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Community Renewable Energy Networks in urban contexts: the need for a holistic approach

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ABSTRACT

Despite a ubiquitous interest in community energy, a review of the literature reveals a fragmented approach in which the technology elements that need to be considered for the effective existence of CREN are well understood but the social aspects have not yet been addressed to the same degree. Thus, while technology is no longer the limiting factor it used to be and there are mechanisms that can be used to deal with the social requirements, the fragmentation remains a challenge. The next necessary step in the exploration of community renewable energy lies in crafting a holistic approach that brings it all together to foster successful implementations. The aim of this paper is to define an urban CREN within this holistic outlook and review the literature that refers to the different aspects that need to be considered for project success in a greenfield setting. In conclusion, the authors suggest the reconceptualisation of CREN as an organisation to create a business model in which the technology and social aspects are approached in a transdisciplinary manner to achieve the effective creation and ongoing operation of such networks.

Keywords

Community Energy
Renewable
Urban
Microgrid

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1. Introduction

Despite the interest in 'community energy' from industry, activists, policy makers, and concerned citizens across the globe, there is limited academic literature addressing the different aspects of this complex entity as a whole. Academic research has paid abundant attention to the technology, and some attention to the social aspects of these implementations but in a fragmented way. Starting in the 1970s, researchers – like Lovins [1] and then Courrier [2] – were already arguing that the transition to renewable energy was a matter of systematically addressing social and situational problems whilst also solving technology issues; it was clear to them that the "so-called soft issues" were just as determinant for the success of a renewable energy project as its technical feasibility. Even today, almost forty years later, researchers are still arguing that the energy transition is more than just a techno-economic problem [3–8], but the approach remains fragmented.

The aim of this paper is to define an urban CREN as a holistic socio-energy [4] entity and review the literature that deals with the different aspects that an interdisciplinary approach to such implementation would need to address for project success in a greenfield setting. The context for this analysis is based in Australia but we believe it is applicable to other jurisdictions as well.

2. Community Renewable Energy Network (CREN)

For the purpose of this research, Community Renewable Energy Network (CREN) refers to an electricity smart microgrid, with mostly renewable electricity generation, owned and operated by a community for its supply of electricity and potential trading benefit. In this context:

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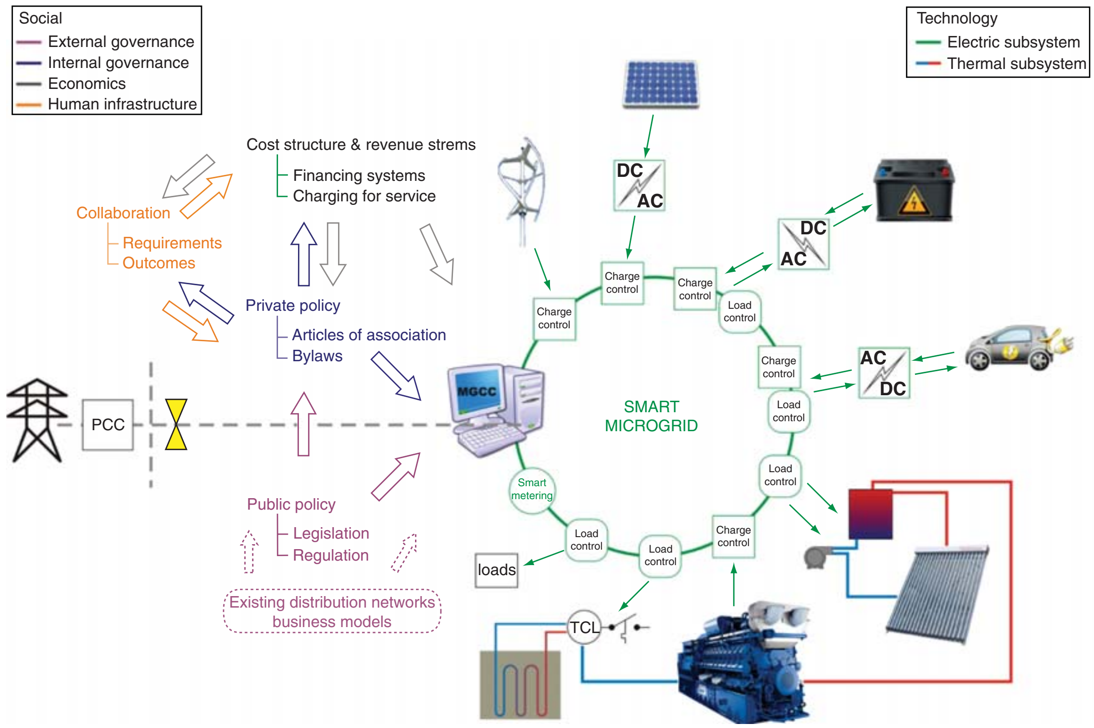

