Towards a citizen-driven low-carbon energy transition

Exploring the potential for collective investment schemes in community renewable energy in Europe to reduce greenhouse gas emissions

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LUCSUS
Lund University Centre for
Sustainability Studies

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Abstract

The European Union's (EU) 'market-oriented' approach to renewable energy development risks undermining the ability of individual citizens to meaningfully contribute to, and benefit from, a decentralised, localised, and decarbonised energy system. In spite of the EU's ambition to involve local communities for co-driving a low-carbon energy transition, there is no comprehensive analysis uncovering the extent to which citizen participation can meaningfully contribute to decarbonise Europe's energy system within an increasingly limited timeframe demanding drastic cuts in greenhouse gas (GHG) emissions at an accelerated pace.

This thesis addresses this knowledge gap by estimating European citizens' expected financial participation in community renewable energy developments as a means to quantify individual citizens' carbon abatement potential within a transitionary period towards a carbon-neutral energy system by mid-century. This is done by using an international survey on environmental and energy-related behaviours and consumption patterns conducted across 31 European countries, and estimating the probability that the average representative European citizen would participate in the collective financing of community-based RE generation schemes, based on a choice experiment.

The results obtained indicate a substantial potential contribution of European citizens –more than €176 billion – for collectively financing the deployment of 91 GW of renewable power capacity across the EU. This would translate into an energy generation potential of 196 GWh annually, which in turn would lead to an 8.3% annual increase in the consumption of renewable energy, and result in an aggregated reduction of over 103 MtCO_2-eq annually – equivalent to a 2.3% annual reduction in total greenhouse gas emissions from 2017 levels for the entire EU. In order to unlock this potential, EU climate and energy policy should generate the necessary economic incentives through a more collaborative approach to competition-based renewable energy deployment.

Keywords: community renewable energy, energy transition, collective investment, greenhouse gas emissions, social potential.

Word count: 13,890 words

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And with that being said…well, let's talk energy!!

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Abbreviations

CE	Choice experiment
CO_2	Carbon dioxide
CRE	Community renewable energy
EC	European Commission
EU	European Union
EU-28	European Union's 28 Member States
FiT	Feed-in-Tariff
GDP	Gross Domestic Product
GHG	Greenhouse gas
$GtCO_2$	Gigatonnes of carbon dioxide
GW	Gigawatt
GWh	Gigawatt hour
kWh	Kilowatt hour
MFF	Multiannual Financial Framework
MNL	Multinomial logit
MS	Member State
$MtCO_2$-eq	Million tonnes of carbon dioxide equivalent
MW	Megawatt
MWh	Megawatt hour
NECP	National Energy and Climate Plan
PV	Photovoltaic
RE	Renewable energy
RES	Renewable energy sources
RQ	Research question
RUT	Random utility theory
tCO_2-eq	Tonnes of carbon dioxide equivalent

1. Introduction

The European Union (EU), being the 3rd largest emitter of greenhouse gas (GHG) emissions globally after China and the US (Global Carbon Project, 2019), has a crucial role to play – as well as the historic responsibility – in the global efforts to limit global warming well below 2°C. The EU's efforts to reduce GHG emissions have focused primarily on reducing the carbon intensity of its energy system, as almost 85% of GHG emissions in the EU are energy-related, while 78% of its energy consumption is fossil fuel-based (EEA, 2018a) .

Launched in 2015, the Energy Union is the EU's largest and most ambitious climate and energy legislative effort to decarbonise its economy to-date, following three different climate and energy policy packages (1996, 2003 and 2009) built around the three dimensions of energy security, affordability, and reliability (European Parliament, 2018). The Energy Union embodies the EU's latest efforts to (European Commission, 2015; Léautier & Crampes, 2016):

a) Reduce its foreign energy dependency through the diversification of its energy mix, the expansion and strengthening of energy interconnections between Member States (MSs), and the consolidation of a European single energy market; and
b) Fully decarbonise its energy system by 2050, with a set of intermediate energy and climate targets for 2020 and 2030.

Importantly, the EU's main goal of carbon neutrality by 2050 places citizens and markets at the core of the energy transition, as they are both called to play a crucial role for operationalising the EU's energy and climate targets (European Commission, 2015). On the citizen front, individual consumers are expected to reduce their energy use and costs through the adoption of new energy generation technologies (e.g. solar panels) and efficiency measures (e.g. smart metering), which will in turn allow them to actively participate in open and competitive energy markets (European Commission, 2010, 2015). These have gone through a "liberalisation" process initiated in the 1990's as a means to break up state-sponsored/owned power utilities' exclusive ownership of transmission networks[1] to prevent new-coming energy suppliers from accessing and using them (Buchan & Keay, 2015), thereby actively deterring external competition and, by extension, preventing reductions on competition-induced energy prices from reaching the final consumer. By unbundling and separating the energy generation activities from the ownership and operation of transmission networks, and having these operated through independent Transmission System Operators alienated from both generation-

[1] These serve as a shared infrastructure and a common carrier for all energy suppliers and therefore as a non-competitive part of the industry (Buchan & Keay, 2015).

supply and distribution-commercialisation activities, EU legislation has re-designed an energy system overburdened with inefficient operating structures and abusive market behaviours characterised by opaque energy prices and limited competition (Buchan & Keay, 2015).

Now under the legislative umbrella of the Energy Union, the implementation of the EU's 2020 Climate and Energy Package has allowed the EU to generate important amounts of electricity from domestically-harvested renewable energy sources (RES), more than doubling from a 8,5% share of total inland energy consumption in 2008 to a 17% share in 2016 (Eurostat, 2018b). This has in turn contributed to an almost 15% GHG emissions reduction – across all sectors – during the same time period (EEA,2018a).

1.1 Realising a citizen-driven low-carbon energy transition

Within this context, community participation in renewable energy (RE) development through, for instance, collective investment schemes in energy cooperatives – where a group of individuals pool their financial resources to invest in a community-based RE generation facility – emerges as an innovative and transformative tool for catalysing the participation of individual citizens in decarbonising the energy system (Berka & Creamer, 2018; Devine-Wright, 2005; Entwistle, Roberts, & Xu, 2014; Haggett & Aitken, 2015; Hoffman & High-Pippert, 2010; Wiersma & Devine-Wright, 2014; Yildiz, 2014; Yildiz et al., 2015). Specifically, collective RE investment schemes operationalise the broader concept of 'community renewable energy' (CRE) defined here as any kind of citizen-led, collaborative initiative aiming to co-finance, co-operate, and/or co-own local-scale RE generation developments with environmental and socio-economic benefits to local communities (Bauwens, 2016; Bauwens, Gotchev, & Holstenkamp, 2016; Seyfang, Park, & Smith, 2013; Walker & Devine-Wright, 2008). These may include providing an additional source of income from selling electricity or through dividends from the ownership of shares and/or land/rooftop rent (Bolinger, 2001; Entwistle et al., 2014; Madlener, 2007; Torgerson, Sorte, & Nam, 2006), lower energy costs derived from local or self-consumption (Walker, 2008), enhanced social cohesion and sense of community (Bomberg & McEwen, 2012; Rogers, Simmons, Convery, & Weatherall, 2012a, 2012b), increased environmental awareness and stewardship (Hoffman & High-Pippert, 2005), and increased acceptance of clean energy alternatives (Breukers & Wolsink, 2007; Walker, Devine-Wright, Hunter, High, & Evans, 2010).

Furthermore, the benefits derived from a more participatory approach to RE finance differ substantially from those stemming from more traditional, larger single-investment schemes in RE. These are widely characterised by large capital investment requirements and, as such, raise a financial entry barrier that risks excluding small-scale investors who lack the financial means to participate in RE developments (Haggett et al., 2014; Walker, Hunter, Devine-

Wright, Evans, & Fay, 2007). Collective investment schemes in CRE address this financial entry barrier through a more participatory approach to RE development: by distributing the initial capital investment needed throughout a large collective of small-scale investors, collective investment schemes lower the investment amount requested to individual participants (Cohen, Kollmann, Reichl, & Azarova, 2019; Haggett & Aitken, 2015; Hall, Foxon, & Bolton, 2016; Yildiz, 2014; Yildiz et al., 2015) and redefine their role from passive energy consumers into proactive, engaged, and empowered energy citizens co-driving and co-benefitting from a more collaborative, localised, and distributive low-carbon energy system

This participatory approach is an important attribute that characterises the collective financing of CRE as an important tool of financial democratisation and stakeholder empowerment. In that respect, CRE plays a key role in facilitating the devolution of agency from incumbent energy stakeholders (i.e. large power utilities) to energy consumers organised into collective citizens' initiatives. In doing so, it reframes the power relationships of the entire energy value chain by redistributing the burdens, responsibilities, opportunities and benefits through a more democratic, stakeholder-diverse, and economically progressive energy system. As a consequence, individual citizens transition from objects of centralised, vertically-integrated systems of energy generation, distribution, and consumption, into subjects of distributed, horizontally-integrated, modular, and multi-directional systems of clean energy exchange (Fig.1).

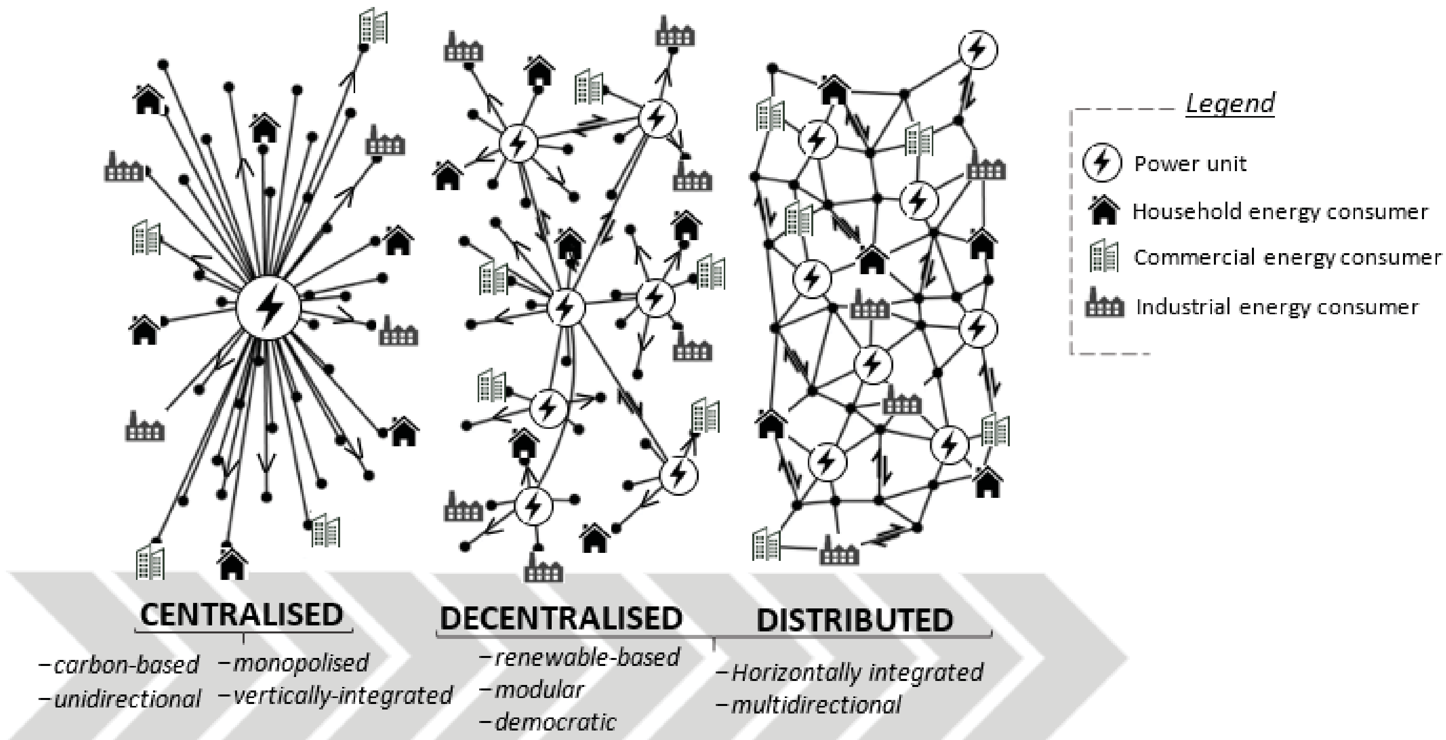


Figure 1. Paradigm shift from carbon-based and centralised energy systems to renewable-based decentralised and, eventually, distributed energy systems (own elaboration based on Baran, 1964).

In addition to the socio-economic benefits mentioned above, citizens' financial participation in CRE has the potential to unlock local communities' contribution to the EU's ongoing GHG emission reduction efforts. By collectively investing in the deployment of localised renewable power capacity, individual citizens are participating in the generation of clean energy and, by doing so, contributing to offset the GHG emissions stemming from the same amount of energy that would have been generated by carbon-based alternatives such as oil, coal or natural gas. This GHG abatement potential 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 to reach net zero-emissions by mid-century in order to stay within a 2°C global warming threshold.

1.2 Research aim and questions

However, notwithstanding Kampman, Blommerde, & Afman's (2016) analysis of the potential contribution of energy self-consumption collectives in the EU, no efforts have been conducted to quantify – yet alone monetise – individual citizens' potential to financially participate in CRE initiatives. Furthermore, no research has yet aimed to translate different levels of financial participation in CRE into GHG emissions reductions. As such, important knowledge gaps remain regarding the quantification of individual citizens' measurable potential in decarbonising Europe's energy system and, by doing so, quantifying their GHG abatement potential within a transitionary period towards a carbon-neutral energy system by 2050. Given the documented socio-economic benefits attributed to CRE, and in light of the knowledge gaps mentioned above, this research aims to address the following research questions:

RQ1. What optimal combination of economic incentives, socio-communal configurations, and policy instruments would maximise individual citizen investments in community renewable energy schemes?

RQ2. How much money are individual citizens willing to invest collectively in community renewable energy schemes?

RQ3. To what extent could individual investments in community renewable energy schemes finance the EU's 2030 renewable energy target?

RQ4. How much renewable energy could citizen-financed community renewable energy schemes generate, and how much would this reduce GHG emissions?

1.3 Contribution to sustainability science

The research questions mentioned above shed light on the conflicting tensions stemming from the imperatives of progressive decarbonisation, energy democracy, socioeconomic development, and climate change mitigation. These are inevitably embedded in highly dynamic socio-technical systems of energy exchange prone to change and resistant to staticity (Cherp, Vinichenko, Jewell, Brutschin, & Sovacool, 2018; Dallamaggiore et al., 2016; Geels, Sovacool, Schwanen, & Sorrell, 2017).

The nature and behaviour of such a complex and dynamic system represents a particularly challenging endeavour for its successful decarbonisation, as this inevitably challenges and re-shapes the economic incentives of a plurality of political, civil society, and energy market actors with different and, more often than not, competing stakes, motivations, influences, practices, norms and values (Fligstein, 1996). This leads, on occasions, to conflicting situations reproducing (or challenging) existing power asymmetries and market imbalances (Fligstein, 1996; Geiger, Harrison, Kjellberg, & Mallard, 2014). In that respect, the decarbonisation of Europe's energy system may be depicted as a truly wicked, almost intractable problem, with energy and climate policies both influencing and being shaped by resource scarcity, environmental degradation, and climate change (Head, 2008; Head & Alford, 2015; Rittel & Webber, 1973).

Within this context, sustainability science's advanced form of complex system analysis serves as a useful tool to more comprehensively understand not only the interacting socio-technical and political dynamics of carbon-neutral energy systems, but also the various challenges preventing the social and ecological welfare functions that sustainable energy systems must aim to deliver for tightly coupled human-environment systems (Turner et al., 2003; Wiek, Ness, Schweizer-Ries, Brand, & Farioli, 2012).

The sustainability challenge stemming from the energy trilemma of security of supply, affordability, and climate action demands for a comprehensive, solutions-driven and actionable analysis addressing the role that multi-stakeholder sustainability initiatives such as CRE generation schemes have for expediting a transition towards a fully decarbonised energy system.

