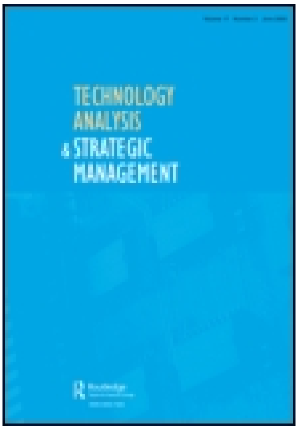

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The challenge of energy retrofitting the residential housing stock: grassroots innovations and socio-technical system change in Worcester, MA

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This paper addresses an intractable problem: how to energy-upgrade the existing residential housing stock on a large scale, potentially saving up to 30% of all greenhouse gas emissions? The paper focuses on the USA, with a case study in Worcester, Massachusetts. To address this problem we conceptualise the residential housing stock as a socio-technical system, with as main elements technology, professional knowledge and know-how, formal institutions, markets and the key actors within each. The analysis demonstrates the interconnectedness of the elements and sub-elements of the system, the need to affect change in all of them, identifies homeowners (consumers) and local authorities as the most difficult to change, and suggests that both technological and social innovation – including grassroots activism and multistakeholder collaboration – is needed. We conceptualise housing retrofitting projects as small-scale niche experiments and as grassroots innovations. In this paper we describe an experiment in Worcester, Massachusetts, in which the vision of the project – as community development – was produced by a coalition (WoHEC) of many local actors. This project illustrates both the potentials of our proposed framework in terms of grassroots innovations and socio-technical experiments and its limitations: learning among stakeholders is often slow and ineffective. More research is needed to refine the conceptual framework and to make it applicable to both grassroots innovations and municipal projects.

Keywords: construction industry; green energy; green innovation; environment; case study; socio-technical systems

1. Introduction

A critical arena for the transformation to a low-carbon economy is in buildings, which account for more than 70% of electricity use (US Department of Energy (USDOE) 2007) and almost 40% of greenhouse gas emissions in the USA (Energy Information Administration 2006). Buildings are more than just physical artifacts; they are part of a socio-technical system, by which we mean

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a stable configuration of dominant technological artifacts and the knowledge how to use them, embedded in institutions, professional practices, cultural meanings and physical infrastructure. A large shift in that system is necessary for the sustainability transition, but it is also very difficult because, in addition to technological innovation, it requires changes in existing institutions, infrastructures, established behaviours of multiple communities of practice, the knowledge networks, belief systems and lifestyles.

Today, every municipal energy action plan (and there are thousands of those) recognises that reducing energy consumption by the existing housing stock is very important. Just as clear has become the recognition that a transition in that system is more difficult than with new construction. For one thing, the relatively high costs of the upgrades rests squarely on the shoulders of homeowners and landlords whose financial resources are often much more constrained than those of new housing developers. Second, it requires mobilising the homeowners to give energy performance a high priority, which so far has proven to be very difficult. Third, landlords and tenants have inconsistent interests. Additionally, the empirical experience accrued in many local energy-retrofitting programmes has so far not translated into a collective learning of how to achieve success in that area.

Two central arguments of this paper are that small-scale experimentation is necessary for affecting a transition in the socio-technical system of residential housing stock; and that in order to increase the effectiveness of such experiments one needs to understand the system and its key actors. The paper describes an ongoing small-scale experiment in which we have participated since 2009 in Worcester, Massachusetts: the Worcester Housing, Energy and Community (WoHEC) group. The salient features of this experiment are its framing as community development, its design through a multi-stakeholder process focused on higher order learning, and its deep connection to the rich network of grassroots organisations in the city. The theoretical framework for this experiment derives from the theory of higher order learning through experimentation and from the concept of grassroots innovation. We describe the evolution of this multi-stakeholder learning group in the context of the civil action in the city, and we describe the difficulties in achieving learning and change in the face of strong institutionalised traditional framings and experiences in housing retrofit projects.

