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The application of renewable energy to social housing: A systematic review

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ABSTRACT

Low-income housing associations provide a unique opportunity for renewable energy installations, through potential scale of implementation sites, and in reducing social and financial costs to tenants. As an emerging field, a systematic review format was chosen as a method of providing a 'state-of-the-art' analysis for practitioners and researchers in the field of renewable energy and social housing applications. While literature reviews are common in analysis of energy applications across many fields, systematic reviews are much rarer. Because research/policy interest in the application of renewable energy technologies and social Šhousing appears to be growing, this review aims to bring together the disparate literature already available. This review set out to determine what are the common 1. Success Factors, 2. Barriers and 3. Motivations, evident in previous research surrounding the application of renewable energy technologies in social housing contexts? Common findings from 67 research cases were synthesised under 3 *a priori* themes of Motivations, Barriers and Success Factors. Many articles revolved around the user interface and potential barriers to integration of technology, particularly where user engagement is not carried out sufficiently. It is suggested that this emphasis reflects a broader trend in applying socio-technical approaches in the field of energy research.

1. Introduction

As accessibility to renewable energy (RE) technologies grows due to enhanced affordability and efficiency, so too do the possibilities and opportunities for its application. In contrast to traditionally centralised electricity provision systems (such as coal-based electricity generation), renewable energy technologies allow for the decentralization of energy generation both in scale (individual buildings) and in the actors who participate and reap the benefits from such generation (individual consumers). With this comes the opportunity not only to address energy demand, but also reduce electricity costs for residents.

Following this, social housing (SH) is becoming a major area of interest for energy researchers. In these settings, renewable energy sources, including solar and biomass, have the ability to provide substantial benefits to the tenants (in terms of monetary savings), while having a positive environmental impact on a larger scale than individual domestic installations (Teli et al., 2016). In its essence, social housing is a service, and as such, during the provision of accommodations, electricity, and water utilities, there exists an inherent swathe of barriers and success factors embedded within the interface between the housing provider and the tenants, particularly where low-income socioeconomic factors are concerned (Moore et al., 2015). While there is a growing literature base surrounding energy efficiency and social housing (see, for example, (Reeves et al., 2010; Urmee et al., 2012)) to date there have been no systematic scholarly reviews of this phenomenon. Most literature surrounding the application of RE and social housing has proceeded on a case study basis.

This paper aims to provide a "state-of-the-art" overview of the application of renewable energy in social housing projects. This review set out to determine what are the common 1. Success Factors, 2. Barriers and 3. Motivations, evident in previous research surrounding the application of renewable energy technologies in social housing contexts? This overview will be a starting point for academics and practitioners, especially as research around the application of renewable energy for low-income and regional communities is growing substantially. The following section introduces the systematic review method employed. The findings from the review are then detailed with a focus on highlighting recurrent themes amongst the included studies, particularly around identified barriers but also success factors. The paper concludes with a discussion of potential avenues of future inquiry.

2. Methodology

A hybrid systematic review and narrative analysis methodology was employed in this study to fulfil the objective of this research: to explore key themes, from a scholarly perspective, of how and why social

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housing providers have chosen to employ renewable energy technologies. Where systematic reviews are often applied in health-related fields, with a quantitative outcome, narrative analyses are common in reviews of literature across case studies with variable and incomparable boundaries. This review combines both methodological choices in its design, combining a replicable systematic review protocol with qualitative analysis technique of coding and thematic analysis in narrative review. This review and analysis method was deemed appropriate as the data being reviewed was highly contextualised and heterogeneous in nature, not allowing for direct comparison, but for an assessment of the recurrent themes across the literature.

A systematic search of eight multidisciplinary databases was performed; Taylor and Francis, Web of Science, Scopus, ScienceDirect, ProQuest, JSTOR, EBSCOhost and Wiley online library. The Boolean search phrase ("housing association" OR "public housing" OR "social housing" OR "council housing" OR "state housing") AND ("renewable*" OR "solar" OR "wind" OR "biomass" OR "woodchip") was used. In a preliminary evaluation stage of this method, only the terms public and social housing were used. Later, these were deemed insufficient to fully capture the various other terminologies used to refer to such housing provision arrangements. Therefore, additional synonyms for public housing, were added to capture more articles. Only articles published between 2000 and June 2016 were captured within this study.

Within the parameters of each database query, articles not of a peer-reviewed nature were removed at the outset. This resulted in the initial exclusion of 2619 database query results. 8453 articles were then exported. Duplicate articles were systematically identified and deleted. Only 1154 identical references were identified in this process, indicating the appropriate coverage of databases selected.

Articles were first systematically reviewed and excluded based on the relevance of their title to the aim of this paper. This resulted in the exclusion of 7044 articles. The remaining article abstracts were then similarly reviewed and excluded, resulting in the exclusion of 100 articles. Full text sourcing for the remaining articles resulted in the identification of 11 articles potentially appropriate to review but not accessible by the authors. Full text review of articles resulted in the exclusion of 107 articles. 5 additional references not captured within the database query were identified over the course of this review. Of these, only 3 were accessible by the authors. To ensure appropriate review techniques, a co-reviewer appraised the exclusion process (Edwards et al., 2002). The final list of articles extracted for review comprised 67 articles. The process of sourcing the literature is graphically illustrated in Fig. 1.