1.4 Thesis outline

Following this introductory section, Section 2 provides a thorough contextual analysis of the current socio-political and economic intricacies shaping the EU's low-carbon energy transition, paying particular attention to its energy market liberalisation efforts and historic GHG emissions reductions, as well as to the investment requirements needed to realise future climate and energy commitments.

Section 3 starts with an overview of the analytical process conducted in this research, followed by a thorough description of the data collection tools utilised for this research, namely the use of an international online survey and a choice experiment conducted across 31 European countries.

Section 4 introduces Random Utility Theory as the central theoretical framework utilised for the elaboration of a probability-based statistical model utilised as the main analytical tool for the research conducted in this thesis, namely the 'alternative specific multinomial logit' model.

Section 5 outlines the analytical process conducted, consisting on an initial estimation of individual citizens' investments, followed by an analytical procedure to maximise the GHG abatement potential stemming from their financial participation. Section 6 exposes the results obtained from this analytical procedure.

Section 7 embeds these results within the EU's broader climate action commitments outlined in Section 2, and discusses the idea of 'collaborative competition' as a promising venue to incentivise individual citizens' financial participation in CRE schemes.

Section 8 concludes.

2. Background

2.1 The EU's historic GHG emissions reductions and future commitments

Since 1990 the EU's GHG emissions reduction efforts have been relatively successful: by 2016 it had managed to reduce its emissions by over 22% compared to 1990 baseline levels (EEA, 2018b), achieving its 2020 target of a 20% GHG emissions reduction well in advance. However, the 0.6% increase in emissions in 2017 (EEA, 2018b) represents a clear derail from the reductions projected with existing (current) domestic carbon abatement measures for 2017, as these project a 2% decrease from 2016 levels; and an even sharper de-rail from the projected reductions foreseen under a scenario where additional (planned) domestic carbon abatement measures are adopted, as these project a 2.3% decrease from 2016 levels (EEA, 2018b, 2018c).

To successfully reach its climate target of a 40% GHG emissions reduction by 2030 (fig.2), the EU must avoid the emission of 377.5 MtCO2-eq[2] every year from 2017-2030 – a volume bigger than Spain's GHG emissions in 2017 (EEA, 2018b). This represents a 6.6% annual reduction of emissions for 13 consecutive years. The European Commission (EC) has taken note and, building on the progress achieved to-date, has recently conducted an upward revision of its 2030 RE and energy efficiency targets, which now reflect a 32% share of RE in its final energy consumption, and a 32.5% increase in its energy efficiency. (European Commission, 2019). The EC foresees that the timely realisation of these targets will lead to steeper GHG emission reductions for the whole EU than the 40% reduction originally anticipated by 2030 – achieving around a 45% reduction relative to 1990 baseline levels (European Commission, 2019).

However, projections incorporating additional (planned) domestic policies and measures by EU MSs are largely insufficient to realise such drastic cuts in GHG emissions (EEA, 2018b). Despite explicitly-stated EU energy and climate targets, tangible national policy instruments and implementation mechanisms from MSs' National Energy and Climate Plans (NECPs) for the period 2021-2030 remain insufficient. Furthermore, assuming the EU maintains its projected pace of reduction for the next 13 years and indeed reaches a 40% reduction by 2030, from that point onwards it will have to further reduce its emissions annually by an additional 157.3 MtCO_2-eq (totalling a reduction of 534.8 MtCO_2-eq every year) if the 2050 goal of a 95% annual reduction is to be realised (EEA, 2018b). This is illustrated in figure 2 below.

[2] Million tonnes of carbon dioxide equivalent.

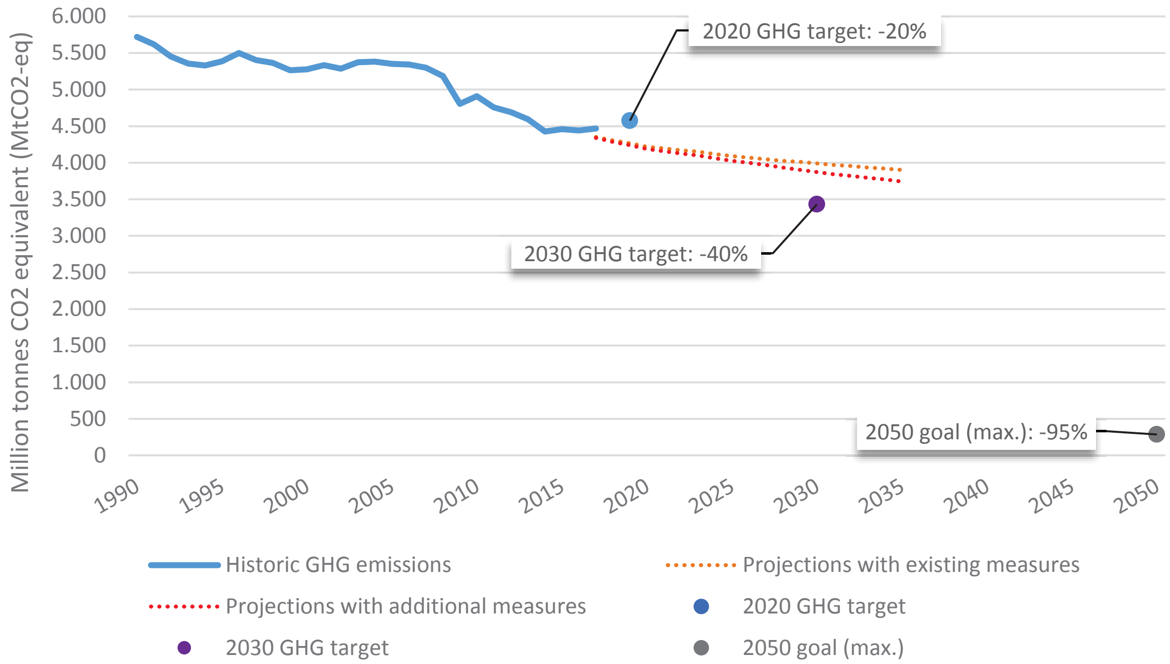


Figure 2. GHG emission trends, projections and targets in the EU (own elaboration based on EEA, 2018b).

In sum, in spite of ongoing decarbonisation efforts, there seems to be no clearly realisable pathway that foresees decarbonisation at the extent necessary to achieve net-zero emissions by 2050. EU MSs must therefore urgently concretise viable and realisable GHG reduction measures to successfully decarbonize their economies and realise an emissions reduction pathway sharp enough to operate within an 'EU carbon budget' of around 96 $GtCO_2$[3] for the period 2010-2050[4] (McCollum et al., 2018).

2.2 Investment requirements and the existing financing gap

The investment requirements to realise such GHG reductions are substantial and currently not being met (Williams, Eichler, Gottmann, Förster, & Siemons, 2018). Estimates indicate an investment requirement of around €380 billion annually over the next 11 years in order to achieve the EU's 2030 climate and energy targets – nearly double the 2018 investments of €201 billion – resulting in a financing gap of €179 billion annually (European Commission, 2018a, 2018b; Williams et al., 2018). Estimates further project that no less than 9% of the foreseen annual investments – at least €34 billion every year – will have to finance the deployment of renewable power capacity to reach a 32% share of the EU's gross final energy

[3] Gigatonnes of carbon dioxide.
[4] The estimated carbon budget for the EU ranges between 90-102 $GtCO_2$ for the period 2010-2050 (McCollum et al., 2018). This is in line with a global carbon budget of 420 $GtCO_2$ associated with a 66% probability of limiting global warming to 1.5°C by 2100 compared to pre-industrial levels (COMMIT, 2019; IPCC, 2018)

consumption by 2030 (Williams et al., 2018). This translates into a cumulative investment of €374 billion over an 11-year period. The financial contribution of €7.44 billion annually coming from European institutions under the current Multiannual Financial Framework (MFF) 2014-2020 is marginal in comparison, while the EC's planned allocation of €11 billion annually for the period 2021-2027[5] is no more ambitious (European Commission, 2018b), as it only covers 32.3% of the annual investments required for renewable power capacity, and a meagre 3% of the total annual investments.

In light of the clearly insufficient volume of public finance allocated to bridge the financing gap to install sufficient renewable power capacity to meet EU climate targets, the vast majority of investment needs will have to be mobilised by the private sector. The EU expects to operationalise these through liberalised energy markets designed to deter monopolistic market configurations, enhance competition, and facilitate stakeholder diversity by increasing the active participation of European citizens as active market stakeholders (European Commission, 2015; European Parliament & Council of Europe, 2018).

2.3 National support mechanisms vs. EU market liberalisation

Reaching out to private sector finance *vis-à-vis* increasing the participation of European citizens operating within liberalised energy markets will require that EU energy and climate policy rewards the reduction of GHG emissions by generating the necessary economic incentives and market conditions for developing decentralised, community-based forms of RE generation such as, for instance, energy cooperatives.

2.3.1 Non-competitive support mechanisms: Feed-in-tariffs

EU MSs have generated these economic incentives through national support mechanisms operationalised primarily (but not exclusively) in the form of long-term, non-competitive Feed-in-Tariffs (FiTs). FiTs may be defined as a state subsidy provided to RE producers in the form of fixed electricity prices above market clearing prices, along with 'purchase guarantees' (Cointe & Nadaï, 2018; Fouquet & Johansson, 2008; Lipp, 2007). As shown in figure 3 below, FiTs introduce a minimum price (a price floor) for electricity generated from clean power sources (e.g. solar, wind); thus guaranteeing a minimum revenue for RE producers who do not have to adjust nor operate in response to the more dynamic, fluctuating, and competitive electricity market clearing prices stemming from liberalised energy markets. In that

[5] This corresponds to a planned allocation of 25% of the EU's next MFF budget for 2021-2027 (€320 billion).

respect, FiT-guaranteed electricity prices may be understood as market-exogenous and non-competitive regulated electricity prices. Furthermore, the 'purchase guarantees' accompanying FiTs guarantee that any and all electricity produced from RES will be bought in the market at the fixed price – regardless of how much is supplied or by whom – before buying electricity generated from other power sources such as oil or coal-fired power plants.

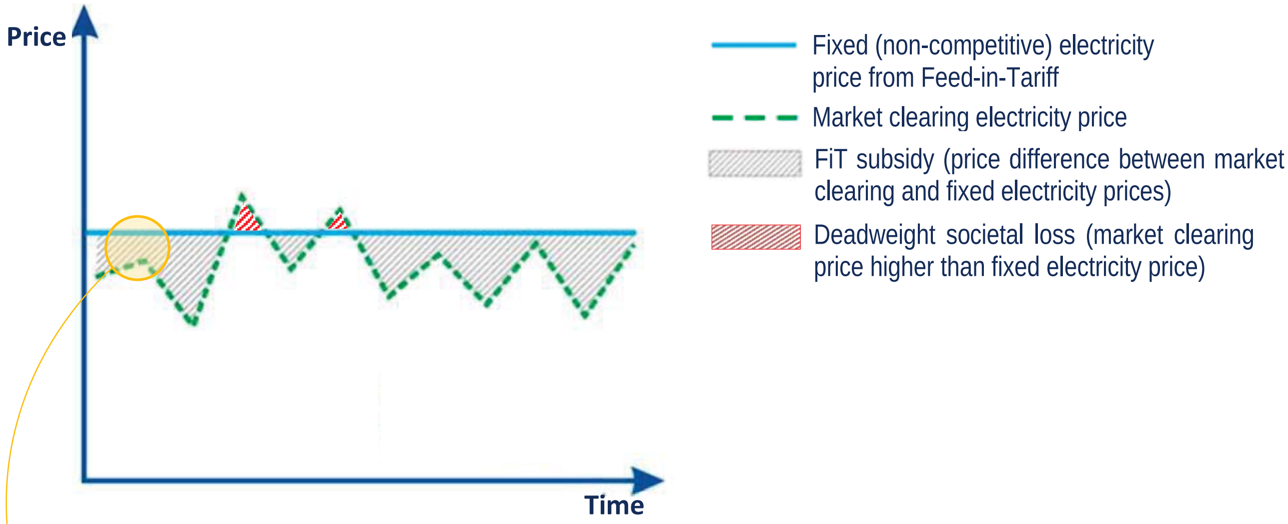


Figure 3. Market-exogenous, non-competitive Feed-in-Tariff design model (adapted from Ramli & Twaha, 2015).

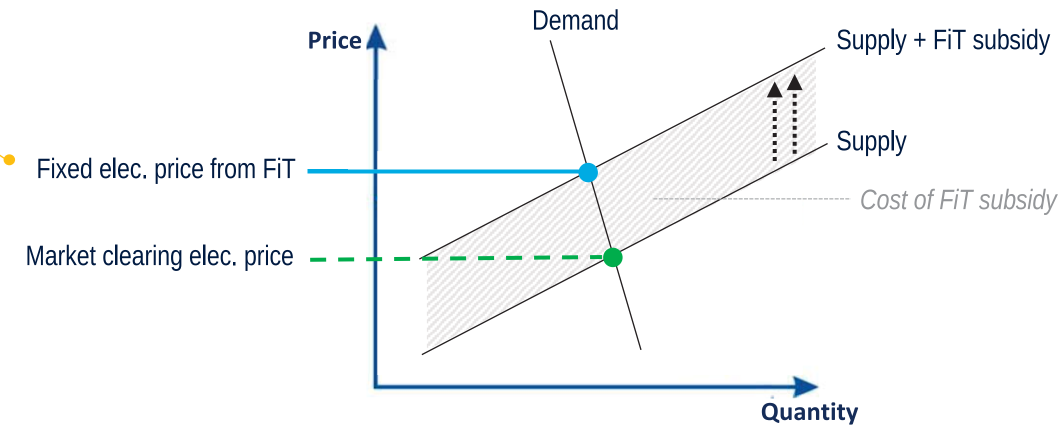


Figure 4. Static supply-demand pairing function of electricity markets (own elaboration).

This approach has had mixed results. On the one hand, the use of FiTs has generated electricity price stability and predictability, and guaranteed the economic viability of RE developments. This has led to increased investor confidence and resulted in the generation of important amounts of electricity from domestically-harvested RES (Cointe & Nadaï, 2018; Couture & Gagnon, 2010; Meyer, 2003). Furthermore, due to the decentralised nature and modularity of renewables, the 'purchase guarantees' accompanying FiTs have proved a successful policy instrument for incentivising the generation of RE by less traditional, smaller stakeholders such as small and medium-sized enterprises (SMEs), energy cooperatives, and municipalities (Couture & Gagnon, 2010; Leiren & Reimer, 2018). In that respect, FiTs have been an important vector for energy democracy and citizen participation, as well as a contributing factor driving societal acceptance of Europe's low-carbon energy transition (Burke & Stephens, 2017; Leiren & Reimer, 2018).

However, the use of FiTs has triggered a drastic increase in retail electricity prices, as the costs incurred for financing their deployment have been absorbed by traditionally less organised groups with little political bargaining power – namely end-use household energy consumers (Gawel, Strunz, & Lehmann, 2017) – in the form of higher electricity bills. The result has been an increase in retail household electricity prices of 46.7% between 2006-2018 (Eurostat, 2018a).

The disparity between household income levels and the costs of energy services is already driving vulnerable households into a situation of energy poverty[6] and exacerbating the increasing tension between energy affordability and decarbonisation objectives (Andersen, Goldthau, & Sitter, 2017; Sunderland & Croft, 2011). It seems clear, then, that the EU's market-oriented legislation and regulatory framework is failing to allocate a balanced distribution of burdens, opportunities, and benefits amongst energy market actors and consumers, with the latter bearing a grossly disproportionate share of the costs and risks associated with Europe's low-carbon energy transition.

