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Citation for published version:
Fuentes Gonzalez, F, Sauma, E & Van Der Weijde, A 2019, 'The Scottish experience in community energy development: a starting point for Chile', *Renewable and Sustainable Energy Reviews*, vol. 113. https://doi.org/10.1016/j.rser.2019.06.046

Digital Object Identifier (DOI):
10.1016/j.rser.2019.06.046

Link:
Link to publication record in Edinburgh Research Explorer

Document Version:
Peer reviewed version

Published In:
Renewable and Sustainable Energy Reviews

The Scottish experience in community energy development: a starting point for Chile

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A B S T R A C T

This study presents an overview of the relevant evidence available up to now regarding the Scottish experience in relation to the development of community energy projects. Scotland has a relevant number of community energy projects which are generating energy, improving the quality of life of communities through sustainable initiatives. This is the result of the implementation of successful policies to encourage community energy by the Scottish government (in comparison with other countries). On the contrary, the Chilean community energy sector is still incipient, despite some interest; public policies have been focused on fostering the concept of distributed generation. Chilean community energy developments have not been analysed in any detail; this paper is a first attempt to do so, and to derive lessons from the Scottish experience that can be useful to Chilean policy makers. We summarise and analyse the Scottish and Chilean community energy sectors and their developments. We further analyse the current Chilean net billing scheme using concepts from game theory, showing that it may not be the best support mechanism for community energy developments. Based on these analyses, we define a list of policy recommendations for Chile, which can help further development in the community energy sector.

Keywords: Community Energy, Distributed Generation, Scotland, Chile

1. Introduction

In recent years, the idea of local and/or civic participation in energy generation has been part of renewable energy targets defined by governments in the UK and Europe, in order to implement energy production projects in a sustainable and decentralised way.

In 2003 and 2005, the UK Government released two reports, which contained statements about encouraging actions performed by citizens aimed at implementing local/community renewable energy projects [1, 2]. Those statements were not mere rhetoric. In fact, many organisations were, at that time, already operating in the community energy sector, including the Scottish Community and Households Renewables Initiative, and the Energy Saving Trust (EST), which provide advice, training and funding, among other services [3]. Since then, additional initiatives have been launched by the UK and devolved governments around the UK [4], such as the Welsh Assembly's Community Scale Renewable Energy Programme, the Community Renewable Energy Fund, etc. Generic support schemes for renewable energy have helped community

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energy developments as well. Apart from the Renewable Obligation System implemented in the UK, a Feed-In-Tariff (FIT) scheme has been implemented since 2010 [5]. There are also other initiatives such as the Seed Enterprise Investment Scheme (SEIS), which offers a tax relief that could apply to some renewable energy projects [6, 7, 8]. These schemes help to increase the amount of renewable energy generating capacity, as well as support the deployment of citizen participation in energy generation projects.

Despite this, some critical views have also been voiced. Some authors argue that current support schemes are useful but not sufficient, and that they need to be complemented with other policies. They also criticise the UK's position as ambiguous, because community energy is being promoted without significant changes in the large-scale generation mix, as a small number of companies dominate the British energy sector, and isolated policies, like the FIT scheme, are unlikely to change the prevailing policy framework, which is based on large-scale developments [7, 9]. Bomberg & McEwen [10] show that uncertainties related to support schemes could inhibit the progress of community energy projects. Frantzeskaki et al. [11] argue that, despite a political desire for community energy, existing mechanisms and policies are inconsistent and incompliant. Underlining this perspective, Berka et al. [12] show that community energy projects face higher costs due to several factors, such as internal processes, diseconomies of scale, local opposition and acceptance, among others. Moreover, despite the existence of around 5,000 community energy groups up to March 2015 in the UK[1] [13, 14], the electricity generation is led by few "major power producers" [15]. Thus, in the UK, the trend would imply a redistribution of just a small part of the whole generation mix towards communities, while other economic agents, such as some householders, farmers, and public bodies, would benefit more from this shift [16]. Nevertheless, the role of communities in energy production is recognised in the UK (and especially in Scotland) through the aforementioned elements by the incumbents of the British energy market. Even the small share of community energy projects in the UK's generation mix is significantly larger than other countries, especially in Scotland.

There may therefore be useful lessons to be learned from the UK, and particularly, the Scottish approach to community energy, which could help countries that want to develop their own community energy sector. This paper focuses on Chile, which has an incipient but still weak community energy sector, despite some interest in further development from the government. In this paper, we provide an analysis of the Scottish community energy sector and its development, compare this with other European countries and the current situation in Chile, and draw out conclusions for Chilean policy.

The rest of this paper has been organised as follows. In section 2, we propose an updated definition of community energy based on the Scottish experience. In section 3, we summarise and analyse the Scottish community energy sector, contrast it with some experience elsewhere in Europe, and include an overview of UK and Scottish government support mechanisms. Section 4 gives an overview of the Chilean community energy sector, compares it to Scotland and uses concepts from game theory to analyse some of its main features. Based on this, section 5 then presents some recommendations for Chile. Section 6 concludes.

[1] More recent studies indicate around 3,500 groups involved in community energy [14].

2. Community energy: towards an updated definition based on the Scottish experience

Before proceeding, it is useful to consider how community energy projects should be defined. The concept of community energy [17] has evolved through the years, reflecting a growth in terms of experience, knowledge and information, evidence, support from public and private entities, new and more transactions between communities and other stakeholders, newly available technologies, more regulations, and so on.

Of particular relevance to this paper is the Scottish Government's definition, which defines community energy as "projects led by constituted non-profit-distributing community groups established and operating across a geographically defined community, including Bencoms" [2]. It then introduces another concept, "Locally-owned Energy", which includes "projects led by regional organisations which are not profit-distributing and have charitable aims such as housing associations and educational institutions or local authorities, as well as commercial businesses including farmers, land managers, rural small and medium-sized enterprises and profit-distributing co-operatives" [18]. It is important to note that both definitions include an understanding in which community and locally-owned organisations carry out their mission and achieve objectives within a specific and well-defined geographic location, affecting a particular community or communities within a certain geographical range.

In order to have more information about the nature and characteristics of such projects, Van Veelen [19] develops a typology of 367 community energy projects in Scotland based on several variables, such as legal body, purpose, ownership, size of installation, technology, among others, defining five categories of projects. Within those categories, the study identifies 211 initiatives (often) described as development trusts, which are legally formed as a company often with charitable status and full community ownership; 63% of them (which had funding information available) had received economic/financial support from the government. On the other hand, only 20 projects are identified as energy cooperatives in which is possible to find projects from 1,000 kW of capacity. If development trusts are taken into account, it is possible to find projects only from 100 kW of capacity [19]. It is therefore clear that, in terms of the number of projects, development trusts are the dominant type of organisation considered by the Scottish people to be involved in energy production. Given that, one question emerges: what is a development trust?

According to the Development Trusts Association Scotland's (DTAS) definition, a development trust is an organisation that is [20]:

1. Engaged in the economic, environmental, and social regeneration of a defined area.
2. Independent, aiming for self-sufficiency and not for private profit.
3. Community based, owned, and managed.
4. Actively involved in partnerships and alliances between the community, voluntary, and private and public sectors.