Figure 1: Elements in a holistic approach to CREN

– community refers to:
  - inhabitants of a specific, well-defined geographic location in an urban setting
  - working as an entity to implement a renewable energy system as primary source of electrical for their community
  - owner of the generation, distribution and consumption of the system
  - responsible, directly or indirectly (if outsourcing), for:
    - management of generation, distribution and control assets
    - operation of the system
    - governance
  - responsible for costs and realisation of benefits related to the system and its operation

– smart microgrid refers to a power network that:
  - uses mostly renewable sources for the generation of electricity and thermal energy
  - uses energy storage to manage the intermittency of renewable energy sources
  - could, if required, use some on-site thermal generation
  - uses smart technology -like smart meters and controllers- to allow active participation and optimal utilisation of resources
  - aims to work islanded but can be connected, on demand, to the grid for the purpose of:
    - trading electricity with the grid bidirectionally -e.g. during emergency peaks
    - participating in a Local Energy Market (LEM) -e.g. trading with other CREN in the same locality

2.1. Why the innovation in the community energy concept

Community is a concept with many and varied meanings that are selectively exploited within many and varied fields for, again, many and varied purposes. Within the context of energy, as Walker et al [9–11] described, 'community' is a term that applies fairly loosely to actors networked in just about any way with the purpose of advancing the implementation of renewable energy.

For areas like Woking [12] in the UK, Bornholm in Denmark, and Freiamt [13], Wildpoldsried [14] and Feldheim [15] in Germany, to name a few notable examples, community renewable energy has meant local governments – suburban in the case of Woking, insular in the case of Bornholm and small regional towns in the German context- managing to provide for their power needs by a combination of RE technologies and fuels that range from PV and wind to biomass and biogas. In the Australian renewable energy setting, community, in terms of implementations, has generally implied the more universally occurring community-owned RE initiative where either a group of residents in a remote location not serviced by existing electrical infrastructure or a group of grassroots investors join resources to install generators -usually wind turbines and some solar- in mostly rural environments, to sell electricity by connecting to the grid [16–19]. Lately -within the past four years- "goal-oriented virtual communities" have been proposed by some researchers who see utilising the smart grid as a way to bring together prosumers and consumers into a Prosumer Consumer Group (PCG) [20–22] for which the understanding of the modes of association is still work in progress [23–25].

CRENs, just as all of these RE community arrangements, fulfil the goal of advancing the penetration of RE technologies necessary to curtail CO_2 emissions and -as in the case of the local government areas- to provide a certain level of energy autonomy. However, for CREN, as opposed to CRE installing generation to sell to the grid, the main objective of the association is to coordinate supply and demand in a way that takes advantage of the collective to optimise the use of resources within the localised community. For urban CREN, the electricity is actually generated and consumed locally, resulting in minimal or no interaction with the larger electricity grid. Thus, a well-designed CREN keeps behind the meter at its single point of connection what grid operators at all levels claim are some of the problems with quality of supply of highly distributed RE -namely unpredictability which affects dispatch capacity and harmonic distortion as well as electromagnetic interference resulting from the vast number of supply connections.

In addition to the technical advantage of internal consumption and single point connection, CRENs also offer the benefit -over those systems implemented by local governments- of having the community actually own the assets directly, without abrogation of ownership rights to a public entity which then represents those rights by delegation within timeframes and parameters that do not necessarily meet the specific needs of the community at any given point in time; it is an accepted truism that shareholders are always better served than voters.

Furthermore, in contrast to a PCG, a CREN as an autonomous entity offers the benefits explained later in this article derived from what some social researches define as 'community' [26] which an aggregation of autonomous prosumers with tenuous links fundamentally based on financial self-interest is unlikely to provide.

Finally, CRENs provide incentives for developers to implement this RE networks to derive a couple of potential benefits: a point of differentiation in terms of environmental responsibility and shared value and as an additional asset for sale within the developments. Even though industry claims that buyers are not at all concerned about electricity sources when making purchasing decisions that include double garages or luxury finishes, the proliferation of rooftop solar does denote a level of interest that could easily be exploited by marketeers selling autonomy and protection from price increases along with the garages and granite bench tops.