While peer-reviewed journal articles were given preference, several conference proceedings and book chapters were also deemed appropriate to the review. Feature articles (i.e. not necessarily academic articles and generally with a journalistic quality) were also included providing they were tied to the objective of this paper, of academic merit, and provided some element of appraisal of the application of the renewable energy technology. Grey literature and government reports were not included within this review. This potentially reduces the number of empirical, or case-based assessments captured. While care was taken in designing the search protocol and scope of the research in order to capture all relevant references, the authors recognise the potential for terms not employed in the search protocol to also be relevant to the application of renewable energy technologies to social housing (for example the use of "low-income housing" in lieu of "social housing").

An axial coding approach stemming from the identified renewable energy technology or application in each article was used. Several *a priori* themes were explored first as a way of entering the data analysis stage of this research. Upon initial reading, it was ascertained that most of the incorporated studies were in case study formats, with much of the discussion focused around the *process* of RE integration with the social housing development, particularly the incentive in the initial stages to employ RE, the hindrances to the development and the success or failure of the development. As such the *a priori* themes were *Motivations, Success factors, and Barriers*. Key words associated with key themes of the research objective were first identified within the reference list as a way of entering the analysis. After exploring the *a priori* themes defined by the research objectives, emergent themes were identified first through the automatic detection and analysis of frequent words, utilising the software program nVivo, and through recurrent concepts found whilst manually reviewing the articles.

3. Findings

As noted, 67 articles were reviewed within this analysis (Table 1). Included articles were published between 2000 and 2016, with the majority of articles published in 2012 (Fig. 2). Author affiliations were recorded to determine a general geographic scoping of the articles within this review. Where multiple geographic affiliations were found

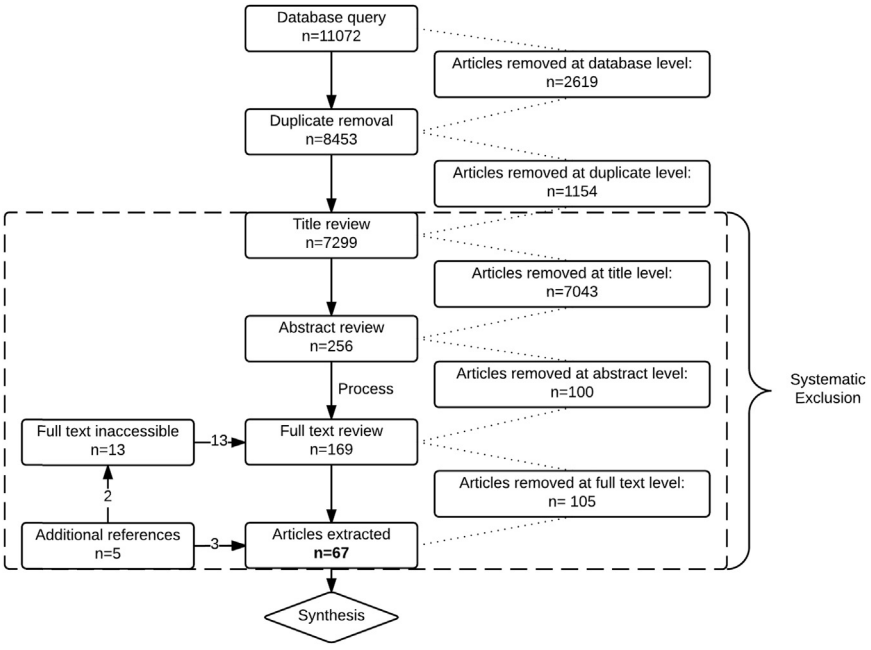

Fig. 1. Systematic extraction process of related literature.

Table 1
Articles considered in analysis.