[2] Community Benefit Society, organisation created for serving the broader interests of a community. Members commonly have shares and democratic rights based on the concept "one member, one vote". Also, assets and profits must be used for the benefit of community.
See https://communityshares.org.uk/resources/handbook/community-benefit-societies

DTAS [20] establishes that a development trust must meet all the four points mentioned before. Additionally, there is no specific legal/organisational structure for a development trust. However, most of the registered organisations in DTAS are companies limited by guarantee with charitable aims[3] and many have trading subsidiaries as well. It is important to note that a development trust is not necessary a “trust” in a legal sense [21]. Nevertheless, under these criteria, could a cooperative be considered as a development trust?

According to the International Co-operative Alliance’s definition and principles [22, 23, 24, 25], a Cooperative is an autonomous association of persons united voluntarily to meet their common economic, social, and cultural needs and aspirations through a jointly owned and democratically-controlled enterprise. The members have an equal say in what the business does and a share in the profits. Comparing this concept with the DTAS’s definition of development trust, it is clear that the economic nature of a development trust and a cooperative are very similar, but there are some key differences. In a cooperative, the main goal is providing benefits to its members/owners [24, 26, 27], as result of the economic activity carried out by the cooperative entity, leaving to the community without a direct access to the profits or benefits. A cooperative is therefore not a charitable organisation [24, 26]. Concerning this, SCENE [28] highlights that the primary motivation of community energy initiatives is “to generate local income and strengthen the local economy”, instead of providing benefits to the members of a particular project. Similarly, Van Veelen [19] notes that energy cooperatives in Scotland tend to be primarily motivated by the financial benefits their members might receive from participation in renewable energy, whereas development trusts’ primary motivation is generating local income. Another important difference is that a cooperative does not necessarily focus on a specific place because its members can belong to one or several communities within a small or big area, which is not necessarily well-defined. Hence, cooperatives do not meet at least two elements listed by DTAS so should not be treated as development trusts, even when both entities could seem indistinguishable in practice.

The information revealed above is useful to establish an updated definition of the concept of community energy based on the Scottish experience, due to the following reasons. Firstly, in the Scottish context, there are mainly two groups of initiatives, which people can use to participate in energy production, namely “non-profit-distributing community groups” or “community energy” per se, and “locally-owned energy”. The main difference between them is related to the legal and organisational structure of projects, where the latter group does not distinguish between pro-profit and non-profit organisations[4]. Secondly, the first group seems to lead the community energy sector in Scotland, mainly through development trusts. Thirdly, energy cooperatives in Scotland are not important in terms of citizen participation in energy production, considering the number of projects. This is a key point in comparison with other countries like England, Germany, Denmark, etc., where energy cooperatives have a prevailing role [19, 29, 30, 31, 32, 33]. Fourthly, as was shown before, an energy cooperative should not be

[3] See http://www.communitycompanies.co.uk/charitable-companies-limited-by-guarantee
[4] It is important to note that, beyond the aforementioned classification, within the Scottish landscape of community energy projects it is possible to find different legal/organisational structures, such as companies with charitable status, transition towns, local environmental groups, community hall associations, among others. The above involve a variety of ownership models like, for instance, full community ownership, shared equity/joint venture, community shares, etc. [19].

considered as development trust so they should not be considered under the first group. This is important from a legal and economic perspective[5] [34].

Regarding the above, we propose the following updated definition of community energy, avoiding distinctions based on legal structures:

A community energy project (or initiative) is a project conceived, carried out, and implemented by people who are:

a) *Interested in generating energy*. We are not exclusively focused on renewable energy sources, as the current constraints on renewable energy use in terms of full availability of energy, capacity factors, utilization of storage devices, backup procedures in case of blackout, etc., still mean that fossil fuels have to play a role in some community energy projects.
b) *Located close to or in the exact place of the project*. This may seem to be a bit vague or imprecise. However, we think that it is necessary to highlight the existence of a geographical scope, without too strictly defining it, as an exact definition could depend on different aspects such as the current legal or regulatory framework, nature of the project, surrounding environment, technology, and many other factors, considering a range from just a few metres to many kilometres. For now, we therefore just note the existence of a scope in terms of geographical distance or area/place, as noted in Van Veelen [19]. This is coherent with the Scottish Government's definitions on these matters.
c) *Well-organised under any suitable legal and organisational structure*. This includes a formal definition of the rules, roles and responsibilities of the project within the community and about their relations with other stakeholders.
d) *The owner or have a high participation in the ownership of the project*, as people should have the right to be involved in the project decision-making process, as well as obtain its benefits and assume its costs and risks. This point is directly related to the two underlying dimensions (process and outcome) of the concept of community energy, stated by Walker & Devine-Wright [17].
e) *The main (and/or the first) beneficiary of the project*. This is related to the above-mentioned point. As long as people are the owner or have a high participation in the ownership of the project, they will have the right to get the project benefits before other possible participants in it. The outcome will then focus on people first, which is the essence of a community energy project.
f) *Primarily interested in welfare maximisation and income generation*, but in order to achieve other aims such as social and/or environmental goals, including an improvement in terms of local economy and energy independence. Here, the focus is not only on providing benefits to some members, but also the community as a whole.

Thus, at least from an economic perspective, a community energy project can be treated as an economic agent that receives assets from other economic agents, which must be managed appropriately, in order to obtain benefits to be invested in social initiatives or used to reach charitable aims. All of this is aimed at helping a community and gaining more (sustainable) independence. Considering this, in terms of energy

[5] For instance, under the Scottish regulation, a community (group) can be eligible for all funding instruments, whereas other organisations, like bencoms and cooperatives, are eligible for all funding instruments unless they formally accept some rules, which shape the distribution of benefits. This would empirically demonstrate the different nature of cooperatives.

production, this entity competes with other organisations, such as power generators and utilities. Therefore, more research is necessary in order to fully understand the community energy sector incumbents' incentives, economic behaviours, key differences, etc.

3. Community energy in Scotland

3.1 Specifics of community energy development in Scotland

Unsurprisingly, community energy and related concepts have been studied extensively. Some literature focuses on the organisational structure of community energy projects, trying to identify which conditions or elements are necessary for projects to be successful [3, 17, 35]. In addition, some literature focuses on remarkable cases, some of them based in Scotland. For instance, Warren & McFadyen [36] show that there was a kind of local 'affection' towards a windfarm from people in the Isle of Gigha, and note that the project faced less public opposition compared to similar projects in Kintyre peninsula. Rae & Bradley [37] note the importance of energy autonomy for communities and the success of community ownership in wind energy installations, considering a remarkable example in the Scottish village of Fintry. Bomberg & McEwen [10] identify that political conditions, which allow or constrain community energy projects, and non-material resources, which facilitate the functioning of community energy groups, mobilise community energy initiatives. They also highlight that a critical element is taking advantage of government resources and support, mainly through communities' knowledge, expertise, and connections. Additionally, the idea of survival, empowerment and autonomy, and income generation in a sustainable way as a main priority, contributed to the mobilisation of communities in energy production. Frantzeskaki et al. [11] note that a common feature in Scottish communities is the willingness to struggle for self-sufficiency and independence, which also applies to the energy sector. They also establish several categories of tensions that are faced by community energy projects, such as incompliant funding mechanisms, time-management and project management risks, financial viability risks, etc. Haggett et al. [38] find, for different stages of a community energy project, that economic motivations are the primary driver followed by control/autonomy, and environmental issues. In a more quantitative study, Seyfang et al. [4] find that the highest proportion of community energy groups in the UK operating in 2012 were located in Scotland, South West England, and South East England. Moreover, the area covered by community-related networks and organisations was higher in Scotland than England. Further stressing the importance of income generation, Okkonen & Lehtonen [39] apply Leontief's Input-Output Model to projects located in three Scottish archipelagos (Orkney, Shetland and the Outer Hebrides) and find positive impacts on employment derived from re-investments of revenues of community onshore wind power. More recently, Haf et al. [40] show the importance of confidence in the Scottish Government and its vision about the community energy sector by performing semi-structured in-depth interviews for four energy groups, including two groups located in the Scottish isles of Lewis and Tiree. They also note the disparity with some Welsh energy groups on these issues.