2.2. Why an approach at this collective level

The essence of the answer lies on the folk wisdom enunciated by two thinkers: Jonathan Kozol's "pick battles big enough to matter, small enough to win" and Aristotle's idea, when describing his concept of emergence, that the whole is greater than the sum of the parts.

Starting with Kozol's folk wisdom legacy. The evidence of anthropogenic induced global warming has long existed [27] and clearly indicated that the reduction of greenhouse gas emissions is a challenge that needs worldwide action. It is, therefore, no surprise that climate change has been discussed at a global level since the first World Climate Conference in 1979 and has remained an issue on the international policy agenda ever since [28]. However, despite the efforts by the United Nations to globalise action, the struggle to reach multilateral agreements considering conflicting interests from diverse countries across five continents has been slow and at times has even halted any progress towards action. Clearly more a war than just a battle, so since the last decade of the past century, there have been calls [29–31] for more regional approaches that consider incorporating the larger concerns into more localised issues and policy implementations that more closely suit the people to which they apply. Elinor Ostrom, Nobel Prize in Economic Sciences 2009, while not discounting the contribution of global efforts, demonstrated through her work over more than three decades that common resources can be successfully managed by associations comprised by the people using those resources rather than by government intervention or privatisation [32]. Furthermore, given that large scale problems such as global warming are the result of the aggregation of actions taken by individuals at different levels of organisation, she also argued that focussing on encouraging polycentric approaches, rather than just worldwide efforts, can produce considerable benefits at multiple scales as well as foster experimentation which leads to important learning [33].

The inherently distributed character of renewable energy sources and technologies offers communities the scale flexibility and localisation that provides concrete benefits like autonomy and cost-free fuel for power generation, while achieving the goal of lowering CO_2 emissions from electricity generation. This RE localisation which contradicts the traditional fossil-fuelled business models inspired by Insull's "massing of consumption" [34], on the other hand, suits the self-interest of individuals and communities, thus providing the ground for winnable battles.

Finishing with the folk wisdom legacy of Aristotle, it is to be noted that a community is not just a sum of individuals but an aggregation of multiple resources that, when combined, provide much more than greater purchasing power and better negotiating position [35–39].

2.3. Why urban

Similarly to other countries implementing community renewable microgrids [40–44], Australia is focussing on this type of system as a means of providing electricity service to remote or rural communities. These communities are characterised by accessibility constraints, and cannot easily or cost-effectively be provided electricity services by the existing transmission and distribution networks. The obvious fit of renewable energy systems to sites that by their very isolation provide ideal conditions for solar and wind harvesting makes them the evident choice for rural and remote settings. There is no arguing that this scarcity of viable alternatives and abundance of renewable resources must make these rural and remote communities a necessary part of the end game for these technologies. However, as researchers [45, 46] argue and Walker [47] concludes after his study on barriers and incentives for community-owned generation and use, the implementation of CREN in *urban* settings is crucial for the proliferation of distributed renewable energy systems, particularly PV as is unfolding in the Australian context now. These systems cannot only be seen as means of supplying electricity services when fossil-fuelled alternatives are not commercially viable, but as an effective way of achieving carbon reductions at the very large scale that the aggregation of individual efforts at grassroots level can provide.

In Australia's context, this is particularly relevant given that 89.5% of its inhabitants live in urban areas [48], and the population of its capital cities has an annual growth on average double that of other regional areas [49]. This disproportion between rural and urban populations makes the magnifying property of density an important consideration when applying effort. For example, a modest 5% increase in penetration of solar electricity generation in urban environments would require an uptake of the same technology by almost half (43%) of all rural population to achieve an equivalent result in terms of installed capacity. However, it is to be noted that the density that makes urban environments an ideal focus for renewable penetration is also what ensures that established fossil-fuelled technologies have a strong presence making incumbent suppliers the default option for most urban end users.

It is argued as common knowledge that the density of urban environments provides disincentives to community energy due to quality of space constraints and the ubiquitous presence of the grid which makes access to reliable electricity very easy and cost competitive when compared to renewable energy system implementation. However, as prices of technologies like PV and batteries fall, the cost parity with the grid is already being achieved by individual RE systems that incorporate all the necessary elements [50], and this favourable position is further enhanced by the increased purchasing power and operational efficiency that derives from the aggregation of RE elements in a community setting. Australia provides a good example of how the apparent urban challenges are mitigated resulting in PV implementations thriving in metropolitan areas.

