] B. Wiersma and P. Devine-Wright, "Decentralising energy: comparing the drivers and influencers of projects led by public, private, community and third sector actors," *Contemp. Soc. Sci.*, vol. 9, no. 4, pp. 456–470, Oct. 2014.

[17] Ö. Yildiz, "Financing renewable energy infrastructures via financial citizen participation – The case of Germany," *Renew. Energy*, vol. 68, pp. 677–685, Aug. 2014.

[18] Ö. Yildiz *et al.*, "Renewable energy cooperatives as gatekeepers or facilitators? Recent developments in Germany and a multidisciplinary research agenda," *Energy Res. Soc. Sci.*, vol. 6, pp. 59–73, Mar. 2015.

[19] M. Bolinger, "Community wind power ownership schemes in Europe and their relevance to the United States," United States, 2001.

[20] R. Madlener, “Innovation diffusion, public policy, and local initiative: The case of wood-fuelled district heating systems in Austria,” *Energy Policy*, vol. 35, no. 3, pp. 1992–2008, Mar. 2007.
[21] Torgerson, “blablabla test 2.”
[22] G. Walker, “What are the barriers and incentives for community-owned means of energy production and use?,” *Energy Policy*, vol. 36, no. 12, pp. 4401–4405, Dec. 2008.
[23] E. Bomberg and N. McEwen, “Mobilizing community energy,” *Energy Policy*, vol. 51, pp. 435–444, Dec. 2012.
[24] J. C. Rogers, E. A. Simmons, I. Convery, and A. Weatherall, “Social impacts of community renewable energy projects: findings from a woodfuel case study,” *Energy Policy*, vol. 42, pp. 239–247, Mar. 2012.
[25] J. C. Rogers, E. A. Simmons, I. Convery, and A. Weatherall, “What factors enable community leadership of renewable energy projects? Lessons from a woodfuel heating initiative,” *Local Econ. J. Local Econ. Policy Unit*, vol. 27, no. 2, pp. 209–222, Mar. 2012.
[26] S. M. Hoffman and A. High-Pippert, “Community Energy: A Social Architecture for an Alternative Energy Future,” *Bull. Sci. Technol. Soc.*, vol. 25, no. 5, pp. 387–401, Oct. 2005.
[27] J. Cohen, A. Kollmann, J. Reichl, and V. Azarova, “Preferences for community renewable energy investments in Europe: A choice experiment across 31 European nations,” *Zenodo*, 2019.
[28] S. Hall, T. J. Foxon, and R. Bolton, “Financing the civic energy sector: How financial institutions affect ownership models in Germany and the United Kingdom,” *Energy Res. Soc. Sci.*, vol. 12, pp. 5–15, Feb. 2016.
[29] M. Aitken, “Wind power and community benefits: Challenges and opportunities,” *Energy Policy*, vol. 38, no. 10, pp. 6066–6075, Oct. 2010.
[30] T. Bauwens and P. Devine-Wright, “Positive energies? An empirical study of community energy participation and attitudes to renewable energy,” *Energy Policy*, vol. 118, pp. 612–625, Jul. 2018.
[31] G. Hübner, E. Löffler, N. Hampl, and R. Wüstenhagen, “Wirkungen von Windkraftanlagen auf Anwohner in der Schweiz: EINFLUSSFAKTOREN UND EMPFEHLUNGEN,” 2013.
[32] N. Lienhoop, “Acceptance of wind energy and the role of financial and procedural participation: An investigation with focus groups and choice experiments,” *Energy Policy*, vol. 118, pp. 97–105, Jul. 2018.
[33] D. Toke, “Explaining wind power planning outcomes:: some findings from a study in England and Wales,” *Energy Policy*, vol. 33, no. 12, pp. 1527–1539, Aug. 2005.
[34] B. Kampman, J. Blommerde, and M. Afman, “The potential of energy citizens in the European Union,” 16.3J00.75, 2016.
[35] W. F. Kuhfeld, R. D. Tobias, and M. Garratt, “Efficient Experimental Design with Marketing Research Applications,” *J. Mark. Res.*, vol. 31, no. 4, pp. 545–557, Nov. 1994.
[36] [dataset] Eurostat, “Electricity production capacities of renewables and waste.” 2019. nrg_inf_epcrw
[37] [dataset] Eurostat, “Population on 1 January.” 2019. tps00001
[38] J. Cohen, K. Moeltner, J. Reichl, and M. Schmidthaler, “An Empirical Analysis of Local Opposition to New Transmission Lines Across the EU-27,” *Energy J.*, vol. 37, no. 3, Jul. 2016.
[39] T. Bauwens, B. Gotchev, and L. Holstenkamp, “What drives the development of community energy in Europe? the case of wind power cooperatives,” *Energy Res. Soc. Sci.*, vol. 13, pp. 136–147, Mar. 2016.
[40] L. Laybourn-Langton, “Community and Local Energy Challenges and Opportunities,” 2016.
[41] J. McLaren Loring, “Wind energy planning in England, Wales and Denmark: Factors influencing project success,” *Energy Policy*, vol. 35, no. 4, pp. 2648–2660, Apr. 2007.
[42] M. Hildebrandt, “Hard times for wind power,” *New Energy*, Aug-2019.
[43] WindEurope, “Collapse in wind energy growth jeopardises German and EU renewables targets,” 2019. [Online]. Accessed on 13/10/19. Available: https://windeurope.org/newsroom/press-releases/collapse-in-wind-energy-growth-jeopardises-german-and-eu-renewables-targets/.
[44] A. Wierling *et al.*, “Statistical Evidence on the Role of Energy Cooperatives for the Energy