The paper proceeds as follows: Sections 2 and 3 present, respectively, the conceptual framework and the elements of the housing stock socio-technical system; Section 4 describes the Worcester case where grassroots innovations, multi-stakeholder experimentation and innovative policies are aiming to get large-scale retrofitting of residential building under way. The final section offers conclusions and suggestions for further research and empirical work in this area.

2. Learning through small-scale experiments and grassroots innovations

Experimentation in niches is widely recognised in the literature on transition management, with the argument that changes in a socio-technical system (regime) are facilitated by both the top–down pressures from the landscape and by opportunities created by bottom–up experimentation on alternative technologies and social arrangements (Rotmans, Kemp, and van Asselt 2002; Geels 2005; Geels and Schot 2007). The concept of strategic niche management has figured prominently in the discussions of socio-technical transitions during the early 2000s (Hoogma et al. 2002; Raven 2005). Related conceptual frameworks around small-scale experimentation stress the social dimensions of change. Social niche management (Verheul and Vergragt 1995; Hegger, van Vliet, and van Vliet 2007) stands in contrast to the more technology-oriented strategic niche management by denoting a social experiment initiated by citizens' groups and/or non-governmental organisations (NGOs) operating outside the institutional structures of firms and governments. Hegger, van Vliet, and van Vliet (2007) also suggest, based on the work on innovation on sanitation, that the 'niche' concept should become more 'social' in order to better contribute to sustainable transformation of socio-technical systems.

Related to the above, we previously developed (Brown et al. 2003; Brown and Vergragt 2008) the concept of bounded socio-technical experiment (BSTE). A BSTE has been defined as a

> . . . collective endeavor, carried out by a coalition of diverse actors, including business, government, technical experts, educational and research institutions, NGOs and others. Cognitively, at least some of the participants explicitly recognise the effort to be an *experiment*, in which learning by doing, trying out new strategies and new technological solutions, and continuous course correction, are standard features. The experiment is driven by a long term and large-scale vision of advancing the society's sustainability agenda, though the vision needs not to be equally shared by its participants. Its goal is to try out innovative approaches for solving larger societal problems of unsustainable technologies and services. (Brown and Vergragt 2008).

Our empirical work in the area of transportation (Brown et al. 2003; Vergragt and Brown 2007) and high performance buildings (Brown and Vergragt 2008) has shown that BSTEs facilitate higher order learning, by which we mean changes in problem definitions or interpretive frames among the participants. In practice, such learning often manifests itself in a collective re-framing of the problem or project. The conceptual support for these empirical observations derives from several bodies of literature – from cognitive psychology (Schön 1983), to sociology and policy sciences (Sabatier 1999; Keohane and Nye 1989; Wildawski 1990; Fischer 1995; Schön and Rein 1994), to organisational sciences (Argyris and Schön 1978; Senge 1990; Sitkin 1992; Wenger 1998, 2000) to studies of technological innovations (Schot and Rip 1996; Bijker, Hughes, and Pinch 1987) – which can be distilled down to this: learning takes place when actors representing a range of interpretive frames, problem definitions and core competences engage in intense interactions around a technological innovation, an issue, a problem or an idea. The issue of higher order learning is central to socio-technical system transitions. This is because the inherent stability of such systems is partly grounded in the resistance to change among the dominant communities of practice and institutions that, along with other elements, collectively comprise the system. Part of the systemic change must involve changes in the interpretive frames and problem definitions shared within communities of practice and other actor groups as well as in re-framing the shared problem (for a review, see Brown and Vergragt 2008).

Along similar lines, Seyfang and Smith have studied 'grassroots innovations' existing in the 'social economy' of community activities and social enterprise, in contrast to the market economy (Seyfang 2009, 72–73; Seyfang and Smith 2007; Smith 2007). These authors emphasise the intrinsic benefits of grassroots innovations, such as reduced environmental impacts, job creation, training and skills development, improved access to services and facilities, and health improvements, as well as those related to growth in social capital and learning, such as personal growth, enhanced sense of community, greater civic engagement and changes in the daily social practices. A more recent (and still ongoing) research by the above authors focuses on a specific type of grassroots innovation – community based energy projects in the UK – which include alternative 'green' lifestyles, neighbourhood insulations campaigns, local renewable energy generation and others (Hielscher, Seyfang, and Smith 2012). The overarching objective of this research is to understand the potential of such multiple projects to collectively contribute to a transition toward more sustainable energy systems. Although the authors do not use the term 'socio-technical experiment', their description of the projects shows strong similarities with the BSTE concept. A close reading of the benefits identified by the authors in these projects also reveals their strong potential to induce higher order learning among the participants. A systematic study of such learning process would be an important contribution to our understanding of how the learning processes in small-scale initiatives can contribute to larger socio-technical systemic changes.