Year of publication	*Title of publication*	*Author*
2000	Application of renewable energy systems in a settlement of social housing	Andreadaki, E., Manolides, K., Chronaki, M., Karagianni, O. & Athanassakos, E.
2002	Means of enhancing and promoting the use of solar energy	Bahaj, A.
2002	Zero energy buildings: Key role for RE at UK housing development	Marsh, G.
2004	Networks and innovation: sustainable technologies in Scottish social housing	Dewick, P. & Miozzo, M.
2004	Evaluation of the first micro combined heat and power for social housing in Belgium	Van Bael, J. & Peeters, E.
2004	Photovoltaics (PV) in social housing	Wheal, R., Fulford, D., Wheldon, A. & Oldach, R.
2006	Appropriate energy efficient building envelope technologies for social housing in the Irish climate	Shanks, K., Lo, N. & Norton, B.
2006	Target group segmentation makes sense: If one sheep leaps over the ditch, all the rest will follow.	Egmond, C., Jonkers, R., & Kok, G.
2007	Urban energy generation: The added value of photovoltaics in social housing	Bahaj, A.S. & James, P.A.B.
2007	Urban energy generation: Influence of micro-wind turbine output on electricity consumption in buildings	Bahaj, A. S., Myers, L. & James, P. A. B.
2008	Public perceptions of opportunities for community-based renewable energy projects	Rogers, J. C., Simmons, E. A., Convery, I. & Weatherall, A.
2008	Building mounted wind turbines on existing multi-storey housing	Sharpe, T.
2008	Decentralised systems and fuel poverty: Are there any links or risks?	Walker, G.
2009	Energizing the Affordable Housing Market: Current Incentives for Integrating Energy Efficiency and Solar Power in Mixed Finance Projects	Lyon-Collis, L.
2009	The role of photovoltaics in reducing carbon emissions in domestic properties	O'Flaherty, F. J., Pinder, J. A. & Jackson, C.
2009	Choice or coercion: dilemmas of sustainable social housing. A study of two developments in Kent	Pickvance, C.
2009	Solar for Social Housing: Elaborated using Pakistan's Case	Rizvi, Z.M
2009	The Energy and Cost Implications of the Renewable Energy Scheme at the Integrated Home for Older People, Plas y Môr, Llanelli, Wales	Roberts, P.
2009	Green build for social housing	Shepherd, K.
2010	Energy efficiency in social housing: Opportunities and barriers from a case study in Brazil	Bodach, S. & Hamhaber, J.
2010	The potential of the Code for Sustainable Homes to deliver genuine 'sustainable energy' in the UK social housing sector	McManus, A., Gaterell, M. R. & Coates, L. E.
2010	The role and benefits of solar water heating in the energy demands of low-income dwellings in Brazil	Naspolini, H.F.
2010	Modelling the potential to achieve deep carbon emission cuts in existing UK social housing: The case of Peabody	Reeves, A., Taylor, S. & Fleming, P.
2010	Sustainable housing for low-income communities: lessons for South Africa in local and other developing world cases	Ross, N.
2010	Community strategies for energy efficiency successful examples from Austria	Strassl, I.
2011	Performance and control of domestic ground-source heat pumps in retrofit installations	Boait, P. J., Fan, D. & Stafford, A.
2011	The impacts of solar water heating in low-income households on the distribution utility's active, reactive and apparent power demands	Naspolini, H.F.
2011	A techno-economic analysis of small-scale, biomass-fuelled combined heat and power for community housing	Wood, S.R.
2012	Sustainable strategies and methods for the energetic improvement of social housing stock in Italy	Brunoro, S.
2012	Domestic heat pumps in the UK: user behaviour, satisfaction and performance	Caird, S., Roy, R. & Potter, S.
2012	Retrofitting homes for energy efficiency: An integrated approach to innovation in the low-carbon overhaul of UK social housing	Crilly, M., Lemon, M., Wright, A., Cook, M. & Shaw, D.
2012	Lowering CO2 emissions in the new build social housing sector: A Spanish case study	Downey, M.
2012	Adoption of innovative energy systems in social housing: Lessons from eight large-scale renovation projects in The Netherlands	Hoppe, T.
2012	The Practice of Innovative Energy Systems Diffusion in Neighbourhood Renovation Projects: A Comparison of 11 Cases in the Netherlands.	Hoppe, T., Bressers, H., & Lulofs, K.
2012	What does it mean to be a friendly outsider? Critical reflection on finding a role as an action researcher with communities developing renewable energy projects	Rogers, J.
2012	Can premium tariffs for micro-generation and small scale renewable heat help the fuel poor, and if so, how? Case studies of innovative finance for community energy schemes in the UK	Saunders, R. W., Gross, R. J. K. & Wade, J.
2012	Energy plus standard in buildings constructed by housing associations?	Stutterecker, W. & Blumel, E.
2012	Improving Energy Efficiency of Social Housing Areas: A Case Study of a Retrofit Achieving an "A" Energy Performance Rating in the UK	Sunikka-Blank, M., Chen, J., Britnell, J. & Dantsiou, D.
2012	Energy Efficiency in Housing Management: Policies and Practice in Eleven Countries	Tsenkova, S. & Youssef, K.
2012	Energy efficiency status of the community housing in Australia	Urmee, T., Thoo, S. & Killick, W.
2013	Shaping people's engagement with microgeneration technology: The case of solar photovoltaics in UK homes.	Abi-Ghanem, D. & Haggett, C.
2013	The sustainable improvement of social housing stock in Italy: Strategies of intervention	Brunoro, S.
2013	Cuando las transferencias tecnológicas fracasan. Aprendizajes y limitaciones en la construcción de Tecnologías para la Inclusión Social. English Translation: When technological transfers fail. Learning and limitations in the construction of Technologies for Social Inclusion	Fressoli, M., Garrido, S., Picabea, F., Lalouf, A. & Fenoglio, V.
2013	A Case Study of Energy Efficiency Retrofit in Social Housing Units	Gagliano, A., Nocera, F., Patania, F. & Capizzi, G.
2013	A Comparison Of The Economic Savings Between Thermal Solar Systems And Thermal Insulation Improvements For Social Housing In Chile.	Garate, M. P. & Guridi, P. M.
2013	Reducing carbon, tackling fuel poverty: adoption and performance of air-source heat pumps in East Yorkshire, UK	Owen, A., Mitchell, G. & Unsworth, R.
2013	Retrofit innovation in the UK social housing sector	Swan, W.
2013	Adoption of sustainable retrofit in UK social housing	Swan, W., Ruddock, L., Smith, L. & Fitton, R.
2013	Solar Capability Building Programme for public housing	Wong, J. L. H., The, P. S., Wang, V. X. & Chia, L. M. H.
2014	User and organisational responses to biomass district heating	Ambrose, A.