Transition in European Countries," *Sustainability*, vol. 10, no. 9, p. 3339, Sep. 2018.
[45] W. Adamowicz, P. Boxall, M. Williams, and J. Louviere, "Stated Preference Approaches for Measuring Passive Use Values: Choice Experiments and Contingent Valuation," *Am. J. Agric. Econ.*, vol. 80, no. 1, pp. 64–75, Feb. 1998.
[46] N. Hanley, R. E. Wright, and V. Adamowicz, "Using choice experiments to value the environment: Design issues, current experience and future prospects," in *Environmental and Resource Economics*, 1998, vol. 11, no. 3–4, pp. 413–428.
[47] J. J. Louviere, T. N. Flynn, and R. T. Carson, "Discrete choice experiments are not conjoint analysis," *J. Choice Model.*, vol. 3, no. 3, pp. 57–72, 2010.
[48] C. F. Manski, "The structure of random utility models," *Theory Decis.*, vol. 8, no. 3, pp. 229–254, Jul. 1977.
[49] D. McFadden, "The Choice Theory Approach to Market Research," *Mark. Sci.*, vol. 5, no. 4, pp. 275–297, Nov. 1986.
[50] R. Wiser and M. Bolinger, "2017 Wind Technologies Market Report," 2018.
[51] [dataset] Eurostat, "Electricity production capacities by main fuel groups and operator." 2019. nrg_inf_epc
[52] [dataset] Eurostat, "Population by age group." 2019. tps00010
[53] European Commission, "National Energy and Climate Plans," 2019. [Online]. Accessed on 21/04/19. Available: https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/governance-energy-union/national-energy-climate-plans.
[54] European Environment Agency, "Annual European Union approximated greenhouse gas inventory for the year 2018.," EEA Report No 16/2019, 2019.
[55] European Environment Agency, "Trends and Projections 2019 - Tracking progress towards climate and energy targets in Member States.," *Country profiles - greenhouse gases and energy 2019*, 2019. [Online]. Available: https://www.eea.europa.eu/themes/climate/trends-and-projections-in-europe/climate-and-energy-country-profiles.
[56] B. Koffi, A. Cerutti, M. Duerr, A. Iancu, A. Kona, and G. Janssens-Maenhout, "CoM Default Emission Factors for the Member States of the European Union." European Commission, Joint Research Centre (JRC) [Dataset], 2017.
[57] Council of European Energy Regulators, "Status Review of Renewable Support Schemes in Europe for 2016 and 2017.," C18-SD-63–03, 2018.
[58] International Renewable Energy Agency, "Renewable Capacity Statistics 2018," 978-92-9260-057–0, 2018.
[59] C. Bauner and C. L. Crago, "Adoption of residential solar power under uncertainty: Implications for renewable energy incentives," *Energy Policy*, vol. 86, pp. 27–35, Nov. 2015.
[60] J. Roberts, "Promoting citizen participation in the energy transition: recommendations for an EU legal framework to support community energy," 2015.
[61] R. Conte and M. Paolucci, "On agent-based modeling and computational social science," *Front. Psychol.*, vol. 5, Jul. 2014.
[62] [dataset] Eurostat, "Baseline projections: demographic balances and indicators." 2019. proj_15ndbims
[63] Central Intelligence Agency, "The World Factbook - Central Intelligence Agency," 2018. [Online]. Accessed on 07/03/19. Available: https://www.cia.gov/library/publications/resources/the-world-factbook/.
[64] [dataset] Eurostat, "Distribution of income by quantiles - EU-SILC and ECHP surveys." 2019. ilc_di01
[65] [dataset] Eurostat, "Women per 100 men." 2019. tps00011
[66] International Energy Agency, "Renewables Information 2018," 2018.
[67] [dataset] Eurostat, "Supply of electricity - monthly data." 2019. nrg_105m
[68] WindEurope, "Wind in Power 2017: Annual combined onshore and offshore wind energy statistics," 2018.