3. Technology aspect

3.1. Smart microgrid and energy management systems (EMS)

The grid that underlies the traditional electricity networks resulted from the need to transport electricity from remote generators to end users in urban centres or mostly clustered rural populations whose only concern about the electricity system was that it made supply reliably available at all times and did so at the lowest cost for consumers. In this traditional supplier-controlled grid, all decisions are made by a centralised operator who 'owns' all the unidirectional flows of both electrons and communications.

The shortcomings of this arrangement -electricity losses during transmission, inefficient provision of capacity to meet sporadic peak demand, vulnerability to vast area blackouts resulting from localised faults, energy conversion inefficiency of base load generators, and limitation of end-user contribution to both their own and overall system functioning, to name a few- made a rethink of the old system a necessity that is addressed by a more modern approach that has come to be known as the "smart" grid.

In the smart grid, distribution can replace centralised generation, the unidirectional, hierarchical communication is replaced by two-way communication between all the nodes in the network, mechanisms like demand side response (DSR) to deal with peak demand are supported by the flow of information and the pervasiveness of control, fault vulnerability is replaced by resilience, multiple generation technologies can supply electricity to the network simultaneously in a localised manner, and a 'choiceless' end-user becomes an empowered customer.

From a national perspective, or even just from the point of view of the existing networks, this kind of new approach requires vast financial outlay to replace existing assets on which large amounts of both pecuniary and valued technology capital has been invested for the past seven decades. Complex and power-valuable organisational and management structures intrinsic to the old system will also need to be overhauled in ways that many incumbents will resist. Thus, the smart grid will come to be as a result of smaller considered implementations within the traditional grid, bringing about the change as an evolution rather than a revolution [51].

The creation of a community microgrid, therefore, seems the ideal building block for a smart grid as at its inception it is not tethered by old paradigms and infrastructures, thus allowing for new approaches as a matter of fact. However, some researchers [52] conclude in their study on smart grids for community energy delivery, communities do not have the economic critical mass that large utilities can achieve when implementing sophisticated technology, hence making the all-important financial aspect the make-or-break pivot point of these implementations. On the other hand, the clustering potential inherent to network configurations, can provide these community microgrids the capability to overcome the pitfalls of small scale when creating their smart grids as part of the bigger one [22, 53–55].

This 'molecular' approach not only facilitates the building of the whole but also provides to the communities themselves multiple benefits like autonomy, flexibility, efficiency and scalability [56]. Furthermore, due to their technology agnostic character, the smart microgrids also offer communities a broad choice of technologies for energy generation from diverse sources, storage options, system and energy flows management, to control mechanisms for varied implementation strategies, and growth [57–71]. Thus smart microgrids provide communities the ideal means of implementing the renewable energy systems required to contribute to the greenhouse gas abatement at a local level.

3.2. Solar, wind and hybrid generation with energy storage

In the past three decades, rapidly advancing renewable energy technologies have gone from struggling attempts [72] to viable alternatives [73] that allow a return to the localised generation and consumption configuration of the original electricity networks. The growing body of research on the established and new solar technologies [74–77] relevant to urban CREN and the consequent understanding and advancement in their production and implementation have resulted in easy accessibility and falling prices that make them increasingly an attractive option to consumers desiring energy autonomy. At present, the main drawback for these systems is the intermittency of their sources, making storage a necessary component of a CREN aiming to optimise the use of RE resources. As it happens, energy storage of all types and at all scales has also been the subject of intense and rapidly advancing research [78–81], which is having the same effect on this type of technology as it did on the generation technologies.

This abundance of technically detailed literature about the different technologies might seem overwhelming for CREN planners who in the 'real' world just need a solution that optimises the use of resources. Albeit there being various, relatively user-friendly, publicly available tools that have resulted from the detailed research [82–86], there is very limited academic literature [87–91] on how to use models to plan community systems that make optimal use of the contribution potential of each of the available generation and storage technologies.