2.3.2 Competitive support mechanisms: auctions

Within this context, EU MSs are progressively substituting FiTs for competition-based instruments in the form of structured, transparent, and (non-) discriminatory tendering schemes (i.e. auctions) as a means to increase the cost-effectiveness of targeted financial support to RES and thereby induce electricity price reductions, while having a stricter control and more predictable outcome over the precise volume of installed renewable power capacity (European Commission, 2014; IRENA & CEM, 2015).

However, due to a combination of high transaction and administrative costs[7], penalties for project delays or incompletion, strict pre-qualification requirements, and the risk associated with not obtaining a return on the allocated investments, smaller citizen-led initiatives are in a disadvantageous position with respect to larger stakeholders with stronger operational and

[6] In the context of developed economies such as the EU, energy poverty refers to the inability to afford the full costs of energy services (electricity, heat, or cooking fuels) to guarantee people's health and wellbeing (Castaño-Rosa, Solís-Guzmán, Rubio-Bellido, & Marrero, 2019; European Energy Network, 2019). Different estimates allocate 65 million people (European Commission, 2010), and between 50 and 125 million people (Garcia et al., 2009) across Europe in a situation of energy poverty.
[7] e.g. project planning and feasibility studies, risk assessments, construction permits, etc.

financial means to make more competitive offers, deterring smaller local players from participating in the EU's decarbonisation efforts (Haufe & Ehrhart, 2018; IRENA, 2017; Langer, Decker, Roosen, & Menrad, 2018; Lundberg, 2019). The German experience – considered by many as a pioneer for introducing innovative energy policy instruments – serves as case in point: on its first four pilot auctions for solar photovoltaic (PV) installations in 2015, only 0.22% of bids (in terms of installed capacity) were won by energy cooperatives (DGRV, 2016). Since then, citizen-led energy cooperatives in Germany have decreased over 16% with more than 163 cooperatives disappearing in just 3 years (Beermann & Tews, 2017). This trend is expected to continue for the foreseeable future due, most fundamentally, to "the introduction of tendering [which] sets up yet more barriers to citizens' energy" (DGRV, 2016, pr. 2). Auctions might therefore eventually threaten the declared political objective of stakeholder diversity in Europe's energy transition due to their potentially detrimental effect on the involvement, participation, and acceptability of local communities in the EU's decarbonisation goals. Ultimately, their increased adoption might undermine small investor confidence and impose too high a barrier for unlocking the EU's social potential for investing and participating in CRE.

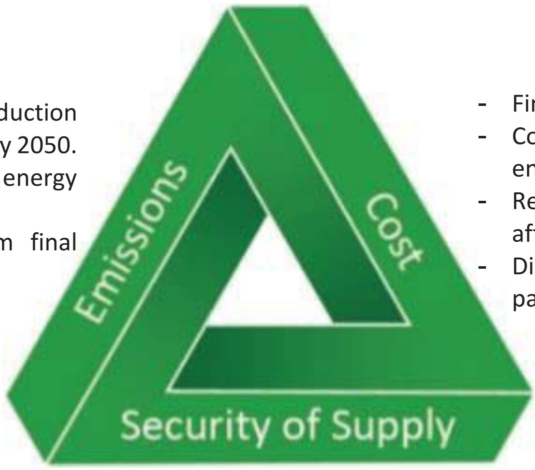
In short, the EU's transition towards a carbon-neutral energy system exacerbates a socially-detrimental relationship between traditional power utilities pressured to maintain profit margins (Gawel et al., 2017); and energy consumers, who are still being treated as passive market actors situated at the margins of centralised, vertically-integrated systems of energy production, distribution, commercialisation, and consumption (Andersen et al., 2017). Despite the Energy Union's main goal to have "citizens take ownership of the energy transition, benefit from new technologies to reduce their bills, participate actively in the market, and where vulnerable consumers are protected" (European Commission, 2015, p. 2), EU policymaking institutions still view European energy customers as objects (rather than subjects) of ambitious decarbonisation goals with socially unjust and economically regressive energy and climate policies.

2.4 Europe's energy trilemma

Accelerating the deployment of clean energy cost-effectively while simultaneously increasing the participation of individual citizens will be a challenging yet critical element for successfully realising Europe's transition to a fully decarbonised energy system by mid-century. The ongoing evolution of national RE support mechanisms to accommodate a more stakeholder diverse and economically distributive approach to RE development while maintaining competitiveness and cost-efficiency serves to illustrate the challenging intricacies related to the EU's energy trilemma of security of supply, affordability, and climate action (fig. 5). Securing a more reliable and diversified supply of energy at the expense of diluted climate and energy targets is not an option, while maintaining a strict and accelerated GHG emissions reduction pathway at the expense of increased electricity prices and a higher incidence of energy poverty is no better alternative.

Expediting RES deployment while maintaining affordable energy and securing reliability of supply is a challenging endeavour that will require changes on the EU energy market architecture in order to operationalise innovative policy measures that recognise and accommodate individual citizens as a legitimate agent partaking in the EU's low-carbon energy transition.

- 40-45% GHG emissions reduction by 2030; 80-95% reduction by 2050.
- 32% RES share in final energy consumption by 2030.
- 32.5% energy savings from final



- Financing gap of €179 billion annually.
- Competitive price provision, reduced end-use (retail) electricity prices.
- Reduced energy poverty, enhancing price affordability.
- Distributive cost allocation, reducing cost pass-through.

- Reduced import-based energy dependence / Diversified energy mix through domestically-harvested RES.
- Enhancing demand and supply-side flexibility; stakeholder diversity.
- Reduced consumption via increased energy efficiency, reducing transmission/distribution losses.

Figure 5. The energy trilemma conceptualised through a three-pillar triangle where climate action is realised cost-effectively and at affordable costs for end-use consumers, while being anchored in a more secure, reliable and diversified energy system (adapted from Lewis, 2014) .

3. Methodology

The data utilised for this thesis was collected from the responses obtained to a choice experiment (CE) on different investment schemes in CRE, performed as part of an international online survey with private citizens across 31 countries[8] with over 605 million citizens. This online survey was conducted during 2018 by the EU-funded ECHOES[9] interdisciplinary project on energy use, behaviours and lifestyles.

Based on the data collected from the CE responses, I conduct a methodologically-structured, three-step analytical procedure to address RQs 1 and 2 outlined in Section 1. The first step of this procedure consists of a statistical analysis of the CE responses, conducted to estimate the effects that different investment characteristics have on the willingness of CE respondents to invest in a RE development. In the second step, the results obtained from this initial estimation are used to identify and bundle together the most preferred investment characteristics (variables) under an "optimal" investment option and estimate the likelihood (probability) that CE respondents invest in it. Thirdly, the resulting probability is mathematically reformulated as a linear function of the investment requirement plus the rate of return (profit rate) provided by that same investment. This is then mathematically solved to obtain an analytical solution that maximises the amount of money the average individual CE respondent is willing to be invested into a RE development. Individual monetary values are aggregated at the country and EU levels, and are referred to as a country's *social potential* to collectively invest in CRE generation schemes. With this, RQs 1 and 2 are effectively addressed, and the results obtained provide the groundwork necessary to address RQs 3 and 4.

The results obtained at the conclusion of the third step in the analytical procedure outlined above are used for measuring the extent by which the total individual investments in CRE obtained can bridge the existing financing gap identified in Section 2.2. With it RQ 3 is effectively addressed.

Finally, the social potential of each MS (that is, the individual monetary values aggregated at the country-level) obtained for responding to RQs 1 and 2 is now taken and utilised as the starting point to quantify the installed power capacity (gigawatt – GW) that could be bought with the total volume of individually committed investments for any given MS and across the EU. The resulting installed power capacities are combined with national energy productivity ratings to quantify the RE (gigawatt hour – GWh) that could potentially be

[8] All 28 EU Member States plus Norway, Switzerland and Turkey.
[9] "Energy Choices supporting the Energy Union and the Set-Plan" – https://echoes-project.eu/

generated annually from citizen-financed CRE schemes for every MS and across the EU. Country-specific annual RE generation profiles are then combined with country-specific net carbon intensities to quantify the GHG emissions that could potentially be abated annually through the generation of clean energy collectively financed by individual citizens in each MS and across the EU. With this, RQ 4 is effectively addressed.

3.1 Data collection

3.1.1 Multi-country survey

The analysis conducted to respond to the RQs outlined in Section 1 utilizes the data obtained from an international online survey conducted with private citizens across 31 countries, as part of the EU-funded ECHOES interdisciplinary project on energy use, behaviours and lifestyles. The survey enquired about individual respondents' environmental and energy-related opinions, values, behaviours, attitudes and choices, and paired them with their socio-demographic characteristics, economic and financial profiles, and energy and resource consumption and mobility patterns. It was presented to respondents over the internet in their native language. About 600 respondents were recruited in each country through a random sampling procedure, with a total sample of around 18,000 completed surveys. In order to ensure a representative sample of the wider populations from all 31 countries, quotas were drawn from sociodemographic indicators pertaining to age, gender, and income levels. The demographic distribution of the final samples, along with the quotas drawn to ensure population representability, is given in table 2 under Appendix I.

The ECHOES project utilised the data obtained from this survey to disaggregate and describe different energy consumption patterns and related environmental behaviours according to respondent's socio-demographic characteristics and economic and financial profiles outlined in the earlier part of the survey. Alternatively, the research conducted in this thesis utilised the data obtained from the responses obtained to a Choice Experiment (CE) conducted as part of the abovementioned survey, to statistically analyse the probability that an investment in a CRE generation scheme will actually occur, to mathematically estimate the quantity associated with such probability, and ultimately to derive a specific RE generation profile and GHG abatement potential stemming from such probability estimation and monetary quantification.

3.1.2 Choice Experiment

The purpose of the CE was to identify respondents' levels of interest in participating in a community-based investment scheme to finance different kinds of RE installations, and to investigate what specific set of investment attributes and related financial and operational conditions of CRE initiatives drive citizen participation in such community investments.

CEs are one type of stated preference elicitation method[10] widely used in numerous applications of economic theory such as in agricultural economics (Birol, Smale, & Gyovai, 2006), transport economics (Cascetta, 2009; Louviere, 1988), health economics (Hauber et al., 2016), and marketing (Louviere & Woodworth, 1983). In regards to environmental and resource economics, CEs are used as a specific methodology of environmental valuation aiming to uncover the different characteristics that individuals value – and therefore attribute to, and elicit a preference over – from a specific environmental asset[11] such as a river, a forest, or a fishery, as well as to different mineral and energy resources (Hanley, Wright, & Adamowicz, 1998).

CEs differ from more traditional approaches to economic valuation of environmental assets (e.g. hedonic pricing, travel cost, market price, cost-based) in the sense that they are conducted through the application of surveys and, in that respect, the data obtained from CEs is based on stated – rather than revealed – preferences (Adamowicz, Boxall, Williams, & Louviere, 1998; Louviere, Flynn, & Carson, 2010; Mavsar, Varela, & Duclercq, 2013). The former ones are obtained via carefully designed formats (e.g. questionnaires), while the latter obtains its data from observations of individual behaviours in real settings (e.g. market data) (Louviere et al., 2010; Mavsar et al., 2013). CEs serve as a particularly well-suited data collection tool in situations where people passively omit their reactions when changes in the state of an environmental asset occur, as people's preferences or values are not reflected or revealed – and therefore not observable – in their actual behaviour (Adamowicz et al. (1998). In these situations, revealed preference data gathering techniques might not be a well-suited option. Instead, stated preference data generation techniques – also known as contingent valuation methods, of which CEs stem from – are the preferred environmental valuation method for eliciting changes in people's passive use values (Adamowicz et al., 1998).

[10] Stated preference methods are anchored in random utility theory (RUT), which operates on the assumption that every individual, being a rational decision-maker, aims to maximise the utility derived from his/her choices (Cascetta, 2009). See Section 4 for a more comprehensive explanation of RUT and its applicability on this research.

[11] This thesis adopts the United Nation Statistical Division's definition of environmental asset, which defines it as "naturally occurring living and non-living components of the Earth, together constituting the bio-physical environment, which may provide benefits to humanity" (United Nations, 2014, p. 13).

The CE section of the survey presented respondents 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 nor intention to invest in any of the investment opportunities being offered by options A or B. Respondents were then asked to choose which of these three options they would prefer if confronted with the same situation in real life. They were asked to pick one option for each of the eight different choice scenarios, resulting in a total of 8 different choices per respondent. A final sample totalling 144,000 data points was obtained from the responses to the CE.

As shown in figure 6 below, each choice scenario showcased a specific RE project as the object of investment. This was limited to two main technologies/installations, namely a wind park and a solar farm. In addition, the choice scenarios included four attributes that varied between choice options A and B (except for option C – opt-out). The attributes included in each choice scenario were:

1. *Profit rate*: the amount of money the individual investor (respondent) would be paid back at the conclusion of the holding period, when the operations conducted by the RE project were finalised. This was displayed as both a rate of return on the initial investment (detailed as a percentage value) and as a Euro value.
2. *Holding period*: the number of years elapsed until the respondent’s initial investment and the profit generated from it are both repaid.
3. *Visibility*: whether or not the RE installation is visible from the respondent's home.
4. *Administrator*: the legal entity overseeing the investment and administering the RE installation, defined as either a private utility company, a community organization (e.g. energy cooperative), or a governmental entity (e.g. municipality).

It is important to note that 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 also avoided the necessity for the respondents to consider compounded interest, thereby simplifying the set of considerations that respondents had to take into account when evaluating the profitability and, by extension, the preferred option stated from the available choice scenarios. Table 1 below shows the two main RE technologies/installations and related set of attributes to be considered in each choice scenario, their corresponding descriptions as presented to the respondents, and the different combination of alphanumeric values assigned to each attribute.

Table 1. Attributes and their corresponding descriptions as shown to survey respondents, along with their values. The choice experiment presented one permutation of each attribute to each respondent (Cohen et al., 2019)

Attribute	Description	Values
RE Technology/ installation	The type of renewable energy project that you are investing in	Wind park; solar farm
Profit rate	The amount of money that you will obtain in addition to your initial investment. For example, if you invest 1000 EUR and the profit rate is 10% then you will receive the equivalent of: *100 EUR profit + your 1,000 EUR =* ***1,100 EUR*** This is a one-time payment (lump sum) at the end of the holding period. Consider this a risk-free investment, where the profit rate is a real rate that already accounts for inflation.	0%, 10%, 20%, 50%
Holding period	The number of years until you get your money back, including any profits.	5, 10, 15 years
Visibility	If the proposed wind farm or solar park is visible from your home.	Visible; not visible
Administrator	The group that handles your investment and is in charge of building and running the power plant. This can be either a community organization, which is a group of private citizens, a utility company, which is a company that provides energy, or a government entity.	Community organization, utility company or government entity

All respondents were shown a control script explaining the scenario and premise of the investment opportunities[12]. Additionally, 75% of respondents from the sample were randomly selected and shown one of three different treatment scripts, which told them that either their local municipality, national government or an EU institution had endorsed the investment opportunities they were being presented with. Each one of these three different endorsements was randomly assigned to the respondents receiving the treatment script, and revealed before each choice scenario. In addition to the three treatment groups corresponding to the three different sources of endorsement, 25% of the respondents from the sample were assigned to the control group where no political support was communicated.

[12] Refer to Appendix I for an example of the opening statement introducing the script to the CE respondents.

Along with the scripts, respondents were randomly assigned a specific capital requirement (level of investment), which stipulated the amount of money they would have to pay today in order to join any of the investment opportunities being offered. The amounts assigned were €100, €500, €1,000, €2,000 or €5,000. All currencies were adjusted from Euros into the equivalent monetary values of the corresponding national currencies, using the European Central Bank's official Euro foreign exchange reference rates (2019).

Respondents were then sequentially shown each of the eight choice scenarios with the three choice options in each scenario (option A, B, or C), and were asked to choose their most preferred option. The order of the choice scenarios shown to respondents was randomized. Figure 6 below provides an example of one of the eight choice scenarios designed for the survey.