There is a significant amount of empirical evidence that would put the Scottish experience as a relevant and pertinent model to follow for other countries that may want to develop, deploy, and implement community energy projects, as can be seen above. Of course, that relevance is due to several factors, which include, among others, economic, environmental, historical, psychological and sociological aspects, such as desire for collective action, cultural milieu, and manifestations of community based actions in land reform. However, given that this is a multi-factorial problem, focusing on some key legal, economical, and statistical elements might be pertinent, ignoring other elements that are beyond the scope of this work. Some questions therefore emerge: how has the Scottish community energy sector evolved in recent years? Could the Scottish experience in community energy be comparable, in some aspects, with other countries' experiences? Is it possible to derive useful lessons from this evolution?

3.2 The evolution and some contrasts of the Scottish community energy sector

In 2011, official statistics show about 1.2 MW of installed capacity, mainly based on wind energy, from projects registered under the FIT scheme [41]. Similarly, since 2011, the EST has been working on reports related to the community energy sector in Scotland on behalf of the Scottish Government [42, 43, 44, 45, 46, 47, 48]. Regarding this, Fig. 1 shows that projects labelled as "Community" reached 26 MW of installed capacity (366 installations) in June 2012 [42], whereas in June 2016, there were 510 installations adding up to 67 MW of capacity [46]. More recently, in 2018, 540 installations implied an installed capacity of 80 MW [48]. This therefore means an increase both in number and installed capacity during the last few years.

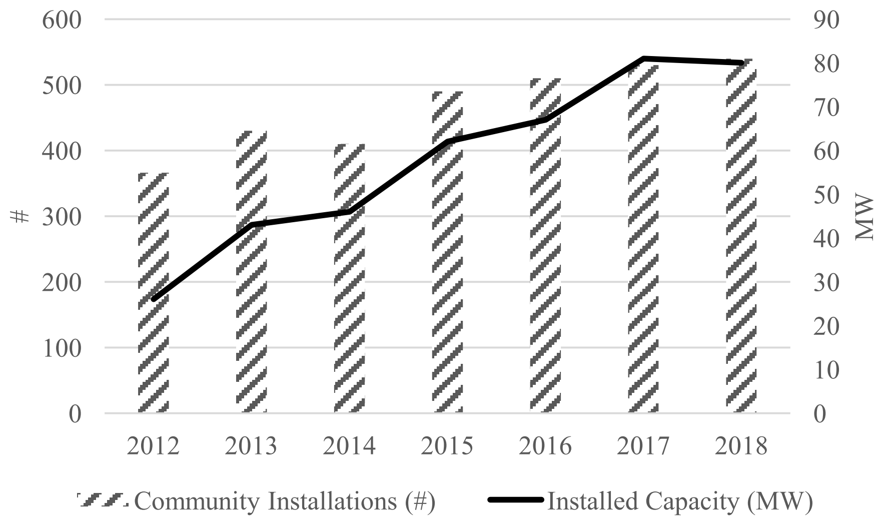

Fig. 1. Operational installations and installed capacity of projects labelled as "Community" [42, 43, 44, 45, 46, 47, 48]

We note that the installed capacity of these projects almost doubled during five years while the number of installations increased from approximately 400 to 540, implying that installations are, on average, larger than before. This evidence reveals a high level of growth in projects strictly led by communities. Statistics show that, in the next ten years, Scotland could see another 100 MW of installed capacity from this kind of initiatives, if the trend continues. This is a stark contrast with other countries where the participation of communities in energy production is still very weak, including, for example, Chile. In terms of energy sources, Fig. 2 indicates that wind energy has been the preferred technology during the last years, followed by biomass, hydro, and waste-to-energy. The participation of solar PV technologies is relatively small in terms of capacity.

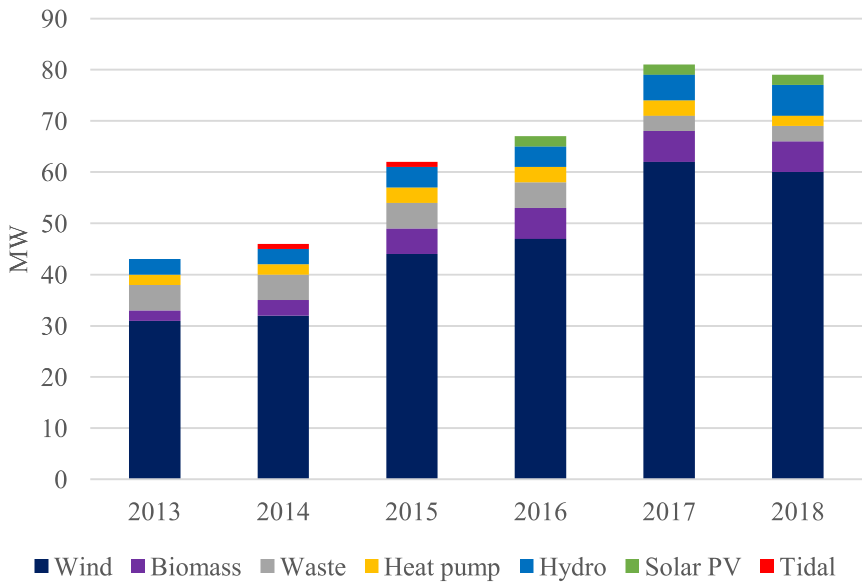

Fig. 2. Installed capacity by technology of projects labelled as "Community" [42, 43, 44, 45, 46, 47, 48]

If we also consider "local-owned energy" projects, the situation is even better. Table 1 shows the minimum estimated installed capacity of this kind of projects, jointly with "community energy" projects. In 2016, the total capacity was 595 MW with an annual production of 1,479 GWh. This was a key milestone from a policy-making perspective, given that the Scottish Government in 2011 established a target of 500 MW of installed capacity by 2020, derived from these two types of projects [18, 49, 50]. In 2018, the total capacity reached 697 MW. Regarding this, the Scottish Government has set a new target of 1 GW derived from community and locally owned energy by 2020 [48].