(*continued on next page*)

Table 1 (*continued*)

Year of publication	*Title of publication*	*Author*
2014	Transpired Solar Collector Installations in Wales and England	Brown, C., Perisoglou, E., Hall, R. & Stevenson, V.
2014	A procedure for analysing energy savings in multiple small solar water heaters installed in low-income housing in Brazil	Giglio, T., Lamberts, R., Barbosa, M. & Urbano, M.
2014	Asset Management of low-zero carbon technology in social housing	Kempton, J.
2014	What do people living in deprived communities in the UK think about household energy efficiency interventions?	Scott, F. L., Jones, C. R. & Webb, T. L.
2015	The ageing population and smart metering: A field study of householders' attitudes and behaviours towards energy use in Scotland	Barnicoat, G. & Danson, M.
2015	Reduction of carbon dioxide emissions by solar water heating systems and passive technologies in social housing	Bessa, V. M. T. & Prado, R. T. A.
2015	Energy analysis and refurbishment proposals for public housing in the city of Bari, Italy	Di Turki, S. & Stefanizzi, P.
2015	The co-construction of energy provision and everyday practice: Integrating heat pumps in social housing in England	Judson, E., Bell, S., Bulkeley, H., Powells, G. & Lyon, S.
2015	Zero-energy home development in Korea: energy-efficient and environmentally friendly design features and future directions	Kim, S., Lee., Kwon., H.J. & Ahn, M.
2015	Improving the installation of renewable heating technology in UK social housing properties through user centred design	Moore, N., Haines, V. & Lilley, D.
2015	Organisational Challenges in the Adoption of Building Applied Photovoltaics in the Swedish Tenant-Owner Housing Sector.	Muyingo, H.
2015	Decentralised combined heat and power in the German Ruhr Valley; assessment of factors blocking uptake and integration	Viétor, B., Hoppe, T. & Clancy, J.
2016	Evaluation of Energy Use in Public Housing in Lagos, Nigeria: Prospects for Renewable Energy Sources	Ezema, I. C., Olotuah, A. O. & Fagbenle, O. I.
2016	Utilising Mixed Methods Research to Inform Low-carbon Social Housing Performance Policy	Moore, T., Strengers, Y. & Maller, C.
2016	Deployment of photovoltaics in Brazil: Scenarios, perspectives and policies for low-income housing	Pinto, J. T. M., Amaral, K. J. & Janissek, P. R.
2016	Post occupancy evaluation of social housing designed and built to Code for Sustainable Homes levels 3, 4 and 5	Pretlove, S. & Kade, S.
2016	Fuel poverty-induced 'prebound effect' in achieving the anticipated carbon savings from social housing retrofit.	Teli, D., Dimitriou, T., James, P. A. B., Bahaj, A. S., Ellison, L. & Waggott, A.

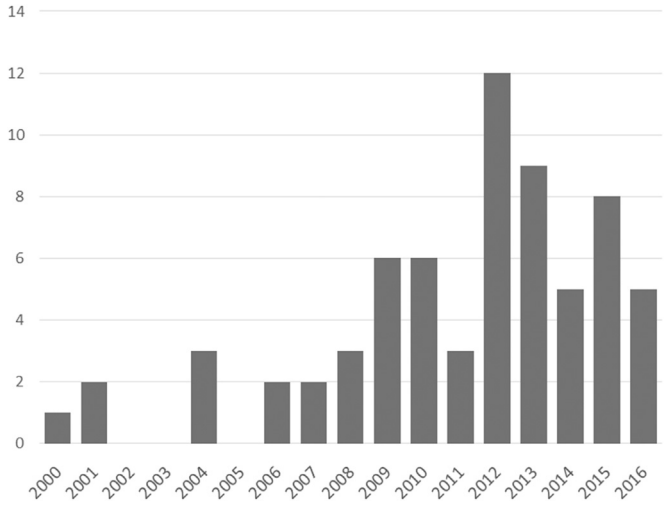

Fig. 2. Publication year of articles within this review.

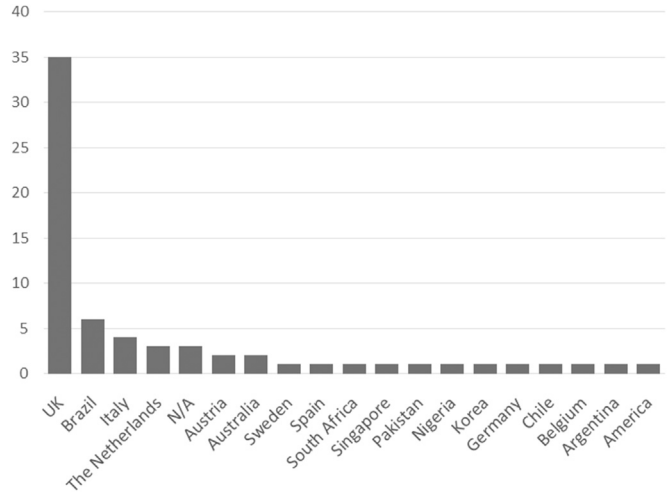

Fig. 3. Origin of articles within this review.

within one article, the primary author affiliation was used. Ten articles were identified to have no author affiliation. Affiliations were heavily skewed toward the UK. Study areas varied but followed author affiliations, with most studies based in the UK (n = 35) and Brazil (n = 6) and with three articles not geographically specific or covering multiple countries (Fig. 3). Articles included in the review were predominantly journal articles, followed by a few book chapters, conference proceedings and one feature article within peer-reviewed publications (Fig. 4.).

A priori themes in this review were (1) motivations, (2) success factors in past adoptions and (3) barriers to implementation and adoption, as mentioned. Data analysis began with keyword searching of 'motivation*', 'success' and 'barrier*'. Occurrences of these keywords were noted, alongside annotations on the context within which they occurred. Articles were then read thoroughly and additional inferences to each of the *a priori* themes were coded. Once each article was addressed, each theme was then delineated towards emergent subthemes, common amongst two or more articles. As these sub-themes emerged, instances of each *a priori* theme were grouped into each subtheme, with some relevant across more than one.