[69] International Energy Agency Wind Technology Collaboration Programme, “Annual Report 2017,” 2018.
[70] EPEX SPOT, “Market Data,” 2019. [Online]. Accessed on 07/03/19. Available: https://www.epexspot.com/en/.
[71] OMI-Polo Português, “Market Data - Spot Prices,” 2019. [Online]. Accessed on 07/03/19. Available: https://www.omip.pt/es.
[72] OMI-Polo Español, “Market Results,” 2019. [Online]. Accessed on 07/03/19. Available: http://www.omie.es/en.
[73] BORZEN SouthPool Energy Exchange, “Market Monitoring - News,” 2019. [Online]. Accessed on 07/03/19. Available: https://www.bsp-southpool.com/home.html.
[74] Independent Bulgarian Energy Exchange, “Market Data,” 2019. [Online]. Accessed on 07/03/19. Available: http://www.ibex.bg/en.
[75] Croatian Power Exchange, “Market Data,” 2019. [Online]. Accessed on 07/03/19. Available: https://www.cropex.hr/en/.
[76] Electricity Authority of Cyprus, “Wholesale Tariff 2019,” 2019. [Online]. Accessed on 07/03/19. Available: https://www.eac.com.cy/EN/CustomerService/Tariffs/Pages/ditimisihondrikis.aspx.
[77] Power Exchange Central Europe, “Market Data,” 2019. [Online]. Accessed on 07/03/19. Available: https://www.pxe.cz/?language=english.
[78] Nord Pool, “Market Data,” 2019. [Online]. Accessed on 07/03/19. Available: https://www.nordpoolgroup.com/.
[79] Hellenic Energy Exchange, “Market Analysis,” 2019. [Online]. Accessed on 07/03/19. Available: http://www.enexgroup.gr/en.
[80] European Network of Transmission System Operators for Electricity, “Transparency Platfrom - Day Ahead Prices,” 2019. [Online]. Accessed on 07/03/19. Available: https://transparency.entsoe.eu/dashboard/show.
[81] Gestore dei Mercati Energetici SpA, “Electricity Markets - Statistical Data,” 2019. [Online]. Accessed on 07/03/19. Available: http://www.mercatoelettrico.org/En/Default.aspx.
[82] Eurostat, “SHARES (Renewables),” 2018. [Online]. Accessed on 07/03/19. Available: https://ec.europa.eu/eurostat/web/energy/data/shares.
[83] International Renewable Energy Agency, “Renewable Power Generation Costs in 2018,” 978-92-9260-126–3, 2019.