Table 1
Minimum installed capacity and annual expected production from community and local-owned renewable energy projects

Year	Minimum estimated community and locally owned renewable energy capacity (MW)	Minimum estimated community and locally owned electricity capacity (MWe)	Minimum estimated community and locally owned heat capacity including CHP and waste (MWth)	Annual expected production of renewable energy (GWh)	Annual expected production of electricity (GWh)	Annual expected production of heat including CHP and waste (GWh)
2012	204	88	117	489	233	256
2013	285	168	114	740	390	330
2014	361	202	159	895	470	425
2015	508	301	207	1,281	720	561
2016	595	354	241	1,479	840	639
2017	666	403	263	1,664	958	706
2018	697	432	265	1,755	1,051	704

Source: [42, 43, 44, 45, 46, 47, 48]

In order to achieve this target, the Scottish government has spent a significant amount of resources for implementing a variety of initiatives, mainly related to setting up a suitable legislation/regulation and proper incentives [18, 51]. One of the most important initiatives is the CARES[6] [18, 41, 52, 53] but there are also other relevant initiatives [53, 54, 55]. It is important to note that every single project has to demonstrate its economic and financial feasibility, and also show how the resources will be managed to benefit the wider community. Other aspects that are taken into account include management, impacts and costs, grid constraints, agreements between community and people involved in the project, etc. An expert panel decides about the resources that will be provided. Another feature of the community energy sector in Scotland is the participation of several organisations that provide useful support to communities, such as Community Energy Scotland[7], EST[8], Changeworks[9], SCENE[10], Local Energy Scotland[11], among others. However, not all is perfect and some schemes complicate community energy projects. On this topic, Creamer [56], based on two-in-depth cases, notes that an incoherence between the length of the funding and the desired or expected outcomes in terms of carbon dioxide reductions and other positive lasting consequences, demanding administrative processes, and competition/rivalry for resources, might affect the development of such initiatives. Due to some changes in the CARES scheme in 2011, a key element has been the applicability and eligibility for the FIT scheme and the Renewable Heat Incentive, both introduced by the UK Government [18, 57, 58, 59]. Under the FIT scheme, which was closed to new applications on the 31st of March 2019[12], there are some additional benefits for community energy initiatives and school installations, in terms of a relaxation of the minimum energy efficiency requirements and validity certification. These benefits also included the possibility of sharing a single grid connection and a tariff guarantee[13] [60]. Nevertheless, the aforementioned closure of this scheme might affect the development and deployment of community energy initiatives. Scotland has also developed a new Energy Strategy[14], which establishes a vision for the entire Scottish energy system up to 2050, taking into account three main themes: a whole-system view, a stable managed energy transition, and a smarter model of local energy provision [55].

Thus, it is clear that the incumbents of the Scottish community energy sector have been working in a suitable way, encouraging citizen participation in energy production by fostering and implementing projects that belong to either "non-profit-distributing community groups" or "locally-owned energy" categories. However, including recent evidence based on other experiences in Europe, in order to have a wider justification over the Scottish contribution to the community energy sector, seems appropriate.

Heras-Saizarbitoria et al. [32] note that approximately 3,000 energy cooperatives were already operating in Europe in 2014. However, almost 80% of these are located in Germany and Denmark. The cooperative sector involvement in energy production has been well described by Yildiz et al. [33] in the former country, where is possible to see classifications by value chain approach and technology, historical development, and regional development. Even when it is also possible to find other models of ownership, such as limited partnerships and civil partnerships, cooperatives are the most relevant organisational form regarding active participation in local energy policy [33]. Nevertheless, other European

[6] Community and Renewable Energy Scheme.
[7] See http://www.communityenergyscotland.org.uk/about-us.asp
[8] See https://www.energysavingtrust.org.uk/about-us
[9] See https://www.changeworks.org.uk/what-we-do
[10] See https://scene.community/our-work-overview
[11] Consortium made up of several organisations: EST, Changeworks, The Energy Agency, SCARF, and The Wise Group. This consortium manages the CARES.
[12] See https://www.energysavingtrust.org.uk/scotland/grants-loans/renewables/feed-tariffs
[13] Available up to October 2015.
[14] It was available for public consultation.

countries like the Netherlands and Sweden currently present a promising perspective. In the Netherlands, 500 initiatives were started by citizens and social groups during the last years, most of them related to the cooperative model [32]. In Sweden, there are currently 81 wind cooperatives, 6 solar PV cooperatives, 10 small-scale district heating producers, 25 eco-villages, and 9 rural communities owning renewable technologies. Additionally, in 2012, around 25,000 householders owned shares in energy cooperatives [31]. This suggests that energy cooperatives are the prevailing type of organisation for citizen participation in energy generation in Europe. Some evidence also shows the existence of other models, which allow involvement and/or ownership by public entities such as municipalities, private organisations including commercial developers or larger generators, and/or local citizens. Furthermore, state subsidies and tax reductions for micro-producers, net metering schemes, project shares sales, limitations on members' ownership, among others, have been deployed in order to boost citizen participation in energy production [31, 32, 33]. However, some of these policies could have adverse effects. For instance, Tews [61] notices that the auction scheme in Germany is a failure in terms of controlled renewable energy expansion, actor plurality, and cost efficiency, highlighting several issues: awards without construction permits, longer implementation deadlines, control exerted by a small number of professional project developers, and variation in prices.

Based on this evidence, we can highlight that Scotland has been strongly pushing energy generation projects led by citizens that aim to directly benefit communities as a whole, rather than only a certain number of people within a community. This might be crucial as investments in entities like energy cooperatives, made by people with sufficient savings to invest, might undermine social cohesion as some people miss out on project benefits [29]. In addition, from an economic perspective, if there is discrimination among the members of a cooperative, its viability might be affected, decreasing social efficiency and making the cooperative a weaker competitor [62]. However, as long as an energy cooperative benefits a community as a whole (or is incentivised to do so), the difference between these entities and community-led projects (such as development trusts) will be indistinguishable in practice. Further research is needed in order to empirically corroborate whether energy cooperatives are only providing benefits to their members and/or communities.

Nevertheless, the Scottish experience in community energy also has some negative or questionable aspects. For instance, it is true that the installed capacity of "non-profit-distributing community groups" (or community energy projects) is lower than the capacity of locally-owned energy projects. However, this difference may or may not be relevant, depending on the number of people who benefit from the project and whether the project benefits the community as a whole or not. This is important given that providing benefits for communities in a sustainable way is the main purpose of community energy projects. Therefore, some metrics might need to be developed in the near future, in order to determine the real contribution to the community energy sector and society from different types of organisations or structures. Additionally, there is such variety of specific legal and organisational structures available in Scotland (and, more widely, in Europe) that may or may not be considered part of the community energy sector. From a public policy perspective, this might be confusing, time-consuming, and demanding in terms of resources, especially for people who want to set up a community energy project. Hence, having fewer specific legal and organisational vehicles may be more convenient for all community energy incumbents. In fact, defining a kind of "Community-Special-Purpose Entity", following our proposed updated definition of community energy and unifying criteria derived from non-profit-distributing community groups and locally-owned energy projects, may be useful to reduce, among others, transactions costs.

In summary, weighing positive and negative features, we consider that the Scottish community energy sector might be considered as leader in citizen participation in energy production. Thus, countries with an underdeveloped community energy sector, including developing countries like Chile, should consider the Scottish experience as a relevant model when developing, deploying, and implementing policies aiming for a robust community energy sector.