Based on this analysis, "success factors" were articulated into 4 common emergent subthemes, including: resident awareness, innovative financing options, economies of scale and trust and communication. Similarly, "barriers" were articulated into six emergent subthemes, including: lack of resident engagement, unclear understanding of users, financial risks, the novelty factor, inadequate policy support and technological complexities. These are discussed below.

3.1. Motivations

This theme covers the motivations for the application of the renewable energy technology.

Several studies highlighted the economic saving potential of RE

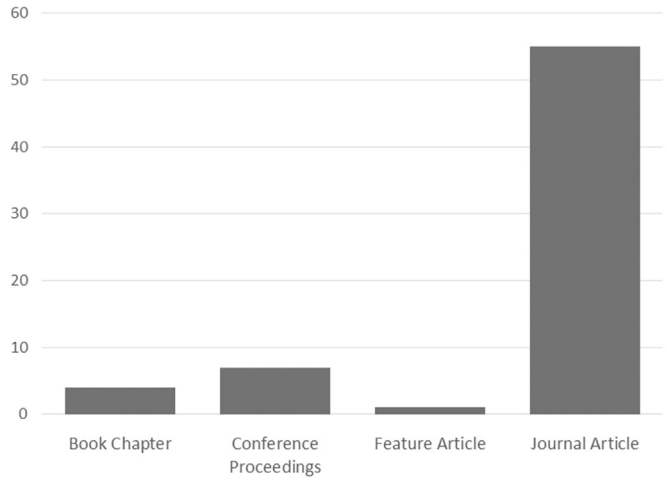

Fig. 4. Article types.

technologies as being the main motivation for the application, rather than for environmental reasons (Ambrose, 2014; Dewick and Miozzo, 2004; Muyingo, 2015). In others, environmentally sustainable design was the main motivation for the application of RE technologies, usually in conjunction with other sustainable design features (Bahaj and James, 2007; Brunoro, 2012; Marsh, 2002; O'Flaherty et al., 2009; Pickvance, 2009; Wheal et al., 2004). Brunoro (2013) highlights the ability for RE technologies to not only contribute to the sustainability of a building, but also the architectural value. One case highlighted the desire that one social housing provider had to not only improve energy efficiency and monetary savings, but also to empower residents by allowing them to control their own energy systems (Ambrose, 2014).

Aside from environmental and financial motivations, *enhancing the comfort and living conditions* of residents was also a common theme amongst the application studied in the literature (Dewick and Miozzo, 2004; Abi-Ghanem and Haggett, 2013; Ambrose, 2014; Barnicoat and Danson, 2015; Bodach and Hamhaber, 2010; Bessa and Prado, 2015; Caird et al., 2012; Gagliano et al., 2013). This is due to customizability of the RE technology to the demand profile of the house, as well as attempting to reduce the need for traditional wood burners for heat sources.

3.2. Success factors in past adoptions

A number of articles focused on the success factors of the application of RE in SH. The main factors identified in the analysis are discussed below.

3.2.1. Resident awareness

Among these, *resident awareness and attitudes* were highlighted in many studies as a success factor in the application of RE to social housing contexts (Bahaj and James, 2007; Fressoli et al., 2013; Moore et al., 2015; O'Flaherty et al., 2009; Pretlove and Kade, 2016; Sunikka-Blank et al., 2012). Abi-Ghanem and Haggett (2013) O'Flaherty et al. (2009) and Owen et al. (2013) argue that in the case of microgeneration technologies, positive energy reduction outcomes are contingent to the design and visibility of the technology. This is both tied to the awareness of economic savings of power reduction, but also pre-existing attitudes towards reducing wastage (Wheal et al., 2004). Judson et al. (2015) found that some residents in social housing developments avoided optimum usage patterns of RE installations because of fears of additional costs. This is also mirrored by Barnicoat and Danson (2015) who found that where resident access to usage data was restricted, uncertainty over usage amounts reduced the efficiency of the system.

Highlighting the failure of traditional cost-benefit analysis to capture positive impacts of an initiative, Moore et al. (2016) and Saunders et al. (2012) found that aside from positive financial and environmental outcomes RE applications also positively influenced the comfort and wellbeing or social housing residents.

Bahaj and James (2007) highlight that although visibility and awareness of the installed technology can influence the energy use behaviour of residents, this is only in conjunction with ongoing engagement and education efforts. While pre-existing energy-saving behaviours amongst social housing residents can be amenable to RE technology applications, without suitable training and engagement this behaviour can also reduce the efficacy of the system (Sharpe, 2008; Sunikka-Blank et al., 2012). For example, Caird et al. (2012), when studying user behaviour for a domestic heat pump application to social housing, found that residents were switching off heating at certain times, reducing the system's ability to heat up sufficiently at other times.

3.2.2. Innovative financing options

Innovative and alternate financing options were also highlighted within the literature as contributing to positive outcomes for social housing developments where capital raising capacity is low (Andreadaki et al., 2000; Saunders et al., 2012; Bodach and Hamhaber, 2010; Brunoro, 2013; Lyon-Collis, 2009; Walker, 2008). Wong et al. (2013) discusses the various merits of applying a “solar leasing model”, whereby a third party (usually a private company) will provide capital support, generally alongside a local council initiative. The financial and support backing of third-party financing bodies can help to remediate some of the barriers regarding perceived risk, particularly around more innovative developments. However some barriers regarding conflicting incentives and motives may occur as a result of introducing additional parties to the development (see below (Dewick and Miozzo, 2004)).

Rogers et al. (2008) explored the potential for an innovative community-based funding model for a renewable energy application for a housing association in Cumbria, UK, but found that while support was present, willingness to be practically involved created a barrier to success. Such community financing mechanisms were also highlighted as a potential alleviation to financial barriers by Viétor et al. (2015).