Appendix

Table A.1. Set of quotas drawn from sociodemographic indicators included in the survey sampling process to ensure population representability (own elaboration based on [52], [62]–[65]).

Country	**Indicator**					
	age		*gender*		*monthly income*	
	mean age in sample	*median age of population*	*% males in sample*	*% males of population**	*Sample***	*population****
Austria	42.8	43.2	53%	49%	€ 1,487	€ 2,063
Belgium	42.0	41.6	50%	49%	€ 1,543	€ 1,899
Bulgaria	42.6	44.2	50%	49%	€ 324	€ 299
Croatia	42.6	43.5	50%	49%	€ 465	€ 518
Cyprus	42.2	38.2	51%	49%	€ 1,058	€ 1,208
Czech Rep.	42.7	42.3	50%	49%	€ 680	€ 690
Denmark	47.7	41.8	51%	49%	€ 2,093	€ 2,449
Estonia	40.1	42.1	55%	49%	€ 805	€ 782
Finland	42.7	42.7	52%	49%	€ 1,772	€ 1,999
France	42.7	41.4	51%	49%	€ 1,682	€ 1,840
Germany	42.8	46.0	49%	49%	€ 1,653	€ 1,827
Greece	42.4	44.7	50%	49%	€ 587	€ 633
Hungary	42.9	42.6	48%	49%	€ 379	€ 416
Ireland	42.8	37.5	50%	49%	€ 1,685	€ 1,907
Italy	42.7	46.3	50%	49%	€ 1,102	€ 1,379
Latvia	41.1	43.5	53%	49%	€ 600	€ 551
Lithuania	43.0	43.8	55%	49%	€ 549	€ 511
Luxembourg	46.5	39.6	53%	51%	€ 3,076	€ 3,006
Malta	42.1	41.6	48%	51%	€ 1,079	€ 1,208
Norway	42.7	39.5	50%	49%	€ 2,780	€ 3,206
Poland	42.8	40.7	50%	49%	€ 498	€ 495
Portugal	39.6	44.9	50%	49%	€ 745	€ 756
Romania	43.7	42.2	50%	49%	€ 222	€ 229
Slovakia	42.7	40.2	50%	49%	€ 521	€ 599
Slovenia	42.6	43.7	50%	49%	€ 777	€ 1,059
Spain	42.8	43.8	50%	49%	€ 1,096	€ 1,184
Sweden	42.7	40.8	51%	51%	€ 1,746	€ 1,948
Switzerland	47.1	42.5	46%	49%	€ 3,056	€ 3,688
Netherlands	42.7	42.6	50%	49%	€ 1,684	€ 1,963
Turkey	38.4	31.4	52%	51%	€ 414	€ 313
UK	42.9	40.0	49%	49%	€ 1,675	€ 1,750
Total	**42.8**	**41.9**	**51%**	**49%**	**€ 1,228**	**€ 1,367**

** Obtained by taking each country's ratio of women per 100 men.*
*** Estimated mean value of equivalised monthly income in EUR; obtained from dividing the net household income per number of household members (based on quartile and 90th percentile cut-offs from survey respondents.)*

**** Estimated median value of equivalised monthly income in EUR (obtained by taking the 5th decile of each country's annual income and dividing it by 12 months).*

Table A.2. Values obtained from 5-step process to calculate wind power annual profit rates under current market conditions.

Source: [a] Own calculations based on [66]–[68].
[b] Own calculation based on [68-80].