4. Community energy in Chile

4.1. Chilean resource availability and electricity industry

The main feature that Chile and Scotland have in common is the high availability of renewable resources, which makes renewable community energy projects feasible.

For Chile, Santana et al. [63] show that the potential installed capacity of wind, from Arica to Chiloé Island, was 37 GW. In terms of solar PV energy, they show that the potential installed capacity for projects without a tracker[15] reached 1,238 GW, whereas for projects with a tracker[16], this reached 1,640 GW. In addition, the potential installed capacity of solar CSP[17] could be as high as 552 GW. The potential hydro energy capacity, considering some territorial constraints, was estimated at 12.5 GW with an average power of 7.8 GW. A 2009 Garrad Hassan study determined the potential capacity of marine energy[18], including wave and tidal. This study shows that the potential for raw offshore wave energy could reach 164.9 GW. For tidal energy, the estimated potential, in terms of raw kinetic energy flux, was estimated between 0.6 and 0.8 GW [64]. However, only an area from Chiloé Island up to the Magallanes Strait would be interesting in terms of taking advantage of this energy source [65]. Chile also has biomass potential. In 2013, the Universidad Austral de Chile carried out a study[19], which found that biomass has a technically useful potential of up to 60,000 GWh/year, which implies an installed capacity of 2.1 GWe, based on the current consumption of native biomass [66].

These numbers are comparable to Scotland. In 2005, the Scottish Government published a study, which highlighted the potential of several renewable energy sources. An installed capacity of 16 GW, 1 GW, and 200 MW was estimated in this study for onshore wind, offshore wind, and hydro, respectively[20]. For biomass, a potential of 450 MW was estimated, mainly based on wood fuel resource and some energy crops. Marine energy (wave and tidal) was proposed as having significant potential with an installed capacity of 1,300 MW, considering suitable

[15] Considering a capacity factor greater than 0.24.
[16] Considering a capacity factor greater than 0.3.
[17] Considering a capacity factor of 0.5 and 200 ha as minimum.
[18] Considering a single Pelamis wave farm of 30 MW of installed capacity in six locations (180 MW) between the fifth and tenth regions of Chile.
[19] Between the regions of Coquimbo and Magallanes y la Antártica Chilena.
[20] This report emphasised the importance of small-scale projects and new improvements in current plants.

places located in the northern and western seaboards of the country [67]. Other investigations have been carried out and other similar estimations have been found in, among others, Andersen et al. [68], Allan et al. [69], and Neill et al. [70].

Table 2
Estimated potentials of renewable energy per capita (kW/cap)[21] [22]

	Biomass	Wind	Solar	Hydro	Marine
Chile	0.12	2.05	121.73	0.69	9.2
Scotland	0.08	3.15	1.32	0.04	0.24

Sources: [63, 64, 65, 66, 67, 71, 72, 73]

Hence, the availability of renewable resources in both countries is significant, as can be seen in Table 2. Chile has huge potential in terms of solar, wind, and marine energy per capita. Likewise, Scotland also has enormous potential in terms of wind energy per capita, although it is less well endowed with solar resources. This is one obvious reason that explains the current installed capacity of Scottish community energy projects, which is mostly dominated by wind projects. From this point of view, Chile could take advantage of its potential not only through projects carried out by large generators, but also, like Scotland, by encouraging community energy projects around the country, based on the variety of renewable sources that Chile has, and not solely on solar. This is relevant for Chile, considering that its current installed capacity is still mostly based on fossil fuels, as shown in Fig. 3.

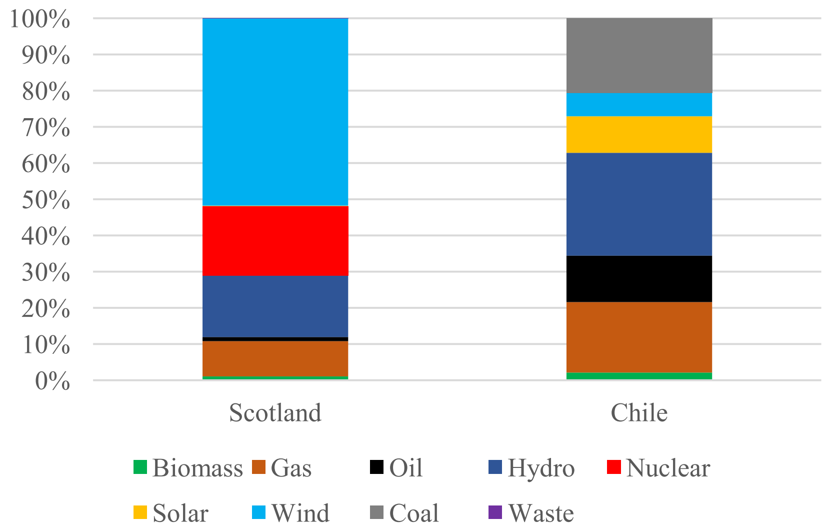

Fig. 3. Scottish and Chilean installed capacity (of power plants) by technology currently in operation [74, 75]

On the contrary, Scotland's electricity mix is mainly based on renewable energy sources such as wind and hydro; still, it is currently encouraging community energy projects around the country, as discussed above.

[21] Due to a scarcity of specific information related to the potential of solar energy in Scotland, an estimation very simple was made which considers the data revealed in Burnett et al. (p.341, 2014) about a baseline average resource of solar energy (W/m^2) and the Scotland's surface (km^2) available in the following website: http://webarchive.nationalarchives.gov.uk/20160106191622/http://www.ons.gov.uk/ons/rel/regional-trends/region-and-country-profiles/key-statistics-and-profiles---august-2012/key-statistics---scotland--august-2012.html

[22] The population considered for Chile is 18,006,407 inh. and for Scotland is 5,400,000 inh. Both estimations are up to 2015.

4.2. Community energy in Chile: current status

Given that the Chilean renewable resources are at least comparable, and in some ways better than the Scottish resource, for instance, in terms of the energy per capita and the significant potential of solar and marine energy, it is necessary to further study the Chilean state of the art in terms of community energy initiatives in Chile. This may be useful to explore what has to be done to foster and deploy decentralised energy projects through community or citizen initiatives, which has been defined in the Chilean Energy Policy as one of the goals to be reached by 2050.

In short, this policy specifies in several ways that Chile needs a more intelligent electricity system, including a higher participation of citizens as producers/managers/consumers. All of this is aimed at having a more secure system that can face unexpected circumstances without major problems, and manages the energy required for users of the electricity system in a decentralized manner [76]. Apart from the resource availability and state of the art, we will analyse if Chile has similar definitions, views, and other elements as Scotland, or whether there are barriers related to resources availability.

In Chile, the concept of community energy is very new. In fact, citizen participation in energy generation has been deployed using a different approach. Instead of focusing on community energy, Chilean policy has focused on distributed generation. Considering Ackermann et al.'s [77] definition of distributed generation as "an electric power source connected directly to the distribution network or on the customer site of the meter", and our definition of community energy shown above, it is clear that both concepts are related. Distributed generation can be seen as a subset of the concept of community energy, because the former limits the scope to a distribution network and one single customer, and seems to be primarily based on technical aspects, whereas the latter is primarily based on economic and social aspects. Nevertheless, it is important to note that both concepts consider consumers as producers (prosumers), who need a network to inject the energy.