Also related to financing outcomes in the literature is the contribution of appropriate generation tariffs in reducing payback times for RE applications. This, in conjunction with a high enough demand profile on site, can ensure maximum efficiency and financial return (Bahaj et al., 2007; Brunoro, 2013; Saunders et al., 2012; Sunikka, 2003). In Hoppe et al. (2012), subsidies are highlighted (alongside other policy instruments) as a contributing success factor, and where successfully applied would lead to greater confidence and trust in approaching additional projects without the need for a subsidy.

3.2.3. Trust and communication

Another contributing factor for the successful application of RE to social housing was highlighted by Dewick and Miozzo (2004), Hoppe (2012) and Fressoli et al. (2013), who suggest that applications are more likely to be successful where long-term relationships and trust are built with external contractors or other intermediary organisations. Hoppe (2012) found that where a breakdown of communication occurred there was also a breakdown in trust between social housing providers and intermediary organisations.

3.2.4. Economies of scale

The *economies of scale* and influence of larger social housing providers can situate providers in a better position to provide incentives for carbon reductions, but also can influence policy at higher levels (Crilly et al., 2012; Moore et al., 2015; Pickvance, 2009; Swan et al., 2013; Tsenkova and Youssef, 2012). The existence of policy and institutional frameworks was also highlighted as a particular success factor in a number of studies, but only where low-level organisational plans are also in place (Downey, 2012; Dewick and Miozzo, 2004; Garate and Guridi, 2013; McManus et al., 2010; Owen et al., 2013; Pinto et al.,

2016)(see next section). Requirements for new-build social housing developments to integrate renewable energy could also influence the successful application and dissemination of RE technologies (Ezema et al., 2016; Downey, 2012; Hoppe, 2012).

3.3. Barriers to implementation and adoption

Many studies were motivated by exploring barriers to the application of renewable energy, both in reducing and hindering the success of applications (Abi-Ghanem and Haggett, 2013; Ambrose, 2014). The most common barriers, which overlap to some extent, are discussed below.

3.3.1. Lack of resident engagement

Social barriers regarding the application and uptake of technologies, including user interaction, were common (Ambrose, 2014; Caird et al., 2012; Hoppe, 2012). Where social housing residents were only informed of the development and not engaged with the process, there was less perceived benefit of the installation, which led to little or no change in energy use behaviours (Moore et al., 2015; Pickvance, 2009; Wheal et al., 2004). Even where engagement is present, over-complication of control mechanisms or information provided can also lead to the disengagement of the social housing residents (Ambrose, 2014; Caird et al., 2012; Owen et al., 2013; Pretlove and Kade, 2016; Boait et al., 2011). As visibility and design are highlighted as factors leading to positive outcomes, cases where little or no visible aspects of the application are present (particularly for biomass technologies that are not as visible as wind or solar) can also lead to disengaged residents. Where housing providers purely intervene and do not empower residents through education and engagements, Judson et al. (2015) summarises user behaviours as a conflict between two competing ideas of passive consumer and reluctant operator.

While promoting the benefits of RE installations can lead to positive outcomes through behaviour change and higher acceptance levels, it is important that the outcomes are not oversold in the outset of the installation (Pickvance, 2009; Owen et al., 2013).

3.3.2. Unclear understanding of users

Only three studies specifically surrounded the residents of social housing. In one study Abi-Ghanem and Haggett (2013) creates a typology of the different forms of users discovered regarding solar photovoltaic (PV) installation and social housing:

1. *The interested user*- residents who are actively engaged through (positive outcomes- appropriate usage)
2. *The non-user* - residents who are not able to access the installation, or purely visual engagement was provided (negative outcomes-invisible usage patterns to residents)
   - These were either passive (disengaged) or active non-users (objection to install).
3. *The "conscious" user*- made aware of usage patterns and demand management benefits (positive outcomes)
4. *The "opportunistic" user*- residents highly attuned to appropriate demand profile management and whose behaviour is shaped by this (positive outcomes).

Another study (Bahaj and James, 2007) also took into account user profiles, indicating three typical usage patterns:

1. Low demand electricity consumption user.
2. Peaky, high demand electricity consumption user.
3. High base load, high demand electricity consumption user.

A third study (Caird et al., 2012) discussed the demography of residents within a social housing development, suggesting that where developments have a higher proportion of elderly residents, usage behaviour should be tailored to suit this. This is also mirrored by Owen et al. (2013). Judson et al. (2015) suggests that pre-existing usage patterns, behaviours and interaction with energy technologies will shape the behaviour of residents when adopting a new renewable energy technology.

3.3.3. Financial risks

Financial risks of implementation were a common theme (Ambrose, 2014; Saunders et al., 2012; Dewick and Miozzo, 2004; Urmee et al., 2012). In one case, financial risk to the provider was avoided by implementing a pre-payment scheme for residents to access heating. This provided a barrier to residents' access to heating due to the required adjustment to payment methods, particularly elderly, disabled and incapacitated residents of the social housing estates (Ambrose, 2014). A shared financial barrier to the application of RE in a social housing context is the lack of financial capital or ongoing capacity to fund and maintain the project, especially when rates of financial return are not attractive enough to third-party financing options (Saunders et al., 2012; Andreadaki et al., 2000; Hoppe, 2012). Split incentives were also highlighted as a financial barrier to the implementation of RE to social housing, as there is a disparity in the motivations and gains between the housing provider and the user (Kempton, 2014; Tsenkova and Youssef, 2012; Urmee et al., 2012) Financial risk can also be taken on by intermediary organisations or local authorities, but this can lead to tension between conflicting desires and outcomes. Or where it is avoided can lead to a form of a "split incentive" whereby the housing provider is left with the burden and the intermediary with the benefit (usually political capital) (Hoppe, 2012).