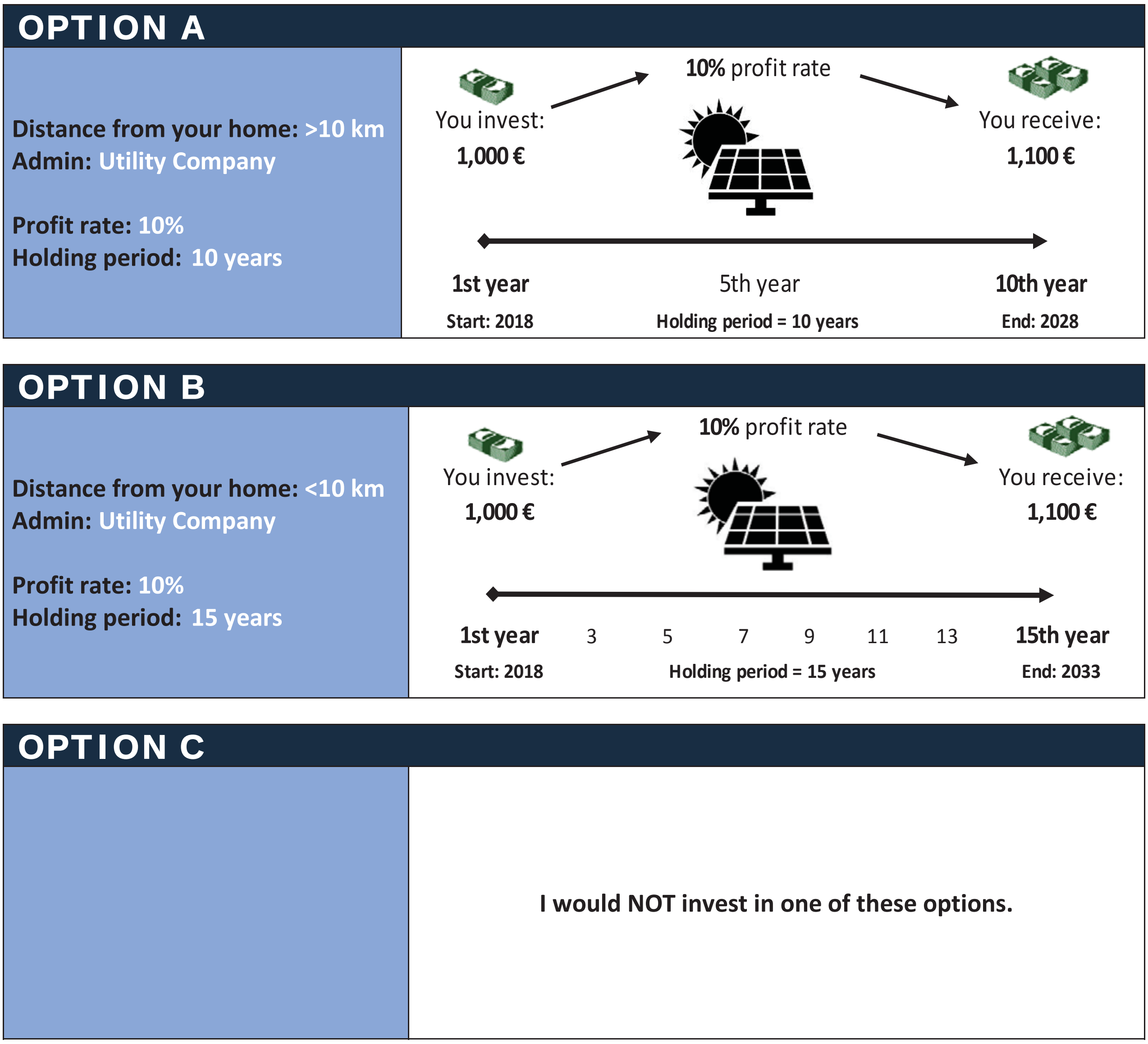


Figure 6. Example of choice scenario from the English version of the survey. Retrieved from internal data repository (ECHOES project consortium, 2018).

4. Theoretical framework and analytical tools

CEs have been extensively applied as a well-suited data generation method for statistical analysis. Specifically, CEs provide the possibility to model and interpret respondents' choices using probability-based models, the majority of which are anchored in random utility theory (Adamowicz et al., 1998; Hanley et al., 1998; Louviere et al., 2010; Manski, 1977; McFadden, 1986).

This section introduces the rationale behind random utility theory (RUT) and motivates the choice of conducting the analytical process employing one of the most widely used probability-based models in RUT, namely the 'alternative specific multinomial logit' model.

4.1 Random utility theory

Random utility theory (RUT) – originally introduced by psychologist Louis Thurstone (1927) for analysing observed inconsistencies in individual behaviour patterns – has been extensively utilised in behavioural economics and market studies to account for the latent preferences determining human decision-making processes and related choices according to people's assumed utility-maximisation rationale (Louviere et al., 2010; Manski, 1977; McFadden, 1986).

RUT adopts the assumption that every individual has an unobservable[13] – and therefore latent – mental construct of 'utility' co-shaping the value that he ascribes to different options, goods, possibilities, opportunities or alternatives described in terms of different attributes such as price, duration, size, weight, temperature, colour, etc. (Cascetta, 2009; Hanley et al., 1998; Louviere et al., 2010; Manski, 1977). An individual assigning different utilities to a set of differing options will result in a scale of preferences that he will eventually manifest by making an explicit choice for one particular preferred option above all others.

RUT further assumes that the preference of any given individual for one particular option over the others is further shaped by two main components: one systematic and observable component, and one random and unobservable component (Cascetta, 2009; Hanley et al., 1998). Due to the existence of this 'random' component, the utility of a person is "inherently stochastic" (Louviere et al., 2010, p. 63), and can therefore only be determined and statistically analysed through discrete choice models[14] using probabilities rather than exact observations. This means that "researchers can predict the probability that individual *n* will

[13] Unobservable to the external observer, yet acknowledged by the individual himself.
[14] These are statistical models used to describe, explain, and/or estimate the probability of specific choices based on two or more discrete variables.

choose alternative *i*, but not the exact alternative that individual *n* will choose" (Louviere et al., 2010, p. 63). As such, statistical analyses using probability-based discrete choice models allow us to "describe how choice probabilities respond to changes in choice options…representing differences in individual choosers" (Louviere et al., 2010, p. 63).

Appendix II provides a more technically-oriented description of RUT, along with the key mathematical functions utilised to statistically analyse the responses obtained from the CE.

4.2 The "alternative specific multinomial logit" model

The multinomial logit (MNL) is one of the best-known and most widely used family of probability-based discrete choice models (Louviere et al., 2010), and the one utilised for the research conducted in this thesis. Specifically, this thesis adopts one of the most widely used probabilistic discrete choice models in RUT, namely the 'alternative specific multinomial logit' model[15]. As with all probabilistic discrete choice models, the alternative specific MNL effectively models the probability that any given individual explicitly selects one particular option given the effects that the values of the option's corresponding set of attributes and the scenario's unique characteristics have on the respondent's latent utility related to that one particular option. As explained in section 3.1.2 above and depicted in figure 7 below, the set of attributes specific to options A and B of the CE include profit rate, holding period, administrator, and visibility. Furthermore, each attribute can be expressed according to different values assigned to it, such that one particular attribute (e.g. profit rate) can be expressed in different ways (e.g. 0%, 10%, 20%, 50%).

Accordingly, choice options A and B from the CE differ from each other according to the unique combination of differing values assigned to their corresponding attributes, in addition to the effects that the unique combination of scenario-specific characteristics included in the eight different choice scenarios have for eliciting different choice probabilities from different individual respondents. Given the effects of different combinations between option-specific attributes and scenario-specific characteristics, the alternative specific MNL model estimates the probability of a discrete choice outcome, as well as any changes in the probability stemming from option- or scenario-related modifications. In other words, the alternative specific MNL estimates both the likelihood that any one specific option under any given scenario is explicitly selected instead of competing options under that same scenario, and the changes (increase or decrease) in that likelihood given any modifications in the design settings.

[15] Also known as "conditional logit model" or "McFadden's choice model". See Beggs, Cardell, and Hausman (1981); Chapman and Staelin (1982); Hausman and Ruud (1987) for examples of the model's applicability.

Figure 7 below provides a schematic display of the CE design, along with the conceptual purpose of the alternative specific MNL as an analytical tool. For a more technically-oriented description of the rationale behind the alternative specific MNL model, along with the key mathematical functions utilised throughout the analytical process, refer to Appendix II.

The alternative specific MNL model is the main analytical tool utilised in this thesis for conducting a methodologically-structured, step-wise analytical process (section 5) to statistically analyse the responses obtained by individual respondents across every EU MS sampled in the CE.

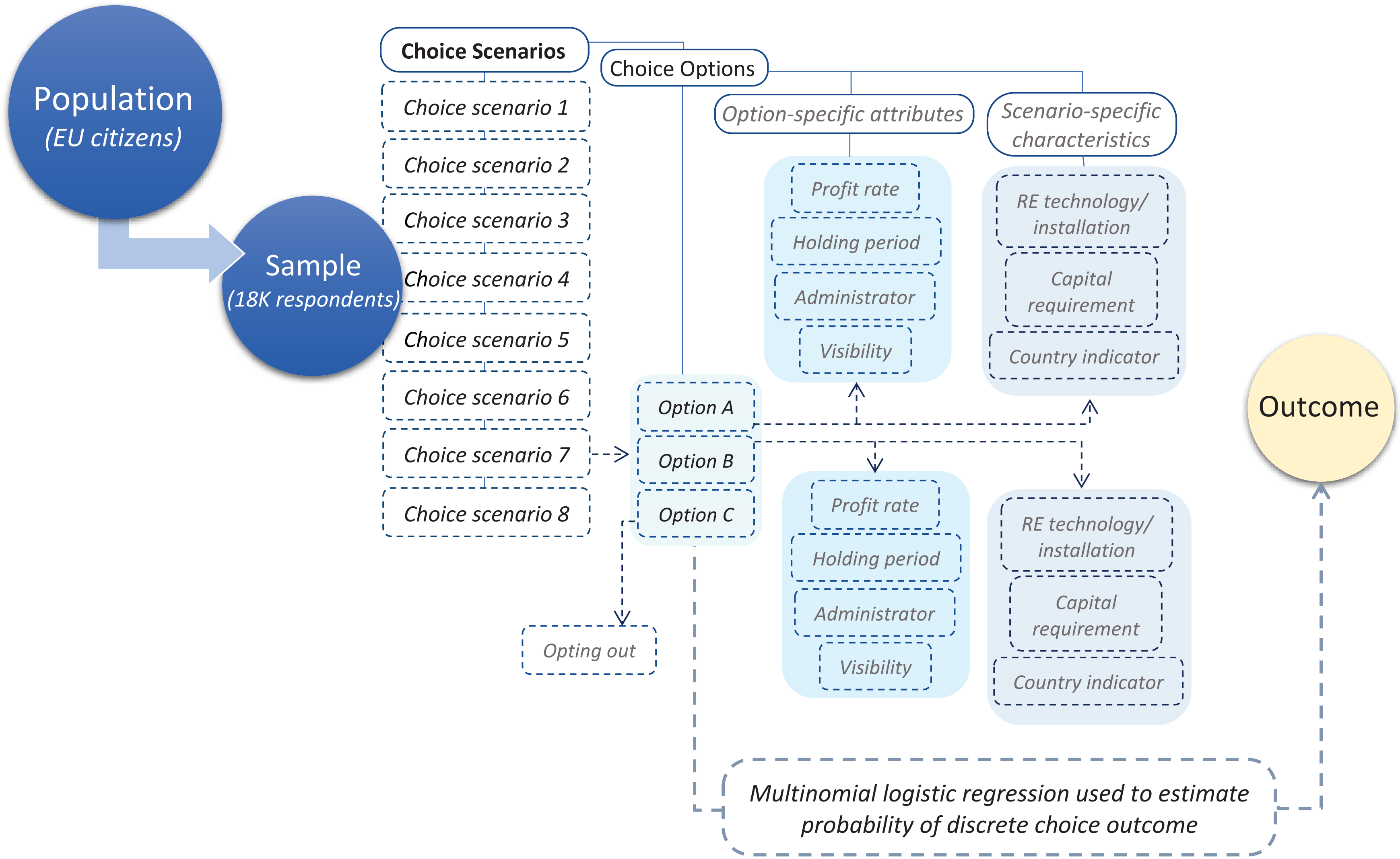


Figure 7. Schematic display of Choice Experiment design, including the conceptual purpose of the alternative specific multinomial logit as an analytical tool to statistically estimate probability of choosing an investment option (own elaboration).

5. Analysis

The aim of this analysis is twofold. Building on the responses obtained across every country sampled in the CE, I first identify the maximum possible level of investment (capital requirement) into a CRE generation scheme expected by the average representative individual citizen in each EU MS. Individual results are aggregated at the country level in order to maximise the expected total investment in CRE for every EU MS. This is referred to as the country's *social potential* for collectively investing and participating in CRE generation schemes.

The social potential of each MS is then taken and utilised as the starting point to quantify the GHG abatement potential of individual citizens across the EU. The rationale behind this second aim is simple: the bigger the amount of collected funds, the bigger the volume of installed renewable power capacity we can 'purchase'. The larger the volume of installed renewable power capacity, the larger the amount of renewable energy generated, the higher the volume of GHG emissions reduced by each individual and, by extension, the more substantial their contribution towards the EU's ongoing energy decarbonisation efforts.

Section 5.1 below provides a condensed overview of the analytical process conducted to address the objectives outlined above. For a more thorough, methodologically-structured, step-wise analytical procedure and technical explanation of the mathematical rationale followed throughout the analytical process explained below please refer to Appendix III.

5.1 Estimating the social potential

Based on the description of the data gathering tools provided in Section 3, the CE reveals the specific preferred option that every survey respondent chooses when confronted with three possible choice options (A, B or C) provided in each of the eight different choice scenarios displayed. Following the rationale outlined by RUT, the preferred discrete choice option selected by any one particular individual is assumed to correspond to the utility level that he/she assigns to that specific choice option (McFadden, 1974).

In order to identify the utility levels that respondents assign to the choice options presented to them, I use an alternative-specific MNL model to first estimate the influence that the attributes of the different investment options (profit rate, holding period, visibility, administrator) and the unique combination of characteristics included under each scenario (capital requirement, RE technology/installation, country indicator) have on the average individual respondent's probability to invest in a RE installation. This allows to a) observe the different levels of interest (utility levels) expressed by respondents for the different investment options being showcased, and b) identify the most preferred variables that, when combined, maximise the likelihood that the average individual selects an investment option from the CE. The results of this initial analysis are outlined in Section 6.1 and complemented with table 4 under Appendix IV.

Based on these initial results, the most preferred set of variables is thus bundled together, with the exception of the 'holding period' and 'profit rate' variables. These are calculated using values reflecting the real market conditions and energy productivity ratings of every EU MS. 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[16] (Wiser & Bolinger, 2018). The profit rate differs from country to country depending on variations of prevailing energy market conditions (e.g. electricity prices) and different national energy productivity ratings. Appendix III outlines the procedure followed to calculate country-specific profit rates, along with table 5 (Appendix IV) illustrating final profit rate figures for every MS and aggregated at the EU level.

Thirdly, the market-derived values obtained for the 'holding period' and 'profit rate' variables are combined with the other most preferred set of variables obtained from step 1, and together modelled in order to estimate the probability of investing in an 'optimal' capital requirement that maximises the level of investment collected by the average representative individual citizen in every MS.