Country	Annual productivity (GWh/GW) [a*]	Market price (€/GWh) [b]	Avg. annual revenue per GW of installed capacity (M€)**	20-year profit rate***	Annual profit rate
France	1,642.201	€ 50,200	€ 82.4	-14.97%	-0.75%
Bulgaria	2,094.066	€ 39,580	€ 82.9	-14.52%	-0.73%
Luxembourg	1,584.466	€ 52,600	€ 83.3	-14.04%	-0.70%
Czech Rep.	1,889.337	€ 48,120	€ 90.9	-6.23%	-0.31%
Germany	1,783.011	€ 52,600	€ 93.8	-3.27%	-0.16%
Slovenia	1,905.333	€ 49,870	€ 95	-2.00%	-0.10%
Slovakia	2,000	€ 51,100	€ 102.2	5.41%	0.27%
Cyprus	1,335.563	€ 79,100	€ 105.6	8.96%	0.45%
Malta	2,126.210	€ 49,900	€ 106.1	9.43%	0.47%
Finland	2,302.752	€ 46,800	€ 107.8	11.15%	0.56%
Latvia	2,212.121	€ 49,900	€ 110.4	13.85%	0.69%
Estonia	2,363.225	€ 47,070	€ 111.2	14.73%	0.74%
Italy	1,845.342	€ 61,310	€ 113.1	16.69%	0.83%
Sweden	2,582.212	€ 44,840	€ 115.8	19.42%	0.97%
EU-28	**2,007.946**	**€ 54,273**	**€ 117**	**20.71%**	**1.04%**
Croatia	1,923.194	€ 61,240	€ 117.8	21.47%	1.07%
Spain	2,064.362	€ 57,290	€ 118.3	21.98%	1.10%
Belgium	2,174.838	€ 55,270	€ 120.2	23.98%	1.20%
Denmark	2,698.076	€ 45,120	€ 121.7	25.56%	1.28%
Hungary	2,240.610	€ 55,510	€ 124.4	28.28%	1.41%
Romania	2,425.222	€ 51,440	€ 124.7	28.67%	1.43%
Greece	2,088.637	€ 60,330	€ 126	29.96%	1.50%
Netherlands	2,474.084	€ 52,530	€ 130	34.04%	1.70%
Portugal	2,282.787	€ 57,450	€ 131.1	35.26%	1.76%
Lithuania	2,724.870	€ 50,000	€ 136.2	40.52%	2.03%
Austria	2,299.781	€ 59,920	€ 137.8	42.13%	2.11%
Ireland	2,368.928	€ 62,310	€ 147.6	52.24%	2.61%
Poland	2,484.980	€ 63,350	€ 157.4	62.37%	3.12%
UK	2,821.780	€ 64,900	€ 183.1	88.88%	4.44%

Table A.3. Values obtained from 5-step process to calculate wind power annual profit rates with current national RES subsidies.

Source: [a] [57].

[b] Own calculation based on [57], [58].