Both the BSTE approach and the approach of grassroots innovations constitute a new model of innovation, contributing to the socio-technical transitions framework and similar to what Rip, Joly and Callon (2010) refer to as the 'regime of collective experimentation'.

3. The socio-technical system of residential housing

3.1. *The US context*

In the US context, the socio-technical housing system has a specific meaning. The system is very much left to the free market. The initiative to build comes almost exclusively from private developers acting in their own economic interests; municipalities act as regulators and gatekeepers, through zoning laws and various requirements. Another characteristic of the US system is that the activities at the level of municipalities, states and the federal government are very distinct and must be all accounted for. Thus, municipalities have a strong role in zoning decisions and permits for developers, while states influence building codes, impose policies regarding energy efficiency and provide financial incentives for energy-related initiatives. The federal government acts from a greater distance: its role is to provide leadership, to support research and demonstration into new technologies, to offer financial incentives for energy-related projects through the tax code and to provide more general 'block grants' for cities and towns. The 2009 Federal American Recovery and Reinvestment Act (ARRA) stimulus package, which offers direct funding for green projects, including energy retrofits of buildings (referred to as 'weatherisation'), is a relatively unusual role for the federal government, especially on this scale. In addition, informal regulations, such as Energy Star label (a federal programme through the Environmental Protection Agency) and LEED standards (Leadership in Energy and Environmental Design, a private initiative by the US Green Building Council (http://www.usgbc.org/)) play a significant role when adopted by municipalities and states, as has been the case during the past decade.

3.2. *Elements of the system*

There are many ways to describe the existing residential housing socio-technical system. For the purpose of this paper we found it useful to distinguish four elements: technology; professional knowledge and know-how; mandatory and voluntary standards and institutions; and markets and consumers. Within each element one can distinguish various sub-elements, such as supply chain or R&D (within technology). Each element also comprises numerous actors, such as moneylenders or real estate agents (within markets), or utilities (within technology or markets). This is described below.

Technology

During the past decade there has been an explosion of trade shows, conferences and fairs featuring new technologies for retrofitting of buildings for energy performance and for measuring that performance. What is striking about these innovations is that, while there have been gradual improvements in their performance over the years, the underlying scientific principles as well as technical and designs concepts have not changed significantly for a decade or two. These technologies have been available and 'shelf-ready' for some time. It is their use that has been lagging behind. In the language of innovation studies we are at the 'technology-push', not the 'market-pull' stage.

In contrast significant progress has been made with regard to microgeneration of heat and electricity by way of wind, passive and active solar and increasingly by way of geothermal technologies. For these technologies, costs have declined while performance efficiency has increased. There are signs of a growing market demand for these technologies. Photovoltaic (PV) panels are becoming an increasingly frequent feature on single and multiple-unit residences in Massachusetts, and the recent pilot programmes with smart metering and feed-in tariffs will increase the attractiveness of electricity microgeneration.

Professional knowledge and know-how

Analysis of millions of energy upgrade projects for existing buildings around the country shows that performance improvements are generally modest, ranging from 9 to 27%, with a national average of 11% (Blasnik 2009), and that misconceptions about what works and what does not in such projects abound (for example, window and door replacements or heating system tune-ups do not work). These data are in contrast with the performance potential and specifications of the available technologies (e.g. insulation materials) and with the best practice cases (of about 50% improvement), and suggest that people who work on retrofitting homes and who usually claim expertise to their clients, urgently need to upgrade their knowledge and skills. There is also a need to create a cadre of trained inspectors and performance evaluators of homes. The current shortage of knowledge and lack of standardised methods of conferring and certifying knowledge was one of the major themes at the conference of North East Sustainable Energy Association in Boston in March 2011 (http://www.nesea.org).