3.3.4. The novelty factor

Organisational barriers both in the disruption during application as well as ongoing structural changes subsequent to the implementation of renewable energy were also highlighted in the literature (Andreadaki et al., 2000; Ambrose, 2014; Crilly et al., 2012; Dewick and Miozzo, 2004; Downey, 2012). Many of these organisational barriers related to the relative novelty of the application of renewable energy to social housing contexts, both regarding specifically technical integration, but also in the uncertainties due to the relative uncommonness of the application itself (Kempton, 2014). Because of a lack (or perceived lack) of viable cases to draw upon, providers are less likely to either approach the application in the first place, or have access to knowledge and support once implementation has occurred. Because of the relative novelty and in some cases complexity of the technology, allotting funding and time for maintenance of the installation, including the contracting of specialist services (which are not always available locally), also became a barrier to many providers (Crilly et al., 2012; Dewick and Miozzo, 2004; Kempton, 2014; Pretlove and Kade, 2016; Muyingo, 2015). Inappropriate management protocols and systems in place, as well as the inadequate partitioning or provision of staffing roles, could lead to the ineffectiveness of the installation (Ambrose, 2014; Hoppe et al., 2012; Muyingo, 2015). Dewick and Miozzo (2004) and Hoppe et al. (2012) specifically highlight the barrier of a lack of inter-organisational cooperation, particularly because of the novelty of the application. This is related to competing profit to non-profit motivations found between contracting agents and social housing providers. This is also mirrored by Downey (2012) who found that where ongoing maintenance or support was not within the perceived remit of contractors or outside organisations, there was a lack of enthusiasm to implement these actions. Delineating adoption profiles in a social housing context, Egmond et al. (2006) defines both an early adoption and mainstream market with regards to the probability of adoption of renewable energy technologies. Egmond et al. (2006) suggests that early adopters are more likely to implement an innovative plan without a historical context of adoption, and should thus be the target of policies that will appeal to an early adopter market (demonstration projects and feasibility studies), rather than a focus on providing subsidies.

3.3.5. Inadequate policy support

Policy barriers such as a lack of institutional support, incentives or requirements at a national scale can also hinder the application of RE to social housing contexts (Bodach and Hamhaber, 2010; Bahaj and James, 2007). Even where there is strong policy and organisational infrastructure in place, social housing providers can also be hindered by restrictive or lacking funding requirements (Downey, 2012; McManus et al., 2010), unsuitable competing policies (i.e. no requirement for energy efficient building standards (Garate and Guridi, 2013), or a cap on spending for social housing agencies) or through organisational barriers such as those listed above (Dewick and Miozzo, 2004). Many of the studies mentioned recent respective national policy developments in the application of renewables to low income housing, and this could be one reason publishing appeared to peak around 2012 possibly as a residual impact of recent concerted policy efforts and grant funding focus on the application of renewables to low income housing, particularly in the UK.

3.3.6. Technological complexities

Innovation was a common theme amongst the reviewed literature (Swan, 2013; Viétor et al., 2015). Application of socio-technical theories, including theories of planned behaviour and multi-level regime perspectives relating to the relationships between users and the renewable energy interface were common (Ambrose, 2014; Abi-Ghanem and Haggett, 2013; Downey, 2012; Scott et al., 2014; Swan, 2013; Viétor et al., 2015). Ambrose (2014) combines socio-technical theory with transition theory in order to understand the interaction between an innovative biomass heating system and the rigid social system of social housing provision and the interplay between tenant and provider. Disruption to organisational regimes due to the novelty of the innovation, both the technology and its usage, proved to be a hindrance to innovation. This disruption also involved the carving of new roles which the required strong adaptive capacity of the SH organisation.

Innovation could be a barrier to implementation as it is usually at a higher cost, (Dewick and Miozzo, 2004; Hoppe, 2012). One study (Judson et al., 2015) suggests that a single user may perceive a technological innovation as either positive or negative depending on how it is presented, and to what extent it disrupts existing practices.

A study (Hoppe, 2012) found that in many social housing developments, innovative measures were put aside in favour of conventional ones due to the perceived financial risk involved. Similarly, Owen et al. (2013), exploring innovation diffusion theory to better understand the influencing factors regarding uptake of RE adoptions, specifically air-source heat pumps, found that complexity of technology was a significant barrier to the adoption of innovative technologies. They also found that the demand profile typical of residents in social housing, particularly elderly fuel-poor residents (generally sentient, high heat users), is not yet catered for in current technology innovation design as well as the required maintenance schedules.

4. Discussion and conclusions

Through this systematic review it was found that much of the previous work surrounding the application of renewable energy and social housing remained within the domain of case-specific studies that provided recommendations based on technocratic or engineering-based methodologies. By extracting data from the 67 articles within this review, it was found that many of the important motivational, success and hindering factors related to the unique relationship between tenant and housing that social housing arrangements produce. This previous focus in the literature on technological case-based articles rather than those that incorporate broader socio-technical applications, is most likely due to the relative novelty of the field, corresponding to an only recent shift in the availability and range of renewable energy technologies available and scalable to social housing contexts. More recent articles have increasingly highlighted the importance of the aspects of tenant acceptance and education, and this is reflective of an overall trend in energy studies to incorporate broader socio-technical perspectives (Sovacool, 2014).