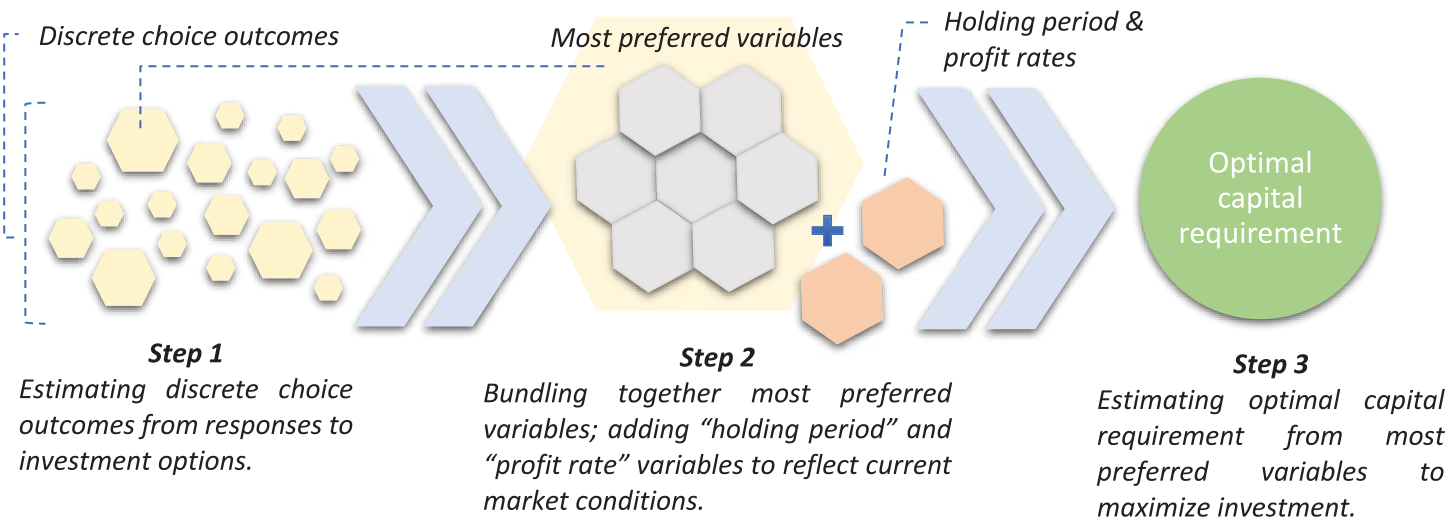


Figure 8. Three-step analytical process conducted to maximise level of investment from the average representative individual in every MS (own elaboration).

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[16] The working lifespan of PV modules is estimated at 25 years (Jordan & Kurtz, 2012). Due to their longer working lifespan than that of wind turbines, I take a conservative approach for determining the 'holding period' variable and select a 20-year timespan to reflect the earliest point at which either one of the two technologies displayed in the CE is dismounted/disassembled.

The results obtained at the conclusion of this third step are then aggregated at the country-level, with the assumption that all individuals between 25-64 years have a reasonable expectation to invest for every EU MSs sampled in the CE. This allows to then obtain each country's social potential for investing in CRE generation schemes. Country-level results are aggregated to obtain the social potential for the EU. The analytical exercise conducted to obtain the resulting figures is shown in table 6 under Appendix IV

5.1.1 Limitations and proposed improvements

The analytical process and simulation procedure for estimating the social potential is subject to various caveats. Most notably, it assumes that all citizens have access to robust (albeit imperfect) market information and community investment options provided by reliable institutions. This is not always the case.

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 and introducing time variability according to different country-specific socio-economic and demographic characteristics would provide a more nuanced analysis of the particular set of variables unique to each country's social potential and, in that respect, would most likely result in a generalised increase – across all countries – of both the probability that they invest in a CRE generation scheme, and the expected amount of money collected for each citizen. Therefore, the current analysis stems from a conservative estimation.

The same rationale could be employed when calibrating the 'RE technology/installation' variable: based on the responses obtained, the analytical process takes the most preferred RE technology/installation on average across the EU-28. A more refined analysis would disaggregate the preferred RE technology/installation on a country basis to determine whether some countries prefer solar or wind technologies. This might lead, again, to a generalised increase (albeit perhaps not in all countries) of the probability of accepting a particular investment option and, as a consequence, the expected probability to invest and amount of money collected per citizen would also increase.

Furthermore, the capital requirement asked for under different investment options could be further disaggregated by income bracket, gender or age, rather than generalised across the entire population. This would result in a more accurate (and appealing) capital requirement offered to different citizens with different socio-economic attributes.

All these measures, when combined, would likely increase individual respondents' investment probabilities, as well as the quantities invested, and would in turn increase countries' social potentials and, as a consequence, the GHG abatement potential of individual citizens across the EU would also increase.

On the other hand, the effects of inflation are not accounted for in the calculation of the profit rates stemming from the investment volumes obtained from the CE respondents. Including the discount effects of inflation when calculating the profit rate would provide a more accurate account of the profitability and attractiveness of the different investment options presented to respondents and, in that respect, influence their responses either by increasing (reinforcing) or reducing (deterring) the latent utilities they have for the different investment options presented to them.

It is also important to acknowledge the potential deviation in behaviour that CE respondents might express when compared with their actual behaviours manifested in a real-life setting. The effects of such a deviation in behaviour are defined as "hypothetical bias". Considered in the context of this research, the hypothetical bias of CE respondents can potentially influence certain responses that do not provide a faithful representation of respondents' actual behaviours when confronted with a similar investment proposition in a real-life situation. This might then lead to an over or under-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.

To account for the effect of a hypothetical bias in the responses of CE participants, the survey asked respondents if they would like to share their email to receive investment information/advice from companies that offer community-based investments in clean energy. Almost half (48%) of CE participants explicitly stated their interest in receiving such information periodically and shared their email accounts. This measure may serve to provide the responses obtained from the CE with greater "credibility", and thereby account for (and reduce) the potential effect that a hypothetical bias may have in CE respondents.

Finally, error bounds could be calculated in the estimation procedure determining the social potential of each MS.

5.2 Maximising the GHG abatement potential

The social potential of each MS is now taken and utilised as the starting point to quantify the GHG abatement potential of individual citizens across the EU. Figure 9 below depicts a flowchart illustrating the rationale followed for the analytical process.

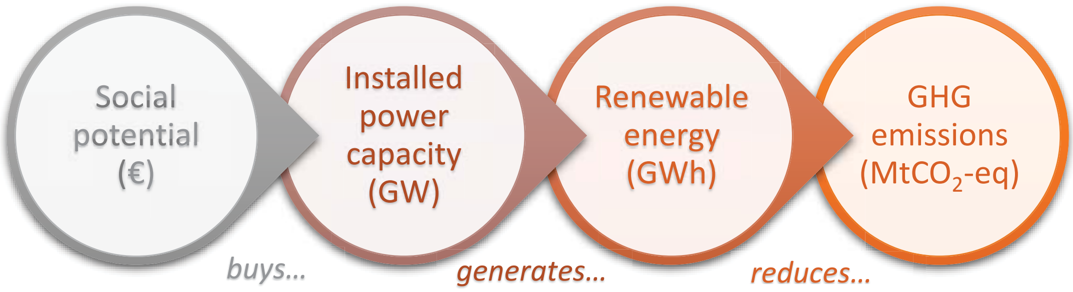


Figure 9. Flowchart of the rationale followed for obtaining the GHG abatement potential derived from Each MS social potential (own elaboration).

I first quantify the installed power capacity (GW) that could be bought with the social potentials of each MS; that is, with the total volume of individually committed investments. 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 the preferred RE technology that the average individual CE respondent has chosen (i.e. solar or wind). The resulting values depict the installed power capacity (megawatt – MW) that could be obtained from the social potentials of each MS under current market conditions both without any subsidies to RE (subsidy-free) and with their addition.

Country-specific power capacities are then combined with national energy productivity ratings to quantify the RE generated annually from the installed power capacity 'purchased' with the social potential of each MS and across the EU. Building on this calculation, I then input the RE generated into each country's 2017 gross final energy consumption serviced by RES in order to quantify the (percentage) increase that the share of RES consumption would represent within each country's total gross final energy consumption[17]. This allows to quantify the impact that the energy generated from CRE schemes has had not only for increasing the share of RES within each country's total gross final energy consumption, but for reaching national and EU-wide 2020 and 2030 RES targets.

Finally, country-specific annual RE generation profiles are combined with country-specific carbon intensities[18]. These are obtained by taking the aggregated emission factors of the fuel mixes of national energy portfolios and subtracting the carbon intensity derived from

[17] Gross final energy consumption (expressed in GWh) refers to the energy commodities (RES and conventional) delivered to industry, transport, households, and services (including public services, agriculture, forestry, fisheries, etc.). This includes a) the consumption of electricity and heat by the power source generating it, and b) distribution and transmission losses. It excludes transformation losses, as these are included in the gross inland energy consumption.

[18] Expressed in tonnes of CO_2 equivalent per megawatt hour (tCO_2-eq/MWh). Taken from Koffi, Cerutti, Duerr, Iancu, and Kona (2017).

wind/solar energy generation. This is done in order to account for the emission factor of local electricity generated from the operation of wind/solar power technology. The resulting *net* carbon intensities of national energy portfolios are then multiplied by their corresponding annual RE generation profiles derived from the total amount of individually-committed investments – that is, from the social potential of each MS. This results in the GHG emissions that could potentially be abated[19] annually through the generation of clean 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. The analytical exercise conducted to obtain the resulting figures is shown in table 8 under Appendix IV.

[19] Expressed in tonnes and million tonnes of CO_2 equivalent (t/Mt CO_2-eq).

6. Results

6.1 Maximising individual investments

An initial descriptive analysis of the responses obtained to the CE indicate that the majority of respondents (79%) chose at least one investment option (A or B) presented to them. Additionally, respondents chose to invest in 57% of the choice scenarios presented to them (table 3 under Appendix IV shows these results for every MS and aggregated across the EU). This shows the high interest expressed by respondents for participating in CRE generation schemes, and implies a high acceptance for RE alternatives and potentially low local opposition.

Specifically, on average respondents are more willing to invest in visible, community-administered wind farm cooperatives with relatively short holding periods and providing higher returns on their investments. This conclusive remark stems from the results illustrated in figure 10 below (table 4 in Appendix IV), which shows the influence that the variables included in each choice option (***β*** and α_i effects) has in the discrete choices manifested by the CE respondents.

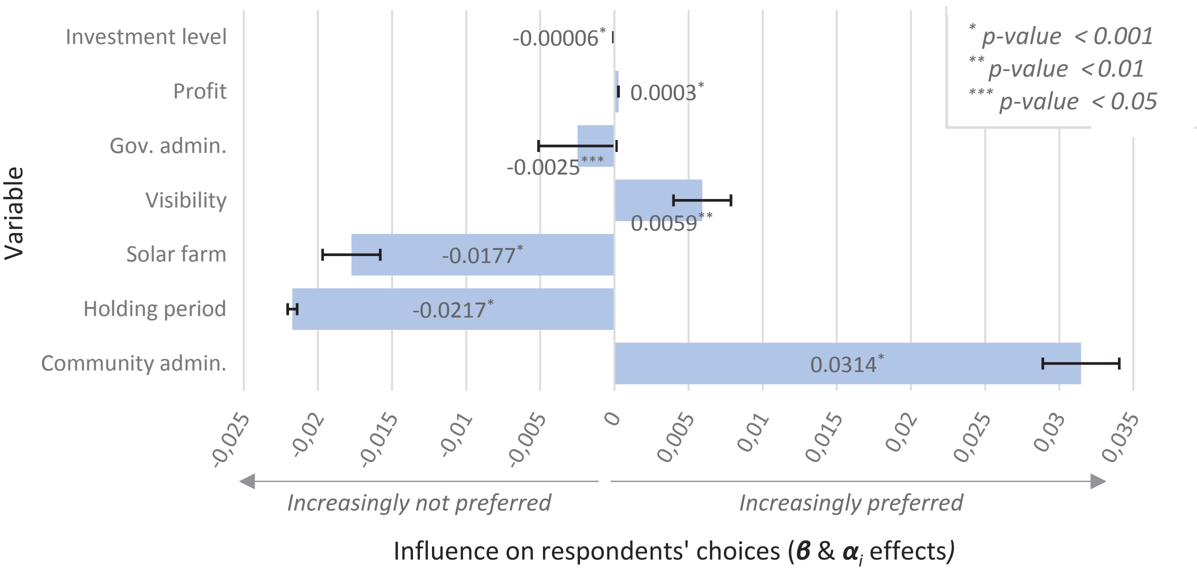


Figure 10. Aggregated effects (**β** and α_i) of option-specific attributes and scenario-specific characteristics (i.e. variables) in respondents' willingness to invest across the EU-28. The ***β*** effect is a measure of the preference given to an option-specific attribute by the average individual respondent, while the α_i effect is a measure of the preference given to a scenario-specific characteristic, as manifested in the responses given by participants. The **β** and α_i effects are quantified and numerically expressed for each variable showcased by the horizontal bars. Larger absolute values indicate stronger effects of any given variable in the average respondent's choice. For any given variable, positive values indicate increased preference and reflect a stronger willingness to invest, while negative values indicate decreased preference and reflect a stronger unwillingness to invest. Standard error values are illustrated by black error bars (⊢⊣), and p-values (*) are expressed for each variable (own calculations based on data obtained from CE responses – refer to table 4, Appendix IV).

As illustrated by figure 10 above, the results obtained after this first estimation indicate that on average for the entire CE sample across all EU-28 MSs, individual respondents:

- Strongly prefer a community-owned legal entity (i.e. energy cooperative) for administering the RE installation they invest in. Furthermore, there is a negative response – although not statistically significant (see p-value) – when confronted with the proposition of having the RE installation administered by a government entity as opposed to a utility company, indicating some kind of distrust or dislike towards government institutions.
- Prefer wind parks above solar farms.
- Are more willing to invest – although not substantially – if they see the RE installation from their household. Specifically, when the RE installation is visible, respondents are on average 0.6% more likely to invest than if the installation was not visible.
- As one would expect, the higher the profit obtained from their initial investment, the more likely they will invest. Specifically, for every additional €100 obtained as profit, we observe a corresponding 2.7% increase in respondents' willingness to invest. However, this is not as strong a variable as the holding period. In fact, we observe how respondents' considerations of the profit rate are counteracted by their latent utilities towards longer holding periods, which seem to hold a more prominent role in shaping/influencing the willingness of respondents to invest (or not) into RE installations. Specifically,
- The longer the holding period the lower the probability respondents will invest: for every extra year respondents have to wait to collect their initial investment and the profit obtained from it, the less attractive the investment becomes and, as such, their willingness to invest decreases by 2.2%. Interestingly, on overage respondents are over twice as susceptible to changes in the holding period than to changes in the profit rate. Even in treatment scripts where a higher profit rate is endorsed by an external national/EU body and guaranteed by the administering unit, respondents seem to be less willing to invest in choice scenarios with longer holding periods but higher profit rates than competing scenarios with shorter holding periods but lower profit rates. These results correlate with the distrust towards government institutions expressed by respondents, and further point towards the potential effect that the discount rate has in shaping respondents' decisions to invest (or not) in an RE installation.

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. As such, the "optimal" investment scenario showcases a 20-year investment on a wind farm, visible to the investor (respondent), and administered by a community-based legal entity (e.g. energy cooperative) 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 figure 11 below (table 5 in the Appendix IV specifies the values obtained from the process followed to calculate wind power profit rates under current market conditions).