Affecting change in that area is a formidable task. For one thing, the home improvement economic sector represents varied areas of specialisation, including architects, carpenters, plumbers, electricians, heating and cooling specialists, and many others, including various generalists with claims to all kinds of knowledge. Furthermore, this sector overwhelmingly comprises small fiercely independent businesses, often single person operations. Additionally, the traditional method of acquiring professional skills often consists of apprenticeships and informal knowledge networks, including marketers of products.

Creating a shared understanding of the appropriate body of knowledge and a well-trained workforce is especially important now, given the hopes we are placing on green jobs as a way out of the economic recession and as a way of enlarging those employment sectors that do not outsource jobs abroad. For example, one analysis (Polin et al. 2008) estimates that home improvements can create twice as many jobs as oil production and processing while salaries are comparable. The New England Green Economy Council predicts many new jobs in the building sector, such as design and engineering, building and construction, technical support and training, and social marketing to consumers (Doyle 2009).

Partly in response to the perceived needs and opportunities, state and federally funded 'weatherisation' programmes are increasingly focusing on certifying knowledgeable contractors and on providing home owners with the lists of such (Lawrence Berkeley National Laboratory (LBNL) 2010, 55–59). Training courses and certificate programmes have also been proliferating in Massachusetts and elsewhere. Some of these are individually designed private sector initiatives while others are run by state-funded community colleges (e.g. Worcester-based Quinsigamond College) or state agencies, such as New York State Energy Research and Development Agency (NYSERDA). We see a great opportunity to develop standardised curricula and apprenticeships, and formal certificates, toward creating a knowledge network around the technologies for energy retrofits of homes.

Mandatory and voluntary regulations and standards

State governments have been quite involved in creating policies to facilitate building retrofits. These policies fall into two categories: strategic subsidies, generally mediated by utility companies (such as the MassSave Program in Massachusetts); and standards. The 2010 announcement by the National Governors Association of the creation of the Policy Academy on State Buildings Efficiency Retrofit Programs (hosted by the Massachusetts Institute of Technology) is an indicator of the national visibility of the issue.

Standards can play a huge role in facilitating change in technology and professional practices. A powerful example of the impacts of performance standards is the federal regulation of car emissions in the 1970s. Adopted at the time when technology for meeting them was not yet available, these technology-forcing standards led to several technological innovations for pollution control. Ambitious building performance standards could likewise open the doors for deployment and further development of new technologies.

Technology-based standards play a complementary role to performance standards by institutionalising new and desirable technologies and professional practices. A building code is a case in point: it is a tool for training and acculturating the newcomers into the field, and it builds a basis for trust between technology providers (building professionals) and its users (building owners and residents). Both performance and technology-based standards provide the basis for rewarding desirable behaviours and sanctioning the deviant behaviours and it streamlines the relationship between professional practitioners and the enforcement authorities. Depending on their use, performance standards additionally can create a language for a dialogue between homeowners and building professionals who perform upgrades, between homebuyers and sellers, and others.

Governments and professional associations and networks recognise that potential, and during the past decade made efforts to introduce voluntary or mandatory use of both kinds of standards, and in various ways. LEED and building codes are the best known voluntary and mandated, respectively, examples of technology-based standards for new construction, and several states in the USA have raised the baseline of the building code for certain kinds of building renovations (see also Guy and Moore 2005). In 2010 Massachusetts adopted a more demanding ‘stretch’ building code for both new construction and major renovation projects in existing buildings (residential and commercial). Among different performance standards, HERS (Home Energy Rating System) is the best known in the USA and its use is one of the requirements of the Massachusetts stretch code. Another well-known standard is the Energy Performance Score in Oregon. The requirement for disclosing energy performance index of homes during real estate transactions is hotly debated across the USA and has been adopted in some places (for example, Oregon requires the use of Energy Performance Scores).