Country	National RES support schemes (M€) - 2016 [a]	RES support per unit of RES power capacity (€/MW) [b]	Av. annual revenue per unit of installed capacity with subsidy (M€/GW)	20-year profit rate w/RES support	Annual profit rate w/RES support
Bulgaria	-	-	€ 82.88	-14.52%	-0.73%
Slovenia	-	-	€ 95.02	-2.00%	-0.10%
Slovakia	-	-	€ 102.20	5.41%	0.27%
Belgium	-	-	€ 120.20	23.98%	1.20%
Sweden	€ 363	12,864.59	€ 128.65	32.69%	1.63%
Finland	€ 172	22,763.37	€ 130.53	34.63%	1.73%
Romania	€ 358	31,972.85	€ 156.73	61.65%	3.08%
Estonia	€ 25	45,955.88	€ 157.19	62.13%	3.11%
Croatia	€ 122	42,657.34	€ 160.43	65.47%	3.27%
Latvia	€ 92	51,714.45	€ 162.10	67.19%	3.36%
France	€ 4,085	87,514.46	€ 169.95	75.29%	3.76%
Austria	€ 730	36,720.32	€ 174.52	80.00%	4.00%
Netherlands	€ 472	61,250.97	€ 191.21	97.22%	4.86%
EU28	**€ 56,686**	**127,242.44**	**€ 212.20**	**118.86%**	**5.94%**
Portugal	€ 1,101	81,507.25	€ 212.65	119.33%	5.97%
Malta	€ 14	121,739.13	€ 227.84	134.99%	6.75%
Poland	€ 586	72,256.47	€ 229.68	136.89%	6.84%
Spain	€ 5,356	111,608.91	€ 229.88	137.09%	6.85%
Denmark	€ 948	121,663.24	€ 243.40	151.04%	7.55%
Lithuania	€ 89	108,404.38	€ 244.65	152.33%	7.62%
Luxembourg	€ 49	163,333.33	€ 246.68	154.42%	7.72%
Hungary	€ 163	146,057.35	€ 270.43	178.92%	8.95%
UK	€ 3,576	87,670.70	€ 270.80	179.30%	8.97%
Greece	€ 1,298	149,007.00	€ 275.01	183.65%	9.18%
Ireland	€ 496	137,510.40	€ 285.12	194.07%	9.70%
Germany	€ 24,450	216,260.68	€ 310.05	219.78%	10.99%
Italy	€ 10,555	203,172.22	€ 316.31	226.24%	11.31%
Cyprus	€ 62	227,106.23	€ 332.75	243.19%	12.16%
Czech Rep.	€ 1,524	323,841.90	€ 414.76	327.78%	16.39%

(-) figure not disclosed.

Table A.4. The social potential of the EU-28 under subsidised investment profit rates (Table A.3).

Country	Optimal capital requirement* (b_N^*)	Probability of investing (P_N^*)	Expected collection per citizen (π_N)	Pop. Expected to invest** (pop_N)	Subsidised social potential: total expected funding collected***($\tilde{\pi}_N$)
Austria	€ 3,625.97	21.20%	€ 768.68	254,544	€ 3,749.38
Belgium	€ 3,087.35	12.01%	€ 370.94	340,815	€ 2,231.73
Bulgaria	€ 4,050.47	22.80%	€ 923.66	465,867	€ 3,666.87
Croatia	€ 8,712.85	35.05%	€ 3,053.46	1,070,614	€ 6,925.85
Cyprus	€ 3,042.93	28.93%	€ 880.39	2,828,695	€ 410.14
Czech Rep.	€ 3,178.23	16.70%	€ 530.78	2,545,292	€ 3,150.01
Denmark	€ 7,070.02	13.53%	€ 956.32	3,168,805	€ 2,820.31
Estonia	€ 6,050.98	34.68%	€ 2,098.68	1,540,716	€ 1,507.56
Finland	€ 2,488.23	14.28%	€ 355.36	1,171,362	€ 1,005.21
France	€ 2,891.86	13.47%	€ 389.67	718,337	€ 13,208.35
Germany	€ 4,052.52	12.99%	€ 526.51	6,016,415	€ 23,809.94
Greece	€ 3,302.02	27.02%	€ 892.27	2,949,119	€ 5,178.80
Hungary	€ 3,085.73	20.93%	€ 645.75	5,934,718	€ 3,523.99
Ireland	€ 3,406.36	13.99%	€ 476.65	5,457,241	€ 1,213.21
Italy	€ 3,983.51	23.00%	€ 916.25	5,087,533	€ 30,200.18
Latvia	€ 2,800.82	14.73%	€ 412.67	3,969,939	€ 441.81
Lithuania	€ 4,277.84	21.51%	€ 920.15	4,877,713	€ 1,417.69
Luxembourg	€ 3,792.53	26.02%	€ 986.79	5,587,789	€ 336.31
Malta	€ 3,851.55	18.42%	€ 709.34	5,804,056	€ 180.56
Poland	€ 4,452.91	18.41%	€ 819.61	9,036,117	€ 17,833.59
Portugal	€ 3,622.96	20.85%	€ 755.44	2,268,200	€ 4,221.26
Romania	€ 6,546.77	30.00%	€ 1,964.06	26,194,723	€ 21,589.66
Slovakia	€ 2,745.70	15.52%	€ 426.25	33,896,476	€ 1,350.69
Slovenia	€ 4,517.52	26.68%	€ 1,205.23	34,154,649	€ 1,411.76
Spain	€ 3,173.58	15.94%	€ 505.88	21,758,508	€ 13,251.33
Sweden	€ 4,286.22	15.19%	€ 651.24	45,221,866	€ 3,313.19
Netherlands	€ 3,864.06	15.07%	€ 582.44	10,992,372	€ 5,263.02
UK	€ 2,849.06	14.35%	€ 408.93	32,960,658	€ 13,967.02
EU28	**€ 4,028.95**	**20.12%**	**€ 810.54**	**232,753,127**	**€ 223,929.37**