Following this idea, the Chilean government gave the right to individually generate energy/electricity for self-consumption through renewable energy or combined heat and power (CHP) sources to regulated customers (mostly residential clients)[23], through the Law 20,571 "Distributed Generation Law" [78], which includes the right to sell their surplus of energy to the grid [79]. In this sense, there were 24.41 MW of installed capacity operating under this law at December 2018 [80]. However, it is important to highlight that this amount includes not only residential installations, but also installations that might belong to small and/or medium businesses. In fact, if we only consider small systems (up to 10 kW or 0.01 MW), which represent almost 91% of the total installations that operate under this law, it is possible to see that these projects have only succeeded in installing 6.3 MW of installed capacity [80]. In addition, such projects are mostly based on rooftop solar energy and concentrated

[23] According to the Chilean legal framework, defined as those clients who have a connected power below 0.5 MW or those clients that have asked for an authorization to be in this category (of regulated customers) having a connected power between 0.5 MW and 5 MW.

in the capital city and its immediate surroundings (Region Metropolitana), as noted in Fig. 4 and Table 3, and focused on individual generation and self-consumption rather than providing benefits to communities.

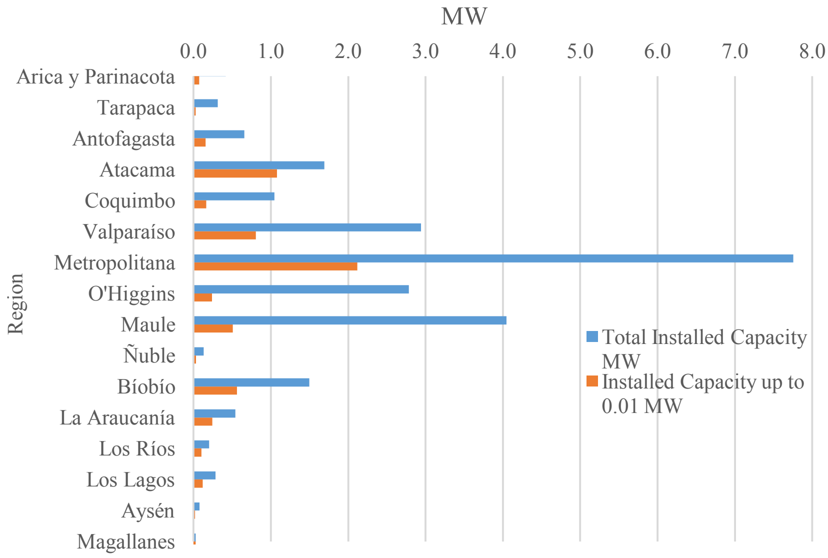

Fig. 4. Distribution of distributed generation projects by region in Chile [80]

Table 3
Installed capacity in MW of distributed generation projects by region and technology in Chile

Region	Biomass	CHP	Hydro	Solar	Total
Arica y Parinacota				0.42	0.42
Tarapaca				0.31	0.31
Antofagasta				0.66	0.66
Atacama				1.69	1.69
Coquimbo				1.05	1.05
Valparaíso				2.94	2.94
Metropolitana		0.05	0.09	7.61	7.75
O'Higgins				2.78	2.78
Maule			0.00	4.04	4.05
Ñuble				0.13	0.13
Bíobío				1.50	1.50
La Araucanía				0.54	0.54
Los Ríos				0.20	0.20
Los Lagos				0.28	0.28
Aysén	0.03			0.05	0.08
Magallanes				0.03	0.03
Total	**0.03**	**0.05**	**0.09**	**24.24**	**24.41**

Source: [80]

Hence, some questions remain. For instance, why do other regions with more potential for solar or wind energy have a lower implemented installed capacity? Is support from the government universally available and, most important, delivered properly? Is a shift in focus from distributed generation to community energy necessary in order to increase the number and capacity of projects conceived by citizens?

One important feature of the Chilean electricity market, as noted above and in [81], is that Chile has a net billing scheme, instead of a net metering scheme like other countries. Under the Chilean context, the concept of net billing means that the energy injected into the grid is calculated and valued at an injection rate (which is different from the consumption rate), and then the resulting value is subtracted from the cost of energy consumption (calculated as the energy consumption multiplied by the consumption rate). In the same vein, net metering means the energy injected into the grid is directly subtracted from the energy consumption, in kWh [82]. The main retail rate applied to most Chilean residential customers is the BT1 rate[24], which combines energy and capacity in a single rate, and consequently there is a difference between the rate of the energy injected into the grid and energy consumption. The rationale of this is that the injected energy has less value due to the utilisation of distribution infrastructure [81, 82, 83]. Conversely, under a net metering scheme the injected energy is valued at the same rate as energy consumption. Another important feature is that there is important divergence among cities in investment, tariffs or rates, capacity, and integration intervals, which means that payback periods for solar PV projects may vary from 6 years up to almost 17 years, depending on the location of the project [81]. In this sense, Becerra et al. [84] assess a wind farm in two different locations in Chile and note that it is possible to generate value from a regulation change. They also highlight that tax expenditures on support mechanisms could be better than a net metering scheme. Varas et al. [85] show that a net billing scheme in the northern part of the country could be profitable, if the investment cost is lower than 2,000 USD/kW[25]. Ramírez-Sagner et al. [86] highlight the fact that residential PV systems are more profitable under larger self-consumption rates and that implies an opportunity to push for more incentives to support distributed generation.

As can be seen above, the net billing scheme is now an important element of the Chilean electricity market, so providing more insight by developing a simple example using game theory seems appropriate. We will do this in the next subsection.

4.3. The best strategies for Chilean residential customers under a net billing scheme

In order to provide a deeper and useful discussion about the convenience of implementing a net billing scheme, taking into account the Chilean experience, we develop a simple sequential non-cooperative game to demonstrate the effects of that scheme on Chilean residential customers, by determining Subgame-perfect Nash equilibria (SPNE). In this game, a consumer can decide whether to generate energy under the Chilean net billing scheme or not. If the consumer decides to do so, we then assume that the consumer buys a solar PV panel from the distributor, in agreement with the Chilean regulation. We consider a solar PV technology useful life of 25 years [87] and representative investment costs for panels of 1 kWp, 2 kWp, and 3 kWp of capacity, which are USD 3,086.72, USD 4,948.06, and USD 6,188.95, respectively [88]. We then calculate representative annual amortizations of the investment costs for those panels, by using the following formulas [89]:

$$VP = C\left[\frac{1-\frac{1}{(1+r)^t}}{r}\right]$$

$$C = \frac{VP}{\left[\frac{1-\frac{1}{(1+r)^t}}{r}\right]}$$

[24] Low Voltage 1, in Spanish.
[25] According to the authors, this cost implies a solar PV plant size around 1 kW. If a net metering scheme was desired, the plant size has to be around 2 kW.

Here, VP is the present value of the solar PV panel, C is the amount to pay under an annual basis during the useful life of the solar PV panel, r is the discount rate, and t is the solar PV technology useful life. We assume that a customer can amortize the whole investment during the PV technology useful life period. The resulting annual amortizations of the installed capacity (investment costs of solar PV panels) are shown in Table 4.