Standards alone cannot do the job of pushing the housing stock toward a transformation. Performance standards are bounded by the implementation reality: they must be sensitive to the cost and feasibility of performing the measurement and implementing the upgrades necessary to meet it. Here, the issues of the professional knowledge and know-how, and of mobilising consumers (discussed in the next section) become central. Furthermore, technology-based standards are a double-edged sword: by institutionalising certain practices they become, sooner or later, a barrier to more radical changes. Finally, all formal standards, by being a product of widely based consultation – either through professional networks or the political process of rule-making – are rarely reaching out for radical change. For that reason, other approaches to mobilising the markets for retrofitting homes need to play a central role in the socio-technical system change.

Markets and consumers; the need for market pull

The bottom line is that owners of the buildings – the consumers of the technology – must want the change. This market pull is needed just as much as technology-push to affect major technological change in the existing housing stock. Recent experience with new construction shows small but significant signs of this emerging market. For example, in Townsend, Massachusetts, zero energy new one-family homes are selling much better than the conventional homes of comparable design, size, price and location (Magnant 2009). Currently, several zero energy multi-unit large residential buildings are under construction in Massachusetts. An the interview with one family who purchased such a zero energy suburban home indicates that the advanced energy features of the house were not the attractant but rather a source of caution and mistrust in their purchasing deliberations; the family became energy enthusiasts only *after* they have lived there for a while (earlier, we exemplified this change in their interpretive frame as higher order learning).

While it is becoming increasingly clear that developers may be the most important agents in creating a market for high-performance homes (Magnant 2009), our understanding of what motivates consumers to purchase (or not) high-performance homes is very limited. Certainly, the real estate agents can potentially play a very important role in creating that market, as they have a deep understanding of what motivates buyers, but real estate agents see themselves as satisfiers of buyers' wishes, not as creators of them and are therefore more likely to follow an emerging market than to create it. So this is a chicken and egg problem. The recent government initiatives to give mortgage lenders incentives to create 'green mortgages' are promising, but are still in their infancy (Harney 2009).

While the above discussion suggests that the market for new high performance homes may be slowly emerging, upgrading existing homes presents a very different set of challenges, with the role of consumers being central and we know even less about homeowners' attitudes and behavioural triggers. Without that knowledge, it is difficult to develop successful programmes and to know how to frame the issues in order to mobilise homeowners.

A major assumption is used by activists and policy makers: that homeowners who consider or implement energy retrofits are not primarily driven by environmental concerns, but rather by prospects of saving money; and thus that financing is the major barrier to upgrading the existing housing stock. Treating homeowners as rational economic actors, the two leading programmes – in Cambridge, Massachusetts and in Berkeley, California – framed the issue as breaking the financial barrier, then developed creative programmes to finance energy retrofits. In the Cambridge case, the effort is part of an ambitious, two-year old privately funded programme, the Cambridge Energy Alliance. Its goal has been to reach out to 50% of households and small businesses by providing home energy audits, financing and implementable plans for certain energy retrofits. The funding would come from local banks which would over time recoup their investments by collecting the cost savings from reduced energy consumption (Cambridge Energy Alliance (CEA) http://cambridgeenergyalliance.org/). In the Berkeley approach, known as PACE (Property Assessed Clean Energy), financing came from the municipality (by issuing municipal bonds), the loan would not be attached to a lender but to the property and would be repaid though surcharge on property tax (Fuller, Portis and Kammen 2009). The PACE financing scheme has attracted a lot of attention nationwide. The enabling legislation was adopted by almost half of the states before the 2010 decision by the largest mortgage lenders in the USA, Freddy Mac and Fannie May, put the PACE initiatives on hold by refusing to give PACE a 'superior lien' status (Van Nostrand 2011). Another, more recent, financing idea is the so-called 'on-bill recovery'. This option is similar to PACE in that the repayment obligation is not tied to the borrower but rather to the building, but in this case the lender is a utility company and the repayment takes the form of a surcharge on utility bills (Van Nostrand 2011). Like PACE, this approach also requires state-level enabling legislation.