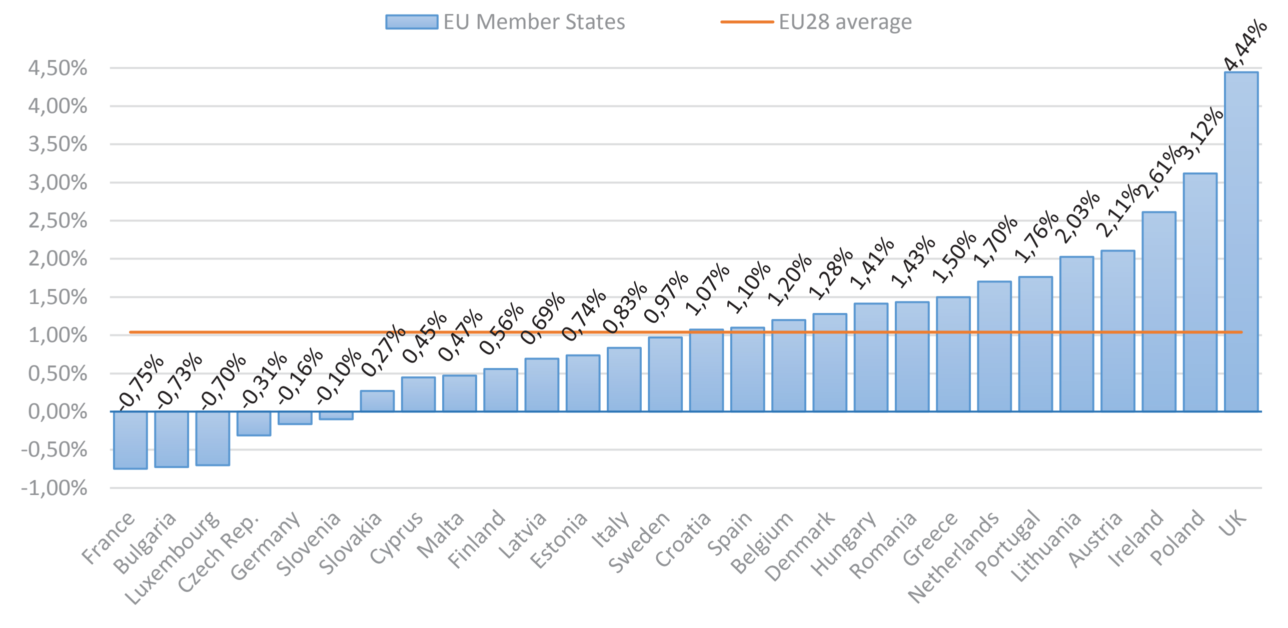


Figure 11. Annual profit rates (expressed in %) derived from national wind power capacities under prevailing market conditions (own elaboration based on data from table 5, Appendix IV).

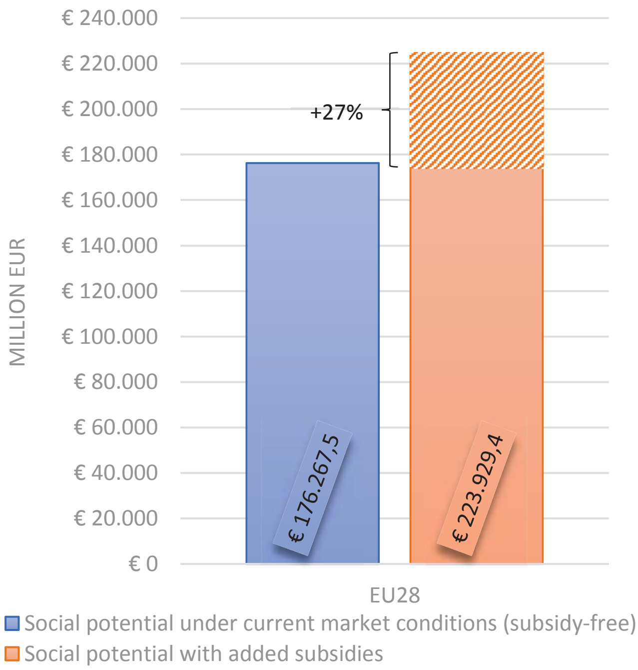
The results obtained depict how, taking the current market conditions and in the absence of national subsidies or any other support schemes (e.g. FiTs, tax exemptions, dispatch priority, etc.) energy generated from wind technology is profitable in 79% of EU MSs, with a +1% annual profit rate averaged for the EU as a whole. This translates into a) an EU average annual profit of €1.2 million per GW of installed wind power capacity, and b) an aggregated total of €19.6 billion in annual revenue from the selling of electricity generated by wind power technology in the EU.

Furthermore, it is worth highlighting that the average 1.04% annual profit rate in the EU represents a higher financial return than that given by numerous interest rates from individual deposits offered by European commercial banks, as well as to the interest rates offered by numerous European national central banks for long-term government bonds. Specifically, wind power generation in Europe results in a higher average EU annual profit rate than 67% of the interest rates offered by long-term government bonds from Eurozone countries (ECB, 2019). In that respect, wind energy seems to be a more attractive investment proposition than many of the more conventional financial alternatives provided by private and public institutions. Participating in a community-managed wind energy cooperative therefore represents a potentially more attractive investment alternative than other more conventional financial products being offered today.

6.2 Country-specific and EU-wide social potentials

The "optimal" investment scenario across the EU identified above, when combined with country-specific profit rates as shown in figure 11 (table 5, Appendix IV) results in the expected maximum amount of funds that can be collected for each individual in each 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 for collectively investing in community-administered wind farm cooperatives.

As illustrated in figure 12 below (table 6, Appendix IV), based on the respondents' estimated feedback to the "optimal" investment scenario, the EU's social potential for collectively investing in community-administered wind farm cooperatives *under current market conditions* – that is, without subsidies or any other support mechanism – is substantial: over €176 billion could potentially be harnessed from European citizens to collectively support community-based forms of RE development, thereby dramatically increasing the deployment of clean and, by doing so, accelerate Europe's low-carbon energy transition. Furthermore, if the national subsidies allocated during 2016 by EU MSs for supporting RE development – quantified in €56.7 billion for the entire EU during 2016 ((CEER, 2018)[20] – were inputted into table 6, the expected volume of citizen investments collected across the EU would increase by 27% reaching a total volume of €224 billion (fig. 12). This is the equivalent to 1.5% of the EU's GDP in 2017.



[20] See table 7, Appendix IV.

Figure 12. Difference between EU social potential under current market conditions (subsidy-free) and with added 2016 national subsidies to support community renewable energy (own elaboration based on CE data; CEER, 2018; and Eurostat, 2018c, 2018d).

These results illustrate the enormous untapped social potential of European citizens for collectively financing the development of community-based forms of RE generation. Materialising that potential would undoubtedly transform the Energy Union from a political commitment to a citizen endeavour and help realise its main goal of having "citizens take ownership of the energy transition, benefit from new technologies [and] participate actively in the market" (European Commission, 2015, p. 2).

A logical question, then, would inquire about what combination of policy instruments would be best-suited to advance a set of economic incentives that increase the expected level of investment of individual citizens and, by extension, increase the social potential of MSs for supporting CRE generation schemes. One insight stemming from the initial estimation of the full data set from the CE sample (fig. 10; table 4, Appendix IV) notes that individual citizens' investment decisions, on average, tend to be more strongly influenced by changes in the holding period than changes in the profit rate stemming from their investments. In fact, the effects of profit rate increases are to a certain extent minimised by longer holding periods when influencing the willingness of respondents to invest (or not) in CRE generation schemes.

This might occur, for instance, due to an unstable regulatory framework imposing retroactive modifications to previously approved policies and thereby generating investment uncertainty. Similarly, highly volatile electricity prices might generate doubtful revenue projections and a more challenging business case, thereby influencing investors' perceptions of risk related to investments and result in reduced confidence.

In the CE a risk-free investment was guaranteed to the respondent. This fact, along with the availability of multiple investment options, may be the reason for the substantial social potential and high rates (79%) of accepting an investment option. Thus, regulators and policymakers should strive to ensure that easily accessible, trustworthy, and risk-insured community investment options are available across EU MSs to unlock their social potentials.

The results outlined above offer policy-relevant insights informing the design of EU/national regulatory frameworks tailored towards increasing market transparency, price stability, and revenue certainty so as to minimise the negative effect that long holding periods have on individual citizens' investment confidence. These considerations are further discussed in Section 7.

6.3 Bridging the financing gap

As outlined in section 2.2, current estimates indicate a financing gap of €179 billion annually to achieve the EU's 2030 climate and energy targets (European Commission, 2018a, 2018b). No less than 9% of the foreseen annual investments over the next 11 years – 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 (Williams et al., 2018). This translates into a cumulative investment of €374 billion over an 11-year period, and positions the EU's social potential of €176 billion for investing and participating in CRE as a critical resource to bridge the existing financing gap.

The social potential of €176 billion that European citizens could contribute through collective investment schemes in CRE respond directly to this need. When evenly distributed throughout the 11-year timespan mentioned above, they result in an annual investment of €16 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 and cost-effective market-driven implementation of a carbon reduction pathway responding to the climate constraints imposed by a 2°C global warming threshold.

6.4 GHG abatement potential of European citizens

Having identified the total volume of individually committed investments for community-managed wind farm cooperatives in each MS, figure 13 below depicts the installed wind power capacity (MW) that could be 'bought' from the social potentials of each MS both under current market conditions (subsidy-free) and with the addition of national subsidies as shown in table 7 under Appendix IV. As mentioned in the previous section, at the EU level these are valued in €56.7 billion allocated by MSs for supporting the development of RE during 2016 ((CEER, 2018).

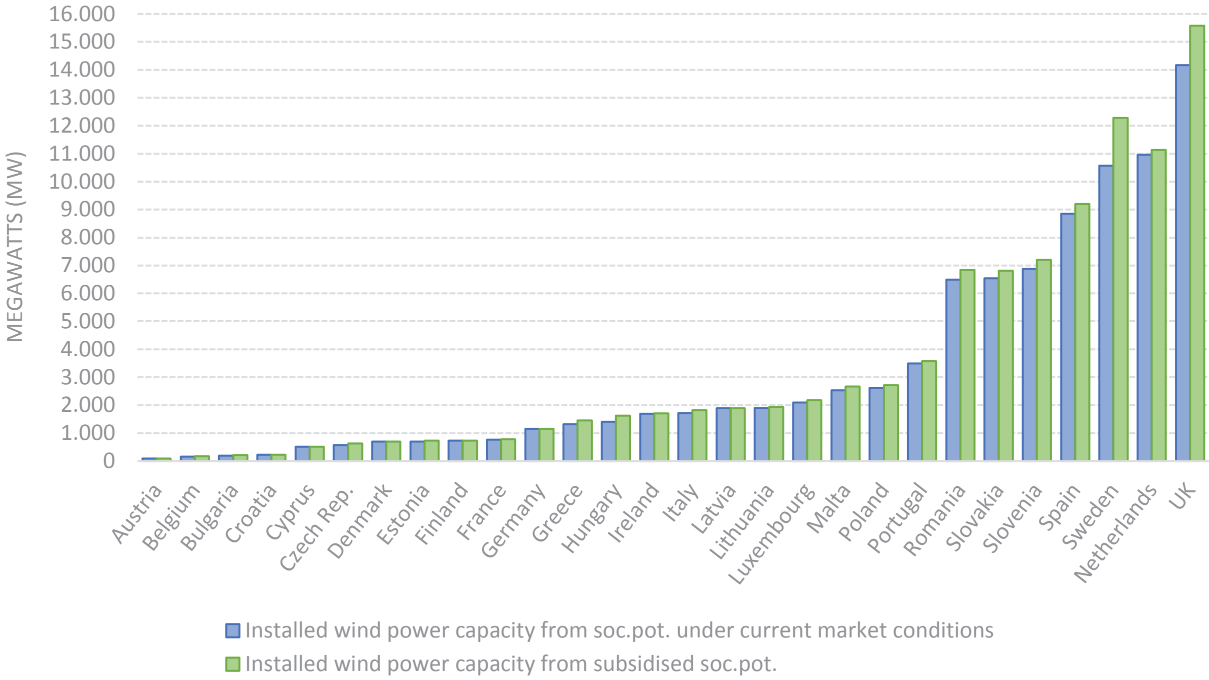


Figure 13. Installed wind power capacities from social potential under current market conditions (subsidy-free) and with additional 2016 subsidies from EU Member States for supporting renewable electricity generation[21] (own elaboration based on CEER, 2018 & WindEurope, 2018). See table 7, Appendix IV for calculations.

Adding together the values depicted in table 7 (Appendix IV; and illustrated in figure 13 above) for each MS, we can conclude that the total EU installed wind power capacity that could be 'bought' with the social potential under current market conditions – that is, in the absence of subsidies – amounts to a total of 90,900 MW (91 GW). This is a volume greater than the national electricity production capacities[22] of 24 different EU MSs (Eurostat, 2019c). When utilising the social potential obtained after the introduction of subsidies for RE generation, we obtain an EU-wide installed wind power capacity of 115,479 MW, greater than the electricity production capacities of 26 MSs and just below those of Germany (203,931 MW) and France (123,443 MW) (Eurostat, 2019c).

When multiplied by the corresponding national wind energy productivity ratings, the installed wind power capacities illustrated in figure 13 above yield the final RE (GWh) generated annually by each MS and across the EU. Building on this initial calculation, the RE generated is inputted into each country's 2017 gross final energy consumption serviced by RES in order to

[21] The corresponding figures for each MS can be found in table 7 under Appendix IV.

[22] As per Eurostat's (2018d, 2019c) own categorisation, these include combustible fuels (coal, natural gas, oil, biofuels and non-renewable wastes), hydropower, geothermal, wind, solar (thermal and PV), tide-wave-ocean, and nuclear fuels.

quantify the (percentage) increase that the share of RES consumption has experienced within each country's total gross final energy consumption[23]. This is illustrated in figure 14 below.

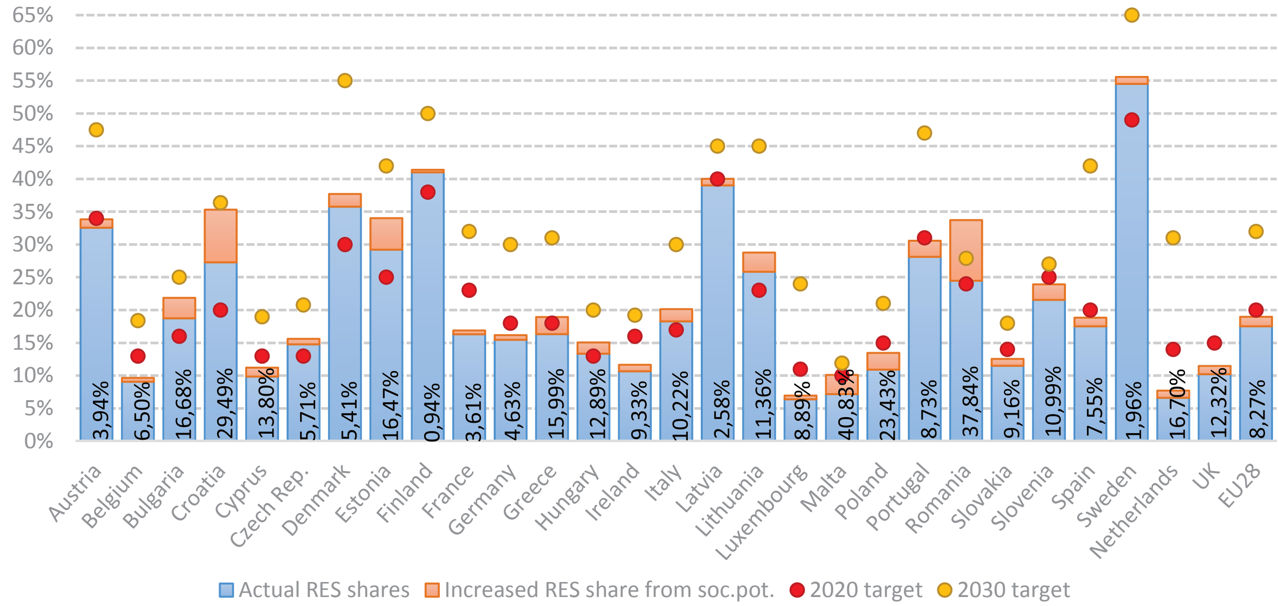


Figure 14. Current (2017) renewable energy shares and percentage increase from social potential under current market conditions (subsidy-free) in every Member State and aggregated at EU level; plus 2020 & 2030 national and EU-wide renewable energy targets[24] (own calculations and elaboration based on table 8 figures, Appendix IV; Eurostat, 2019e; IEA, 2019; European commission, 2019a, 2019b).

Results indicate an average 8.3% increase in the consumption of RES across the EU when the social potential is included (fig.14). This translates into a total of 195.85 GWh of additional energy consumed. Assuming such consumption does not add to – but instead substitutes – 195.85 GWh of energy consumed from conventional energy sources, we can then conclude that the energy generation derived from the social potential in the EU would result in an average 8.3% increase in the share of RES. This would increase to 10.5% after the introduction of subsidies for RE generation.