Table 4
Annual amortizations in USD of the investment costs of solar PV panels for residential consumers considering different discount rates and installed capacities

Discount Rate / Capacity	1 kWp	2 kWp	3 kWp
5%	219.01	351.08	439.12
7%	264.87	424.60	531.08
10%	340.06	545.12	681.82

The estimations for annual generation are 1,500 kWh, 3,000 kWh, and 4,500 kWh respectively, for the three aforementioned capacities [88]. The estimated annual generation can be valued using an electricity injection rate of 0.10 USD/kWh (valid in August 2017) and multiplying that injection rate by the production of each panel. The consumption rate, which is different from the injection rate, is 0.14 USD/kWh [90]. If we take the average consumption of a residential low-medium income consumer (LMIC), which is 1,800 kWh/year [81], and the same for a residential high income consumer (HIC), which is 7,865 kWh/year [81], we can multiply the consumption rate by those average consumptions levels to get gross costs.

The consumer therefore has to pay for its consumption and also for the investment cost of a solar PV panel, which will be annually amortized during the useful life mentioned above, minus the payment derived from the injection into the grid[26]. Thus, in this game, consumers and distributors can choose between to generate under a distributed generation scheme (G) or not to generate under distributed generation scheme (NG), and between to sell a solar PV panel (SP) or not to sell a solar PV panel (NSP)[27], respectively. An example is given in Fig. 5.

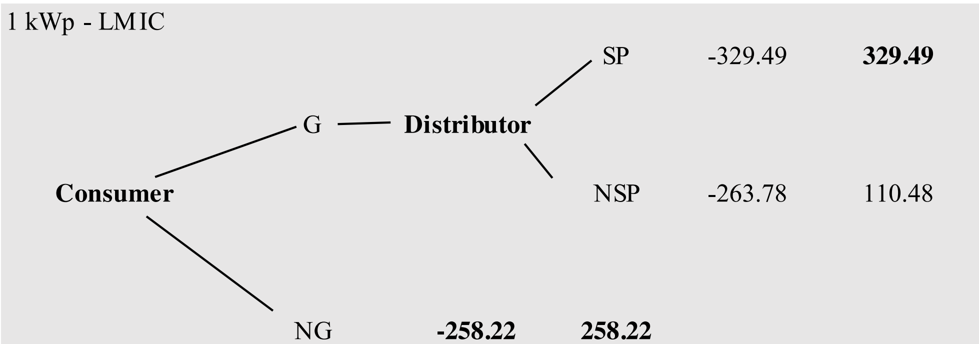

Fig. 5. Sequential non-cooperative game solved by backward induction procedure for LMIC, considering 1 kWp of installed capacity and 5% as discount rate.

[26] Every value has been obtained considering a exchange rate of CLP 644.697649 / USD available in https://www.oanda.com/lang/es/fx-for-business/historical-rates.
[27] Under this strategy, consumers can buy solar PV panels from other sellers at a 30% cheaper rate.

It is important to notice that every outcome revealed above is shown in USD per year and reflects the sum of the consumption per year, the investment for the solar PV panel amortized under an annual basis, and the annual payment for injecting energy into the grid.

In Table 5, the SPNE for LMIC, HIC, and the distributor, considering different discount rates and installed capacities, are shown.

Table 5
SPNE for LMIC, HIC, and the distributor, considering different discount rates and installed capacities

Discount Rate / Capacity	1 kWp	2 kWp	3 kWp
10%	NG ; (SP, NG)	NG ; (SP, NG)	NG ; (SP, NG)
7%	NG ; (SP, NG)	NG ; (SP, NG)	NG ; (SP, NG)
5%	NG ; (SP, NG)	NG ; (SP, NG)	G ; (SP, NG)

Considering the assumptions listed above, the resulting strategies for LMIC and HIC (without brackets), and for the distributor (within brackets), which are also SPNE, producing energy under the current distributed generation scheme in Chile is not economical for consumers in most of the cases, due to the costs and potential benefits. Producing energy would only be an efficient strategy[28] for consumers if they amortize the initial investment during the whole useful life of the solar PV panel, if they can buy a device with a higher installed capacity (which is more expensive), and if they have low discount rates through those years, which are strong assumptions. If a consumer decides to generate energy in any other situation, that consumer would be harmed because its selected action would not be optimal given the choice made by the distributor[29].

Even if the investment costs are substantially lower, the conclusions are similar. Table 6 shows a case where investments costs are reduced by 30% relatively to current rates.

Table 6
SPNE for LMIC, HIC, and the distributor, considering different discount rates and installed capacities, and an investment cost 30% lower

Discount Rate / Capacity	1 kWp	2 kWp	3 kWp
10%	NG ; (SP, NG)	NG ; (SP, NG)	NG ; (SP, NG)
7%	NG ; (SP, NG)	NG ; (SP, NG)	G ; (SP, NG)
5%	NG ; (SP, NG)	G ; (SP, NG)	G ; (SP, NG)

Hence, these results might explain, at least in some sense, why residential consumers and distributors are not very interested in distributed generation schemes in Chile – the economics are just not favourable. A review of the incentives and how the current Chilean policies are addressing them is therefore necessary.

4.4. Other specific initiatives

[28] It is important to note that payments for consumers are negative but less economically "harmful".
[29] This is because the consumer will lose more, as can be seen in Fig. 5.

In 2014, the Chilean Government began a discussion about the associativity between communities and large generators, based on the following pillars: paying taxes where the power plant is located, price equality, and sharing benefits[30] [31]. However, the Chilean Government decided to push just the first two[32] [91, 92]. The Chilean Government has also carried out other initiatives related to the concept of community energy. In particular, the programme named "Comuna Energética" seeks to increase citizen participation in the energy sector in every municipality. The programme focuses on renewable energy and energy efficiency projects, and comprises two main stages: the first one is a local energy strategy, and the second one is a certification process [93]. Some featured projects are related to energy efficiency, energy generation through solar PV panels, and energy usage/production awareness [94]. There is another initiative called "Fondo de Acceso a la Energía" which provides funding for small-scale solar PV projects in rural and isolated locations [95].

Taking the private sector into account, there are currently more than 20 cooperatives that are involved in the electricity market. Many of them are providing distribution services in rural zones. There is also an incipient initiative currently carried out by Fundación Proyecto Propio and Rubik Sustentabilidad[33]; private entities which seek to help communities conceive renewable energy projects with an installed capacity between 1 and 3 MW, contributing to the development of social projects in those communities. This initiative highlights the importance of establishing Power Purchase Agreements (PPA), to have a more sustainable source of benefits and carry out social projects in the community [96].

The community energy sector in Chile is still incipient, as was shown before, but there are upcoming opportunities to improve this situation through proper policies that move the sector in the right direction, giving correct incentives to the economic agents. The Chilean renewable energy potential also offers a huge possibility to develop community energy projects. Thus, considering international experience, such as the Scottish experience in community energy, seems appropriate.