3.3. Plug-in electric vehicles

Although not strictly a necessary part of a CREN, plug-in electric vehicles are likely to become itinerant components that can be either a load or a charge that has a considerable effect on a system that intends to rely principally on RE energy sources and storage. PEVs, regardless of the technology -hybrid or full electric-present benefits and challenges to any electric system to which they attach -be it a large regional grid or a neighbourhood microgrid [92–94]. Albeit there being a growing body of technical literature aimed at dealing with ways of addressing the challenges and harnessing benefits of PEVs [95–99] from a technical point of view, there is a lack of academic literature on the governance and strategic management of PEVs in a CREN. Research is needed into the social aspects of the connection -like driver convenience, financial incentives and internal governance- and their impact on behaviours that could yield a relevant contribution to making the batteries of those vehicles provide additional storage when needed while reducing the likelihood of creating excessive load on the system at any given point in time.

3.4. Geothermal and solar systems for temperature management

Direct geothermal, although widely used in other parts of the world, in Australia is an emerging technology [100] that is having its potential for cooling and heating buildings researched at present [101]. For the purpose of this CREN research, geothermal is only considered as a means of reducing cooling and heating requirements; ergo, more a contributor to dwelling efficiency rather than to the general energy generation pool of the system.

Solar hot water systems for generating thermal energy is a mature technology that has wide acceptance within the general community because of its proven effectiveness in reducing GHG emissions while achieving cost reductions in electricity expenditure. In Australia, these systems are generally used by individual dwellings as means of providing a large proportion of the hot water needs for that dwelling, and there is no research into the contribution that these systems could make to a CREN -not only as providers of hot water for direct use but as providers of thermal storage for the general system or as providers of heat for absorption chillers to deliver cooling services either at communal or individual level.

4. Social aspect

Even though the social aspects of community renewable energy have not been the subject of the same level of attention as the technical factors, there is a sizable body of literature on the subject. Community engagement [36, 37, 102–105], financial participation models [106], trust [10], equity issues [107], different degrees of individual involvement [108], community attitudes [109] and perceptions [110], the use of social and economic instruments to positively modify attitudes and behaviours to energy generation and use [111] as make-or-break elements for the successful implementation of CREN have been considered as on par with the technology solution by the literature. Nevertheless, this research has suffered the same fragmentation as the technology research; there is a paucity of research integrating all the different elements that need to be brought together to make a CREN a feasible possibility from either a community or a developer perspective.

Considering the governance requirements, given the industrialised nations' 'carbon lock-in' [112], which in Australia is exacerbated by the vast mining interests and incumbents in the energy industry influencing the perception of fossil fuels as economic pillars of the national economy [113], the legislative and regulatory backing necessary for the transition to renewables at national level is going to require disruptive change. Due to the fact that governments come and go, and with them the pushes for or against renewable energy utilisation, the implementation of the initiatives necessary for this change becomes a Sisyphean task when it relies on top-down approaches guided by the policies of the government of the day. A bottom-up approach like the one implied by CREN is more likely to provide the required change on a more stable basis, for a longer time horizon than an average electoral cycle.

5. Conclusions and future work

This review of the literature that deals with the discrete elements of a CREN reveals that there is abundant information about its components, but it seems that the complexity entailed in connecting those disciplines at the level of specialisation and depth that traditional academic research requires stands in the way of the needed integration.

Existing research suggests that for the successful implementation of CREN:

- RE technology is no longer the limiting factor it used to be before steady advances in generation and storage, coupled with efficiency gains in consumption, made autonomy for these systems an attainable reality
- the smart grid approach -allowing bidirectional flow of information and electricity as well as flexibility, scalability and technology agnosticism- provides the necessary underlying distribution and control infrastructure
- the social aspects -at high level, namely collaboration, economics and governance- need to be considered on par with technology and intrinsically incorporated into any working solution
- the lack of a holistic perspective on these complex systems makes a transdisciplinary approach the next necessary step in the exploration of community renewable energy

It is the contention of the authors that, instead of attempting to connect the elements from either the technical or social science perspectives, it would be helpful to seize all the contributions from those disciplines and concentrate on how to bring them together.

The next step of this research focusses on reconceptualising CREN as an organisation providing a service -either for or not for profit- thus offering that 'outside' standpoint that brings together all the elements into a business model aimed at making a CREN work. The research will delve into suitable business models considering things like:

- mix of technologies for optimal system implementation
- cost structures and revenue streams to optimise funding and ongoing operation
- clearly defined management structures and governance to ensure collaboration and equity
- necessary relationships and partnerships

to provide a convincing value proposition that underpins the creation and ongoing operation of a CREN for the benefit of the community.

Even though this research will focus on Australian urban conditions, very similar business models could apply to RE implementations in developing nations to provide electric power to communities isolated from the public distribution networks.

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