Furthermore, the GHG emissions that could be potentially abated from these 195.85 GWh of RE amount to 103.4 $MtCO_2$-eq annually. This represents a 2.3% reduction in annual emissions from 2017 EU aggregate levels, and a 1.8% annual reduction from 1990 baseline levels. Furthermore, the abatement potential obtained across the EU amounts to over 3% of the GHG emissions stemming from the energy sector in 2017.

[23] Gross final energy consumption (expressed in GWh) refers to the energy commodities (RES and conventional) delivered to industry, transport, households, and services (including public services, agriculture, forestry, fisheries, etc.) (Eurostat, 2018d). This includes a) the consumption of electricity and heat by the power source generating it, and b) distribution and transmission losses. It excludes transformation losses, as these are included in the gross inland energy consumption (Eurostat, 2018d).
[24] UK's 2030 RES target not identified in its National Energy and Climate Plan (NECP) submitted to the EU.

6.5 Reaching the EU's 2030 GHG emission reduction targets

As mentioned in Section 1.2, in order to reach a 40% GHG emission reduction by 2030 the EU must avoid the emission of 377.5 MtCO2-eq every year from 2017-2030. This represents a 6.6% annual reduction of GHG emissions for 13 consecutive years. Considering that the EU's average annual reduction of GHG emissions between 1990-2017 has been of 0.9%, having an additional 2.3% annual reduction from CRE generation schemes inputted into its projected annual GHG emission reductions represents a substantial acceleration of its pace of reduction and, in that respect, would improve – yet by no means resolve – the EU's performance to achieve its 2030 target within the foreseen timeframe (fig. 15).

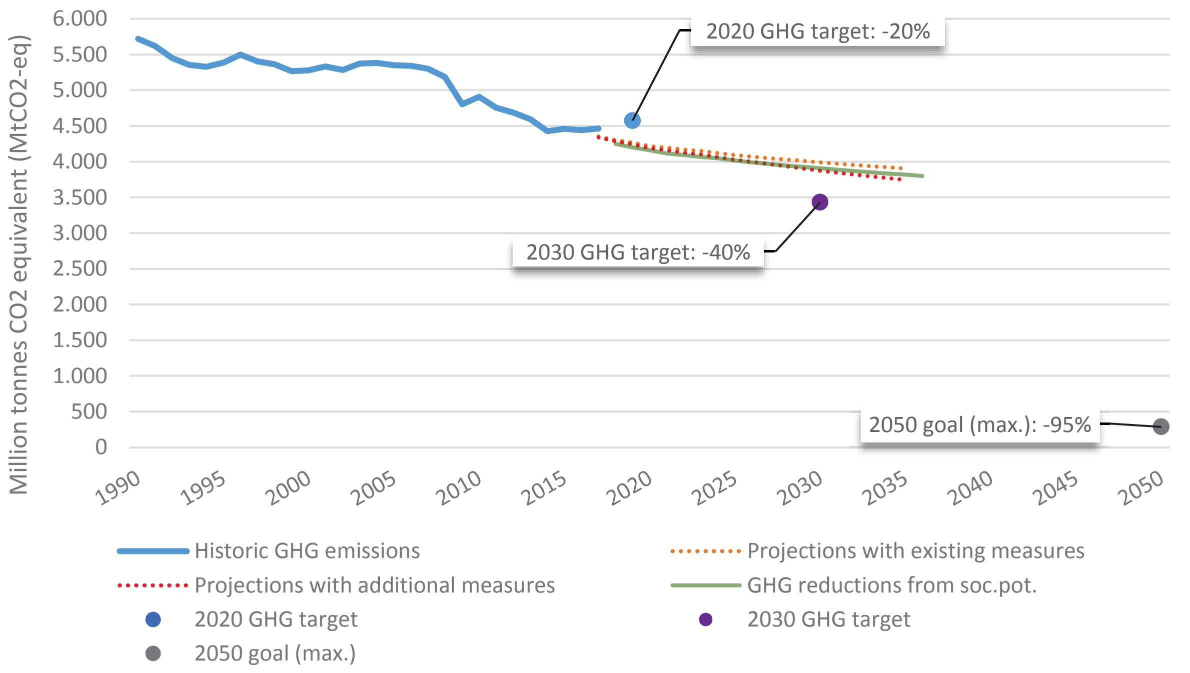


Figure 15. EU's GHG emission trends, projections with existing and additional measures, and GHG reduction targets; plus contribution from community-administered wind farm cooperatives collectively financed by individual citizens – i.e. social potential, highlighted by green line (own calculations and elaboration based on EEA 2016b, 2018a; and CE data).

As shown in figure 15 above, the carbon abated by individual citizens collectively investing in CRE generation schemes – albeit desirable both for environmental and socio-economic reasons – is by no means sufficient to put the EU on track to achieve its 2030 GHG reduction target. The EU would still need to reduce an extra 274 MtCO2-eq every year to achieve a 40% annual reduction by 2030, over twice the volume of GHGs emitted by the Czech Republic in 2017. The EU must therefore urgently adopt 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 $GtCO_2$ (McCollum et al., 2018).

7. Discussion

It is critical to note that the experimental design of the research presented herein guaranteed a risk-free investment operationalised through a trustworthy and straightforward vehicle. These facts, along with the availability of multiple investment options, may be the reason for the substantial social potential and high acceptance rates of the investment options being offered. Thus, regulators and policymakers should strive to ensure that easily accessible, trustworthy, and risk-insured community investment options are available across EU MSs to unlock their social potential for investing in CRE generation schemes. Appropriate auction and revenue mechanisms is one critical aspect for creating a positive environment for collective investments in CRE. This section presents ideas that would help move towards a risk-free regulatory environment for collective investments and thus help satisfy the main policy recommendation that flows from this empirical analysis. With it, this section aims to shed light on the challenge that represents organising the deployment of increasing amounts of RES through a liberalised market architecture, and the implications that this has for unlocking the EU's social potential for investing in CRE.

7.1 Balancing stakeholder diversity and cost-efficiency: 'collaborative competition'

Unlocking the EU's social potential will require a coherent and harmonised regulatory framework that provides a level playing field to all stakeholders by facilitating equal and non-discriminatory market access and participation, and thereby providing an opportunity for developing bottom-up, community-anchored RE generation schemes along with more traditional, larger RE developments. Ideally this should be done through policy instruments interfering minimally on the functioning of electricity markets in order to avoid any potential disruption on their price formation/signalling role. In that sense, competitive tendering schemes (i.e. auctions) for RES development might benefit from a more nuanced approach that takes into consideration the specific cost structures (capital and marginal) and market maturities of a diversified range of RE technologies, along with the unique financial, material and operational capabilities of a diversified range of small, medium and large-scale RE developers.

Such an approach could be operationalised through a new generation of integrated competitive tendering schemes tailored along three dimensions: technology, stakeholder, and spatial distribution. This would allow the allocation of highly targeted financial support addressing *the combination* of specific RE technologies (e.g. solar PV, wind, hydro, biofuels, etc.) deployed by a specific subset of geographically-dispersed market stakeholders (e.g. SME power utilities, energy cooperatives, municipalities, large power utilities, etc.). These could submit bids and operate contracts either independently or collaboratively in the form of, for example, commercial partnerships through subcontract agreements between a) various energy cooperatives, bundled together in their shared role as a RE generator, and b) a larger power utility operating as an energy aggregator and distributor.

In that way, competitive tendering schemes would incentivise the establishment of a 'collaborative competition' anchored in innovative partnerships between a range of different stakeholders involving more traditional incumbents such as, for instance, larger power utilities holding more robust market information and stronger commercial and marketing capabilities; and more innovative – yet less experienced – newcomers such as smaller scale energy cooperatives collectively financed by e.g. individual citizens and municipalities.

Specific quotas determining a minimum amount of stakeholder diversity and technology differentiation could be introduced, and tailoring auction price floors/ceilings accordingly. This would allow to then:

a) Calibrate a much more targeted allocation of limited financial resources resulting in distributed – rather than concentrated – economic gains;
b) Provide a 'weighted' level playing field through equal and non-discriminatory market access and participation, while simultaneously;
c) Support not only the cheapest RES at a specific point in time, but a wider range of RE technologies with unique techno-economic profiles and market diffusion rates, as part of a diversified portfolio of domestically-harvested clean energy technologies.

This 'collaborative' alternative to competition-induced RES development might be a promising venue for unlocking the EU's social potential of €176 billion for investing and participating in CRE, without compromising the desired cost-efficiency resulting from the use of competitive tendering schemes for RE support such as auctions. It would still keep a competition-oriented approach to RE support resulting in (expected) progressive technology cost reductions and more competitive – yet volatile – electricity prices, while at the same time maintain a controlled volume of auctioned power capacity without overly impairing the allocative efficiency of liberalised energy markets. By doing so, the economic incentives needed to increase small (and large) investor confidence in what have traditionally been riskier investments into RE technologies would facilitate the participation of individual citizens collectively organised around community-based RE generation schemes. Their GHG abatement potential could then be awarded in a more cost-effective and distributive way, and the Energy Union's main goal to have "citizens take ownership of the energy transition, benefit from new technologies to reduce their bills, [and] participate actively in the market" (European Commission, 2015, p. 2) would be within reach.

7.2 Citizen empowerment through collective finance

The reflections forwarded here may serve as an entryway to undertake a broader analysis and more detailed deconstruction of the ongoing transformation that energy markets must undergo for accommodating what is expected to be an increasingly diverse set of energy actors combining traditional players with newly emerging 'market participants'. In that respect, the broader idea of *stakeholder and rent diversification* behind the concept of 'social potential' developed through this research might serve as a valid conceptual tool to further explore and uncover how the EU's energy market regulatory framework is being operationalised for supporting a more participatory and democratic low-carbon energy transition that empowers citizens to become "carbon sinks".

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. This occurs through a particularly distinctive and powerful approach consisting not so much in openly questioning or actively confronting the financial system and broader economic paradigm that energy systems are embedded in, but instead on leveraging and harnessing its immense transformative potential as a means to expedite the pace of RES deployment through community-based forms of energy generation. It is the position concluded in this research that without the collective and consistent pooling of citizens' financial participation, a truly democratic low-carbon energy transition built around an empowered citizenry and collective agency will not occur.

These conclusive remarks highlight the need to build a *financially democratic lock-in* into Europe's energy architecture, and establish a reasonable amount of *citizen dependency* for financing the expansion and localised deployment of RES through, in this case, community-managed wind energy cooperatives.

8. Conclusion

The EU is in the midst of a profound transformation of its energy system, with the environmental imperative of carbon neutrality driving the deployment of clean and renewable energy sources through market-driven mechanisms (e.g. auctions) that can potentially undermine the ability of European citizens to meaningfully contribute to a decentralised, localised and decarbonised energy system. This one particular challenge is representative of the broader institutional legacies, embedded political and regulatory frameworks, market structures and financial flows, and individual/collective energy behaviours and consumption patterns collectively reinforcing and reproducing the sociotechnical inertia of our current energy system, characterised by fossil fuel path dependency, energy-intensive infrastructural lock-in, and sunk capital costs. Such a system of energy and material resource use and exchange cannot be successfully sustained into the future without risking irreversible climate change and environmental disruption.

Transformative change must occur if a truly democratic, participatory and, most crucially, timely low-carbon energy transition is to take place. With this end in mind, the research conducted in this thesis explored the social potential that collective finance in CRE generation schemes has for catalysing the proactive participation of individual citizens as legitimate and necessary agents co-driving the decarbonisation of Europe's energy system. It does so by taking the responses obtained from an international survey and Choice Experiment on environmental/energy-related behaviours and consumption patterns conducted across 31 European countries, and estimating the probability that the average representative European citizen would participate in the collective financing of community-based RE generation schemes. Estimates are calculated using a probabilistic discrete choice model anchored in random utility theory, namely the 'alternative specific multinomial logit' model. Outputs are aggregated at the country and EU levels.

The results obtained indicate a substantial social potential of €176 billion from European citizens willing to financially support and collectively participate in community-administered wind energy cooperatives across the EU. This 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 2017 levels.

In light of these results, EU energy and climate policy must strive to generate the necessary economic incentives and market conditions to incorporate the participation of less traditional, experienced and/or organised RE developers (e.g. energy cooperatives) in jointly expediting the increased penetration of renewable energy collectively financed by individual citizens. The EU's current climate and energy regulatory framework, NECPs and related set of national subsidies to RE generation do not address this need successfully and, as such, undermine the ability of European citizens to partake in, and economically benefit from, a carbon-neutral, spatially-distributed, and diversified energy system.

The extent of citizenry empowerment and collective agency derived from €176 billion is substantial. It will be a critical element not only for challenging the institutional legacies that protect the status quo and support an energy pathway characterised by concentrated corporate benefits and socialised environmental costs, but for unlocking the role of individual citizens as a legitimate and indispensable actor co-driving a climate-compatible energy system that serves today's society without denying a healthy environment and liveable planet to future generations.

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Appendix List

Appendix I: data collection tools

Table 2: Set of quotas drawn from sociodemographic indicators included in the survey sampling process to ensure population representability (own elaboration based on ECHOES project international survey, 2018; CIA, 2018; and Eurostat 2019a, 2019b, 2019f .

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).*

Example of the opening statement introducing the control script to the respondents of the Choice Experiment (ECHOES project consortium, 2018):

> *"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."*

Appendix II: theoretical framework and analytical tools

a) Technically-oriented description of random utility theory (RUT), along with the key mathematical functions utilised to statistically analyse the responses obtained from the Choice Experiment (CE).

Building on the description of the data gathering tools provided in Section 2.1, let's consider a representative individual CE respondent *n* confronted with a choice scenario *L*[25] with different opportunities (choice options)[26] to invest in for financing a RE installation. The utility *U* that he/she ascribes to any choice option *i* will be a function of a) *i*'s different set of attributes Z_{in}[27], plus b) the unique respondent-specific characteristics *S* of individual *n* – which will also affect the utility of any given choice option *i* (Cascetta, 2009; Hanley et al., 1998). This may be mathematically represented as follows[28]:

$$U_{in} = Z_{in} + S_n \quad (1)$$

Based on equation (1), we can assume that any choice option *i* will be preferred over some other choice option *j* if *i*'s utility U_{in} is bigger than *j*'s U_{jn} ($U_{in} > U_{jn}$); as long as the unique respondent-specific characteristics *S* influencing individual *n*'s preferred option *i* are also taken into consideration (Adamowicz et al., 1998; Hanley et al., 1998).

RUT further assumes that the preference of individual *n* for one particular choice option *i* over the others (in other words, his/her utility function as depicted by (1)) is further shaped by two main components: one systematic (and observable) component *V*, and one random (and unobservable) component *ε* (Cascetta, 2009; Hanley et al., 1998). As such, the latent utility *U* of any one particular individual CE respondent *n* will result from the sum of the utility's systematic and random components. Equation (1) can therefore be re-formulated as follows[29]:

$$U_{in} = V(Z_{in}, S_n) + \varepsilon(Z_{in}, S_n) \quad (2)$$

the utility *U* that individual *n* ascribes to choice option *i.*

the systematic/observable component of the utility that individual *n* ascribes to choice option *i.*

the random/unobservable component of the utility that individual *n* ascribes to choice option *i.*

[25] Corresponding to one of the eight different choice scenarios displayed in the CE.
[26] Corresponding to options A, B, and C from the CE.
[27] Also described as "alternative-specific characteristics". As stated in Section 2.1.2, these include profit rate, holding period, visibility, and administrator.
[28] Based on Hanley et al. (1998).
[29] Based on Hanley et al. (1998).