5. Discussion and recommendations

In the UK, and especially in Scotland, the community energy concept has been promoted explicitly and defined in a better way compared to several countries, including Chile. The definition and promotion of community energy sector in Scotland has been an catalyst in the deployment and implementation of a range of initiatives, including private and public supporting entities/organisations, grants and loans schemes, and so on. It is true that the community energy sector in Scotland is still a small part of the whole electricity sector in terms of installed capacity. But, at the same time, the growth that the community energy sector has undergone in recent years is remarkable. Moreover, the range of projects has been wide; although the main energy source has been wind, there are also significant levels of other renewable sources. In addition, energy cooperatives (private profit organisations) do not have such significant role, and more social organisations like development trusts, seem to be leading the community energy sector in Scotland, considering the number of projects. Conversely, in mainland Europe, energy cooperatives seem to lead the community energy sector, but it is not clear if these entities are providing benefits to some members or communities. This is a

[30] See http://www.nuevamineria.com/revista/proyecto-de-asociatividad-la-palabra-en-juego/
[31] See http://www.latercera.com/noticia/asociatividad-de-proyectos-de-energia-con-comunidades/
[32] See http://www.pulso.cl/empresas-mercados/gobierno-zanja-la-discusion-por-ley-de-asociatividad-y-divide-proyecto-en-tres-partes/
[33] See https://www.proyectopropio.cl/generacion-comunitaria/

key element, because the essence of a community energy project is providing benefits to communities and not only to some members. Therefore, Scotland should be recognised as a worldwide example in community energy development.

On the contrary, despite the fact that Chile has more potential in terms of renewable energy, Chilean public policies on this matter seem weak and contradictory, especially, if we consider that the scope up to now seems focused on the promotion of distributed generation projects. Distributed generation is a more specific concept, related to the concept of community energy, but not always convenient for residential consumers and distributors. This has resulted in several deficiencies, such as a geographical concentration of projects, a small installed capacity derived from those initiatives, and a mix based exclusively on just one renewable energy source. Especially damaging has been the difference in tariffs between the injection and consumption of energy by residential consumers, even when there might have been technical reasons for this. This is a challenge for Chilean policymakers. In this sense, a change in tariffs could be one of the main opportunities for Chile to help the community energy sector.

Beyond this, considering the specific legal/organisational structures available in Chile seems crucial. In this sense, it seems that in Chile more existing social and collaborative organisations like neighbour committees and indigenous communities, could take an important role to push citizen participation in energy production [97], particularly community energy rather than distributed generation projects.

Still, how could these projects face potential asymmetries in terms of treatment in comparison with other incumbents of the Chilean electricity market? We theorise that generation as a PMG[34] could be a path forward. A PMG is a project connected to the network, which has less than 9 MW of excess capacity, has the right to be exempt from transmission costs, and is subject to the electric system operator [98]. It can avoid the gap between injection and consumption tariffs. If the PMG is connected to the distribution network, that project is catalogued as a PMGD[35]. If these projects have an installed capacity up to 3 MW, they can also avoid an environmental assessment[36], which could help to push these initiatives in a faster way. This is relevant considering that most of them are focused on generating energy throughout renewable energy sources, so are likely to have positive net environmental effects given their small capacities.

Additionally, considering the evidence presented above, a community engaged with a certain type of generation project is a minimum requirement in order to carry out projects successfully. Support from the government, as well as other entities would enable an increase in people's involvement and knowledge, in terms of management and other skills necessary to deal with community energy projects. This is critical due to the size of these projects, the variety of disciplines involved, the diversity of backgrounds and skills, etc.

Even though community energy organisations have more social objectives than many firms, a primary motivation is usually still profit maximization, which then helps to achieve other objectives that benefit the community's development. This profit maximization is demanding,

[34] Small Generation Source, in Spanish.
[35] Small Distributed-Generation Source, in Spanish.
[36] See https://www.sea.gob.cl/sea/proyectos-actividades-sometidos-eia

but it is what helps to communities gain more economical (understood as a variety of resources including energy) independence in a sustainable way. In the long-term, this also helps governments to save and manage resources in a better way. To achieve profits, the specific legal or organisational structure does not matter significantly, but skills do, and it is very important that organisations remain focused on profit maximization, in order to help the whole community.

Altogether, the establishment of a thriving community energy sector in Chile requires rethinking the electricity market with a major component of decentralised generation, through community energy instead of distributed generation. We therefore make the following recommendations:

1. Review the current narrative around distributed generation and its promotion, considering current (and future) incentives and gaps, in order to improve uptake, or (preferentially) change the focus towards a broader concept such as community energy.
2. Explicitly define long-term objectives in relation to community energy projects.
3. Review tariff structures and prepare a pathway to adapting a legal and regulatory framework to support community energy projects, avoiding negative impacts on electricity markets.
4. Consider giving priority to the development of community energy projects as a PMG or PMGD with an installed capacity up to 3 MW, given that most of them will be based on renewable energy sources. This will avoid extra costs and delays.
5. Analyse the current electricity network and design a long-term roadmap, in order to incentivize the reinforcement of the grid to support the connection of these projects.
6. Carry out more research, especially addressing sociological issues, in order to know more about Chilean communities and discover who would like to be involved in community energy initiatives.
7. Foster the independence of communities, developing and delivering skills and tools in order to properly manage community energy projects in the future, through new private and public supporting entities.

6. Conclusions

This paper has discussed the Scottish experience in community energy development, considering the main evidence available up to now. The Scottish experience should be recognised as a worldwide example of how communities are trying to deal with several issues, including increasing economic independence through renewable energy projects. Obviously, it has faced and still faces important challenges, but also opportunities. With the support of a range of private and public entities, communities are currently taking advantage of these opportunities.

In comparison, the Chilean community energy sector is weak and incipient. This is mainly due to the Chilean government’s support towards distributed generation schemes instead of community initiatives in energy production, even when that would not be convenient for consumers under the current net billing scheme. However, given the potential in terms of renewable resources, geographical conditions, communities, and so on, a wider community energy deployment is possible in the medium or long term, if this is supported with explicit government policies.

This will present an enormous challenge, because it challenges the way electricity markets are currently operating. Nevertheless, it could be an effective tool to tackle climate change, increase the renewable energy participation in the electricity mix, and improve the economy and quality life of communities. This paper aims to be a first step in getting a deeper understanding of this phenomenon, building on the Scottish experience to derive useful recommendations. More research will be necessary in the near future to help Chile and other developing countries to develop a thriving community energy sector.

Acknowledgements

We would like to thank Jelte Harnmeijer (Scene); Colin Pritchard (The University of Edinburgh); Bregje van Veelen (Durham University); Francisco Merino (Chilean Ministry of Energy); Ruth Evans (Local Energy Scotland); and Sebastián Barrios and Carlos Díaz (Rubik Sustentabilidad) for their valuable comments.

The work reported in this article was partially funded by CONICYT through a Doctoral Fellowship for Fabian Fuentes Gonzalez CONICYT-PFCHA/Doctorado Nacional/2017-21170460, CONICYT, FONDECYT/Regular N. 1190253 grant, by CONICYT, FONDAP N. 15110019 (SERC-Chile) grant, by CORFO CEI2-21803 grant, and by the UK Engineering and Physical Sciences Research Council through grant number EP/P001173/1 (CESI).

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