** wind farm, 20-year holding period, subsidised profit rate, visible, community-administered*
*** aged between 25-64*
**** in millions of EUR*

Table A.5. Total and RES final energy consumptions (2017 values) and percentage increase in RES share, after the addition of RES derived from subside-free social potential per country (own calculations with input data from [82] and survey responses from CE participants).

Country	Gross final energy consumption (GWh)	Gross final energy consumption from RES (GWh)	RES share	Energy generated per year (GWh) from social potential	Gross final energy consumption + RES from social potential (GWh)	Increased RES share	Pct. point increase	Pct. increase in RES
Austria	340,345.47	110,810.46	32.56%	4,366.03	115,176.49	33.84%	1.28%	3.94%
Belgium	425,100.26	38,506.95	9.06%	2,503.00	41,009.95	9.65%	0.59%	6.50%
Bulgaria	126,708.43	23,737.02	18.73%	3,959.85	27,696.87	21.86%	3.13%	16.68%
Croatia	83,578.56	22,796.26	27.28%	6,722.33	29,518.59	35.32%	8.04%	29.49%
Cyprus	19,108.17	1,882.21	9.85%	259.73	2,141.94	11.21%	1.36%	13.80%
Czech Rep.	314979.107	46,492.29	14.76%	2,653.28	49,145.57	15.60%	0.84%	5.71%
Denmark	182,998.28	65,463.01	35.77%	3,543.27	69,006.29	37.71%	1.94%	5.41%
Estonia	37,583.21	10,978.04	29.21%	1,808.28	12,786.32	34.02%	4.81%	16.47%
Finland	306,574.47	125,722.31	41.01%	1,183.14	126,905.45	41.39%	0.39%	0.94%
France	1,822,208.08	297,012.12	16.30%	10,733.32	307,745.44	16.89%	0.59%	3.61%
Germany	2,636,405.29	407,365.03	15.45%	18,844.58	426,209.61	16.17%	0.71%	4.63%
Greece	202,423.52	33,040.46	16.32%	5,283.09	38,323.55	18.93%	2.61%	15.99%
Hungary	223,212.81	29,764.84	13.33%	3,838.02	33,602.86	15.05%	1.72%	12.89%
Ireland	136,140.00	14,499.86	10.65%	1,353.30	15,853.17	11.64%	0.99%	9.33%
Italy	1,400,662.30	255,858.36	18.27%	26,138.47	281,996.83	20.13%	1.87%	10.22%
Latvia	49,032.47	19,127.77	39.01%	493.07	19,620.84	40.02%	1.01%	2.58%
Lithuania	64,795.89	16,740.07	25.84%	1,901.10	18,641.17	28.77%	2.93%	11.36%
Luxembourg	45,516.86	2,904.17	6.38%	258.11	3,162.28	6.95%	0.57%	8.89%
Malta	6,208.78	445.15	7.17%	181.78	626.93	10.10%	2.93%	40.83%
Poland	861,189.45	93,894.58	10.90%	22,002.10	115,896.68	13.46%	2.55%	23.43%
Portugal	194,446.55	54,669.56	28.12%	4,774.17	59,443.73	30.57%	2.46%	8.73%
Romania	287,090.92	70,244.23	24.47%	26,580.88	96,825.11	33.73%	9.26%	37.84%
Slovakia	132,398.29	15,212.24	11.49%	1,393.09	16,605.33	12.54%	1.05%	9.16%
Slovenia	58,556.63	12,617.36	21.55%	1,387.15	14,004.51	23.92%	2.37%	10.99%
Spain	1,013,784.81	177,526.90	17.51%	13,395.95	190,922.85	18.83%	1.32%	7.55%
Sweden	410,019.55	223,455.02	54.50%	4,373.01	227,828.02	55.57%	1.07%	1.96%
Netherlands	587,799.21	38,817.92	6.60%	6,481.12	45,299.04	7.71%	1.10%	16.70%
UK	1,546,620.86	157,843.35	10.21%	19,439.32	177,282.67	11.46%	1.26%	12.32%
EU28	**13,515,488.20**	**2,367,427.51**	**17.52%**	**195,850.57**	**2,563,278.08**	**18.97%**	**1.45%**	**8.27%**