The probability that individual *n* chooses option *i* from any other competing option *j* may be mathematically expressed as[30]:

$$Prob(i|C) = Prob[V_{in} + \varepsilon_{in}) > Max(V_{jn} + \varepsilon_{jn})], \text{for all } j \text{ options in choice set } L \tag{3}$$

Equation (3) tells us that the probability *Prob* that individual *n* chooses option *i* from the choice set *L* equals the probability that the systematic and random components $(V_{in}, \varepsilon_{in})$ of option *i* are larger than the maximum possible value *Max* of the systematic and random components $(V_{jn}, \varepsilon_{jn})$ of any other option *j* competing with option *i*.

b) Technically-oriented description of the 'alternative specific multinomial logit model', along with the key mathematical functions utilised to statistically analyse the responses obtained from the CE.

Different assumptions on the probability distributions of the error term for the random/unobservable component ε will result in different probability-based discrete choice models (Louviere et al., 2010). The usual assumptions made are that the error term is Gumbel-distributed[31] and independently and identically distributed (IID) (Hanley et al., 1998; Louviere et al., 2010; McFadden, 1974). If incorporated, these assumptions then lead to the adoption of the multinomial logit (MNL) model for analysing equation (1), as outlined in McFadden (1974). The mathematical equation of the MNL will result from computing the error term as a Gumbel extreme-value random variable (ϵ_{in}) into equation (1), resulting in its reformulation as:

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

The alternative specific MNL effectively models the probability that individual *n* chooses a certain option *i* given its corresponding set of attributes Z_{in} and the unique respondent-specific characteristics S_n of individual *n*, as shown by equation (3). The *effects* of the variables within *Z* and *S* on the latent utility levels of individual CE respondent *n* are represented by the vectors $\boldsymbol{\beta}$ and $\boldsymbol{\alpha}_i$[32]. Ultimately, the actual observed choice of individual *n* (M_n) relates to the underlying latent utility U_{in} such that:

$$M_n = i \;\; if \;\; [U_{in} > Max(U_{jn})] \text{ , for all } j \text{ options in choice set } L. \tag{5}$$

The purpose of modelling equation (4) through an alternative specific MNL is to estimate the probability that the respondents of the CE will choose any of the options (A, B or C) presented to them in the eight different choice scenarios. In order to estimate the alternative specific MNL model we must first choose one alternative from equation (4) as the base

[30] Based on Adamowicz et al. (1998); Cascetta (2009); Hanley et al. (1998); Louviere et al. (2010)
[31] Also known as a "Generalised Extreme Value Distribution – Type I".
[32] Where $\boldsymbol{\alpha}_i$ are coefficients uniquely related to choice option *i*.

alternative, and assign a value of zero to its corresponding coefficient vector $\boldsymbol{\alpha}_i$. This allows to interpret the $\boldsymbol{\alpha}_i$ estimates in relation to the probability of choosing the base alternative. Based on the three different options (A, B, and C) included in the CE, option C (opt-out) is chosen as the base alternative in all the simulations. This allows to more easily interpret the output of the model as the effect that option-specific attributes *Z* and respondent-specific characteristics *S* have on the probability of opting-out from any investment option (A or B) presented in the choice scenario. In other words, by setting the base alternative (option C – opt-out) to zero, we are able to estimate the likelihood/probability that individual respondent *n* won't invest in any of the options (options A and B) presented to him/her. This, in turn, will allow us to estimate the likelihood/probability that individual respondent *n* will actually invest in any of the options (A and B) offered to him/her.

Appendix III: analytical process

Methodologically-structured, step-wise analytical procedure and technical explanation of the mathematical rationale followed throughout the analytical process outlined in section 5.1.

Step 1: Estimating the effects (β and α_i) of the variables within different investment options

Equation (4) is modelled using a maximum likelihood estimation of the full dataset from the entire CE sample in order to estimate the values of $\boldsymbol{\beta}$ and $\boldsymbol{\alpha}_i$, and obtain a general understanding of the effects that the attributes of the different investment options (alternative-specific variables included in *Z*) and the unique combination of characteristics assigned to every individual *n* (respondent-specific variables included in *S*) have on the respondents' choice probabilities. The alternative-specific variables included in *Z* are:

- The total profit gained from the investment (profit rate + initial investment) – expressed in national currencies.
- The holding period – expressed in years.
- The visibility (or lack thereof) of the investment.
- The legal entity administering the investment (either a community group or a government institution – the utility company as an administrator is selected as the omitted group).

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

The respondent-specific variables included in *S* are:

- The initial capital requirement each respondent was offered to invest – expressed in national currencies.
- The RE technology/installation that the choice scenario featured (wind farm or solar park)
- An indicator variable for the country of residence[33].

Step 2: estimating the probability of accepting an investment option

The results obtained from this initial estimation serve to identify the most preferred set of variable expressed by the average individual respondent, and to bundle these together in order to maximize the expected level of investment π_n that the average, representative individual *n* is willing to provide for funding a RE installation, for each sampled country *N*. In

[33] For the purposes of this first step in the analytical process, there is no need to include additional respondent-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 in the actual indicator variables of the country of residence of the respondents.

order to calculate this amount I first impute the probability P_n that the average individual *n* will choose an investment option A or B. I then multiply this value by the capital requirement b_n that individual *n* is asked to contribute with for funding an RE installation. This is mathematically represented as:

$$\pi_n = P_n b_n \tag{6}$$

Further on, the total amount of expected funds collected for community-administered wind farm cooperatives is then obtained by multiplying equation (6) by country *N*'s population pop_N with a reasonable expectation to invest (aged between 25-64) [34]. By doing so I obtain the expected total investment $\tilde{\pi}_N$ contributed to community-administered wind farm cooperatives at the country level, where individual *n* is a resident of country *N*. Equation (6) is thus reformulated as follows:

$$\tilde{\pi}_N = (P_n b_n)\ pop_N \tag{7}$$

The value represented by $\tilde{\pi}_N$ is described here as a country's *social potential* for investing and participating in community-administered wind farm cooperatives. Furthermore, the probability P_n that the representative individual *n* will invest in an option with capital requirement b_n will result from he/she ascribing a higher utility *U* to any one investment option (A or B) than to opting-out (option C). This is mathematically expressed as:

$$P_n = Prob(U_{An} > U_{Cn} | U_{Bn} > U_{Cn}) \tag{8}$$

As such, P_n may be expressed as a linear function of the capital requirement b_n asked for to individual *n* plus the rate of return *r* offered along b_n. This is expressed as:

$$P_n = \widehat{F_n} + \hat{\gamma}_{1N} b_n + \hat{\gamma}_{2N}(b_n r_n) \tag{9}$$

$$P_n = \widehat{F_n} + b_n(\hat{\gamma}_{1N} + \hat{\gamma}_{2N} r_n)$$

I estimate F_n (expressed as $\widehat{F_n}$) using the results obtained from the country-specific MNL models with settings for the alternative-specific variables Z_{in} and respondent-specific-variables S_n that will make equation (9) for P_n true even when there is a capital requirement asked for of $b_n = 0$. Therefore, $\widehat{F_n}$ depicts the probability of choosing option A or B for a visible wind park with a 20-year holding period, managed by a community administrator, and with an initial capital requirement of zero. This quantity is inputted for each MS sampled using country-specific estimates of the MNL model (i.e. estimating equation (4) only using the respondents from a specific nation *N*).

[34] 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 Eurostat (2018c, 2019d)

Since the aim is to maximise a country's social potential $\tilde{\pi}_N$ for private citizen investments, I input the P_n values into equation (9) taking the most preferred alternative-specific variables Z_{in} stated by respondents in order to make the investment option (A or B) most preferable, on average. Therefore, based on the results obtained from the initial analysis in Step 1 (see table 4), an 'optimal' investment scenario is designed to accommodate the RE installation as a wind farm, visible to the respondent, and administered by a community-based legal entity (e.g. cooperative) for all cases.

For the other two alternative-specific variables in Z_{in} (holding period and profit rate) I choose 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 (Wiser & Bolinger, 2018). The profit rate differs from country to country depending on variations of prevailing energy market conditions and different national wind energy productivity ratings. The calculation of the profit rates as shown in table 5 below, 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 capacity (11.5 GW) for that same year. The resulting figure (€ 1,939.13/kWh) depicts the European average of total installed generation capacity costs for wind energy in 2017. This figure is used as the default value for all countries.
2) Secondly, for each MS the values from the wind energy generated (GWh) in 2017 are taken and divided by the country's installed wind power capacity (GW) for that same year. This is done to obtain the country-specific productivity ratings of their corresponding installed generation capacities.
3) Thirdly, the 2018 average spot electricity price (€/GWh) for each MS is taken from the different European electricity markets servicing the corresponding countries.
4) Taking the information obtained in steps 2-3, each country's average annual revenue (expressed in EUR) from the generation and sale of wind energy per GW of installed capacity is calculated by multiplying the country-specific productivity ratings by the corresponding national electricity prices.
5) With this information, the profit rates for each country are calculated as follows:

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

Step 3: Maximising the expected funds collected per country

As mentioned in Step 2 above, using the baseline data obtained from the individual responses and the calculations outlined above and as shown in table 5, the linear function (9) derived from the representative probability P_n of individual *n* accepting an investment option is inputted into equation (6), giving a system of equations relating to the social potential π_N such that:

$$\pi_n = \underbrace{P_n} b_n \quad (6)$$

$$P_n = \widehat{F_n} + b_n(\hat{\gamma}_{1n} + \hat{\gamma}_{2n} r_n) \quad (9) \longrightarrow \pi_n(b_n) = b_n\left[\widehat{F_n} + b_n(\hat{\gamma}_{1n} + \hat{\gamma}_{2n} r_n)\right] \quad (10)$$

Taking the first derivative of $\pi(b)$ with respect to b_n I obtain:

$$\frac{\alpha\pi(b)}{\alpha b} = \widehat{F_n} + 2b_n(\hat{\gamma}_{1n} + \hat{\gamma}_{2n} r_n) \quad (11)$$

As shown below, by setting $\frac{\alpha\pi(b)}{\alpha b}$ equal to zero and solving equation (11) I obtain an analytical solution for the optimal capital requirement b_n^* from equation (6) so that the expected level of investment π_n that the average, representative individual *n* is willing to provide for funding a RE installation is maximised, for each sampled country *N*[35].

$$b_n^* = \frac{-\widehat{F_n}}{2(\hat{\gamma}_{1n} + \hat{\gamma}_{2n} r_n)}$$

The optimal capital requirement b_n^* is inputted back into equation (9) and solved in order to obtain the optimal probability P_n^* of choosing an investment option offering an optimal capital requirement b_n^* for the average individual respondent *n* to invest in the financing of a community-administered wind farm cooperative with a 20-year holding period in country *N*. When solved, P_n^* is thus mathematically expressed as:

$$P_n^* = F_n - {}^1/_2\, F_n \quad (12)$$

The final amount of funds collected from the average person in each nation is then given by:

$$\pi_n^* = P_n^* b_n^* \quad (13)$$

Equation (13) indicates the expected maximum amount of funds that can be collected for each individual *n* in each nation *N* based on the most preferred variables inputted in the simulation of the alternative specific MNL model. Finally, I multiply equation (13) by country *N*'s population pop_N with a reasonable expectation to invest (aged between 25-64) in order to estimate its social potential for investing and participating in community-administered wind farm

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

cooperatives. Table 6 below showcases the results obtained at the conclusion of this analytical process.

Appendix IV: results

Table 3: Distribution of responses to investment options and choice scenarios (own calculations based on CE responses).

Country	*Respondents saying "yes" to at least one investment option*	*Scenarios where an investment option was chosen*
Austria	82%	57%
Belgium	71%	48%
Bulgaria	88%	64%
Croatia	95%	80%
Cyprus	82%	60%
Czech Rep.	80%	56%
Denmark	64%	44%
Estonia	91%	84%
Finland	74%	46%
France	71%	48%
Germany	74%	49%
Greece	88%	62%
Hungary	84%	60%
Ireland	81%	51%
Italy	83%	61%
Latvia	68%	44%
Lithuania	80%	58%
Luxembourg	83%	62%
Malta	90%	64%
Poland	76%	55%
Portugal	81%	59%
Romania	86%	67%
Slovakia	80%	55%
Slovenia	82%	63%
Spain	75%	49%
Sweden	64%	44%
Netherlands	76%	58%
UK	73%	46%
EU28	***79%***	***57%***

Table 4. Aggregated effects (β and α_i) of option-specific attributes and scenario-specific characteristics (i.e. variable) in respondents' willingness to invest across the EU-28. The β effect is a measure of the preference given to an option-specific attribute by the average individual respondent, while the α_i effect is a measure of the preference given to a scenario-specific characteristic, as manifested in the responses given by participants. The β and α_i estimated effects are quantified and numerically expressed for each variable. Standard error and p-values are calculated for each variable (own calculations based on data obtained from CE responses).

Variable/trait	***β & α_i effects***	***Std. Err.***	***P-value***
Community admin.	0,031473	0,002579	0
Holding period	-0,021723	0,00032	0
Solar farm	-0,01774	0,001945	0
Visibility	0,005923	0,001938	0,002
Profit	0,000267	3,70E-06	0
Level of investment	-0,000059	2,10E-06	0
Government admin.	-0,002493	0,002626	0,342

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

Source: [a] Own calculations based on Eurostat (2019e); International Energy Agency (2018); WindEurope (2018).
[b] Own calculation based on IEA Wind-TCP (2018), EPEX SPOT (2019), IBEX (2019), CROPEX (2019), EAC (2019), PXE (2019), Nord Pool (2019), EnEx (2019), ENTSO-E (2019), GME (2019), OMIP (2019), OMIE (2019), and BSP Energy Exchange (2019).

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%
EU28	***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%

* *amount of energy generated (GWh) per unit if installed generating capacity (GW) in one year – expressed as GWh/GW.*

** *in millions of EUR*

*** *indicating an average 20 year lifespan of a wind farm*

Table 6: Analysis of the social potential for every EU Member State and aggregated at EU level under current market conditions/subsidy-free (own calculations based on CE responses and Eurostat 2018c, 2019d).

Country	*Optimal scenario**	*Probability of accepting investment*	*Expected collection per adult citizen*	*Pop. expected to invest***	*Social potential: expected EUR collected per country****
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
EU28	***€ 3,847.19***	***20.12%***	***€ 638.02***	***276,273,139***	***€ 176,267.55***

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

Table 7: Subsidies provided to renewable energy by each EU Member State in 2016, along with gross electricity produced and volume of financial support per unit of electricity produced, for each country (own elaboration based on CEER, 2018).

Country	*RES support schemes (M€)*	*Gross electricity produced (TWh)*	*RES support per unit of gross elec. (€/MWh)*
Belgium	0	85.520	0
Czech Rep.	1,524	83.309	18.30
Denmark	948	30.522	31.06
Germany	24,450	649.119	37.67
Estonia	25	12.176	2.04
Ireland	496	26.087	19.02
Greece	1,298	51.405	25.25
Spain	5,356	274.779	19.49
France	4,085	556.184	7.34
Croatia	122	12.820	9.48
Italy	10,555	289.768	36.43
Cyprus	62	4.887	12.59
Latvia	92	6.425	14.25
Lithuania	89	4.266	20.87
Luxembourg	49	2.196	22.22
Hungary	163	31.859	5.13
Malta	14	0.856	16.76
Norway	82	149.633	0.55
Austria	730	68.351	10.68
Poland	586	166.635	3.52
Portugal	1,101	60.280	18.26
Romania	358	65.103	5.49
Slovenia	0	16.500	0
Finland	172	68.752	2.50
Sweden	363	156.010	2.33

UK	3576	339.399	10.54
Netherlands	472	115.170	4.09
Slovakia	0	27.064	0
Bulgaria	0	45.277	0
Total	***56,768***	***3,400.352***	***17.06***

Table 8: Analysis of the annual GHG abatement potential derived from community-managed wind-farm cooperatives (own calculations based on Koffi et al., 2017).

Country	***Energy generated annually (GWh)****	***Net carbon intensities (tCO_2-eq/MWh)*****	***Annual GHG abatement potential (tCO_2-eq)******
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 gigawatt hours (GWh).*

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

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