While literature reviews within the field of energy studies are common, the use of a systematic review protocol in extracting and compiling information is quite rare, particularly when also including narrative review component. It is possible that this lack of attention paid to systematic reviews is also reflective of the historically case-based technological (and often quantitative) emphasis of energy studies, and it is suggested that as the field does move to increasingly incorporate broader socio-technical perspectives, systematic reviews may become more pertinent and useful. It is suggested that the systematic review methodology provides a structured protocol within which to approach a comprehensive literature review on a given topic, however it is still susceptible to human errors in judgement, particularly around inclusion criteria, and for this reason the peer-review process is integral.

The application of renewable energy to social housing creates opportunities for potentially streamlined and widespread strategic renewable energy interventions, but this also poses unique barriers and complications as it is generally not driven specifically from the bottom-up. The literature was overwhelmingly dominated by the importance of understanding residents, engaging them appropriately and maintaining that engagement.

This review set out to determine what are the common 1. Success Factors, 2. Barriers and 3. Motivations, evident in previous research surrounding the application of renewable energy technologies in social housing contexts? With regards to success factors (1), it was found that perceived benefits by tenants are important, both in the adoption and acceptance of the technology, but also in the ongoing maintenance and efficient operation of the technology. However, in many cases a major barrier (2) to implementation was the over-complication of information provided to tenants. With regards to motivational factors (3), despite environmental considerations playing a strong role in providing incentives for the application of RE, unsurprisingly, due to the low income nature of social housing developments, a large motivational factor for the implementation remained the perceived financial incentives and security that such decentralised generation can yield. In practice however, evidence of the financial viability of renewable energy applications varied widely due to factors ranging from geographic location (and respective policy platforms and incentives in place), culture of energy use and capacity for adaptation.

5. Recommendations for practice

The following recommendations for social housing providers or intermediaries interested in the practical application of RE to SH, have been taken from this review:

1. **Visible energy-use monitoring.**
   Design and accessible location of energy monitoring equipment can enhance energy awareness and proper use.
2. **Engagement should be ongoing.**
   Where engagement only occurs at the commencement of the project there is enhanced risk of disengagement (i.e. the use of field trips to engage).
3. **When presenting modelling to the provider, be sure to provide information to residents.**
   Major restrictions to the success of many social housing RE applications were related to trust stemming from perceived risk of a new technology application. Highlight that although this is an innovative project by integrating the community, the application has been performed successfully in other contexts.
4. **Avoid “invisible energy”: promote appropriate engagement not advisement.**
   Cases where social housing residents were not engaged in the

implementation process confounded theability for the project to effect real change in energy use behaviours due to lack of perceived benefit. Providing overly complicated information to residents also can reduce the effectiveness of the installation, creating passive rather than active users of the technology. Users can become disengaged when system operation is not explained properly, or when efficient usage patterns and times are not highlighted, even with passive technologies such as solar. We suggest the provision of a number of different information forms including;

- A community information event,
- The provision of an information leaflet at the commencement of the installation outlining key information about living with solar and what to expect
- An additional leaflet once the system is installed that highlights technical aspects, particularly around how the RE technology works in more depth, optimal usage patterns and potential troubleshoots (if appropriately timed these could also reduce time and funding costs from additional information sessions)

5. **Pay particular attention to the demography and potential skill level of social housing residents.**
   Demography and pre-existing skill sets play a large role in whether the RE system is operated effectively. Social housing developments where there is a higher level of elderly or incapacitated residents should be considered. This is also important, as residents will naturally gravitate towards “familiar” patterns of use surrounding technology. Understanding behaviours beyond just timing and extent of usage patterns (when and how much), to more subtle behavioural motivations can also influence the success of the system. Understanding the demography of residents can also aid in designing appropriate resources and information, particularly around font sizing and wording.
6. **Where possible, engage local and well known contracting early.**
   Applications where there were high levels of trust and long-term relation with contracting and social housing providers were more likely to be successful. Early involvement in the development can also lead to better technical application outcomes, but also in community and trust building.
7. **If possible, appoint a tenant representative or committee to liaise with your organisation.**
   Cases where a tenant representative was appointed to liaise with the housing provider or intermediary organisations led to a better acceptance of the technology, as well as the diffusion of learning through peer communication.
8. **Ensure residents are aware costs will be divided equally where possible.**
   Instances where residents perceived a disparity between personal costs and those of other residents led to distrust of the intervening body.
9. **Ensure the benefits of the project are communicated to the residents.**
   Cases where benefits of RE installation were not correctly conveyed to residents led to frustration and disengagement with the technology or incorrect usage.
10. **Avoid "overselling" the benefits.**
    Whilst communicating the benefits (cost, environmental, ease of use) is important, cases where benefits have been "oversold" to residents by housing associations lead to distrust and ultimately inefficient use of the renewable energy technology.
11. **Avoid "coerced consumption".**
    While social housing applications comprise an attractive solution to influencing energy behaviours broader than individual domestic levels, this level of control can also lead to “coerced consumption”. This occurs when residents are not adequately informed or consulted prior to a development.

6. Recommendations for further research

The key recommendation from this review is that while the literature is dominated by the acknowledgement of the importance of appropriate engagement techniques, with specific exception of work by Moore et al. (2015) there is little work around exploring these potential approaches in actual detail. This is of strong relevance to both practitioners and researchers interested in exploring the capacity for renewable energy applications for social housing in practice.

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