"Imagine you are being offered the opportunity to buy a share of a renewable electricity project that will cost you 1000 EUR. ***You choose*** *to invest in the presented opportunities or not. If you choose to invest, you would have to pay 1000 EUR today.*

You get *to own a part of a solar or wind power plant that is co-owned by you and other private citizens. The power plant sells carbon-free renewable power into the electricity grid to make money over time.* ***You are paid*** *back your initial investment plus any profits made from selling the power. You get one lump-sum payment after a period of time called the "holding period".*

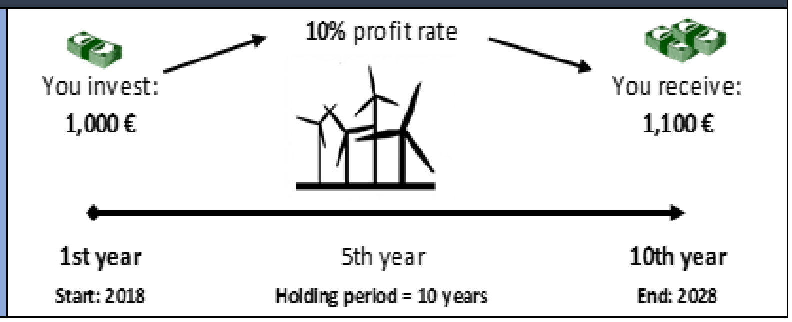
Suppose also that your municipality's government recommends these projects as a good way to increase the penetration of renewable electricity. Please select your most preferred option for each of the questions below.

Please consider each question separately, such that A and B are the only community renewable investment options available to you in each question."

OPTION A

Distance from your home: >10 km
Admin: Utility Company

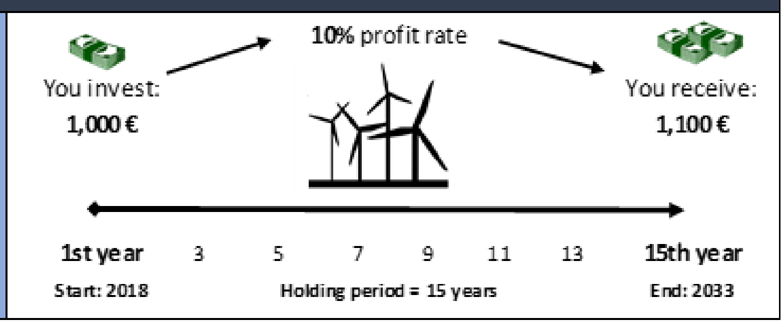
Profit rate: 10%
Holding period: 10 years



OPTION B

Distance from your home: <10 km
Admin: Utility Company

Profit rate: 10%
Holding period: 15 years



OPTION C

I would NOT invest in one of these options.

Figure A.1. Opening statement introducing the control script to the respondents of the Choice Experiment; and example of choice scenario from the English version of the survey.