The implementation experience in these two progressive pioneering cities, as well as others (Brown and Vergragt 2012), has been disappointing: despite the strong outreach, easy access to energy audits and the availability of financing, home owners have been slow to implement the energy- and money-saving upgrades. This outcome is consistent with the national statistics: among the 10,000 motivated homeowners who took the initiative to have free energy audits performed in their homes, only about 25% followed up with implementation, even when the majority of the costs would be covered by various tax breaks and other subsidies (Doyle 2009). Clearly, breaking the financial barrier is a necessary but insufficient condition for progress in this area.

Indeed, the experience from the above as well as from the approximately 30 other programmes we reviewed points to two other key barriers. One is the availability of a skilled workforce to successfully upgrade the housing stock and the difficulty for the consumer to identify experts they can trust. Trust is an essential element here, as the quality of the work (especially inside walls) cannot be judged by non-experts and because its effectiveness in the form of energy savings requires prolonged follow-up times. Also, there is little accountability for shoddy job that does not yield energy savings. Here, institutionalisation of such elements as an agreed-upon body of knowledge, professional licensing expertise and creating appropriate standards of performance, would be immensely helpful.

Another major barrier to homeowner mobilisation is the opportunity costs in terms of limited attention and personal time and the overall burdensomeness: energy is not a high priority for most people and a home energy retrofit is a time consuming, messy, disrupting project, with uncertain outcomes. Figuring out how to overcome these barriers will require both practical experimentation and critical analysis. The homeowners need to be viewed not only as individually acting rational utility maximises but also as community members acting in a social and cultural context. This view is beginning to take hold among the research community, as summarised in Section 4.

3.3. *Challenges to systemic change*

Identifying the dimensions of the socio-technical system of the housing stock reveals the interdependencies between its elements and the drags in the system. It shows how enhancing market pull does not work in the absence of professional knowledge and know-how; and how standards do not work in the absence of a market pull. It is clear that change in one element, or one component of an element, is not sufficient to affect the system.

It also shows an important difference between the socio-technical system of existing housing stock and more 'typical' socio-technical systems described in the transition literature (including the new construction). For one thing, the change in this system is not about diffusion of a new technology and the emergence of new institutions, social practices and infrastructure around it. Rather, it is about making harmonised changes within all the system elements.

Homeowners are clearly a very difficult yet essential actor to mobilise. We argue that they need to be viewed from multiple perspectives: as both rational utility maximisers and as community members acting in a social and cultural context. Therefore, championing of change needs to come from several actors representing different elements and sub-elements of the socio-technical system, working collaboratively. Some actors, such as policy makers, homeowners, relevant professions and trades, and financial institutions are apparent. Others, such as grassroots activist organisations, are less obvious.

Most programmes we reviewed (Brown and Vergragt 2012) have been organised and implemented either by the municipality or by a major non-profit organisation (such as a large environmental organisation). While local in scope, these are mostly top–down initiatives that view building owners as passive 'targets': of social marketing campaigns, educational programmes and sales pitches from the programme champions, but there is no guarantee that overcoming the well-recognised barriers with the above approaches will suffice to mobilise homeowners. It is quite possible that champions of community-wide retrofitting of homes need to dig deeper into the *cultural meanings* of energy upgrading of homes and to re-frame the problem accordingly. For example, framing it alternatively as an issue of high quality of life, or thriftiness, or improving the house's market value, or product quality, or social trend setting, or as increased community cohesion by joining others who have taken the initiative, may be more effective. Most likely, different frames will speak to different people. In fact, multiple frames may work for the same people. Drawing on the work of Schön and Rein (1994) and Nisbet (2009) on the role of framing, we hypothesise that the Cambridge and Berkeley framings have not been adequately aligned with the core values of the homeowners or that multiple framings need to be used in these programmes.

The issues of framing and deploying bottom–up approaches deserve special attention if we consider that systemic change in the energy performance of the housing stock requires multiple actors, from policy makers to grassroots organisations, to work collaboratively. Much experimentation on a small scale is needed to implement change in this socio-technical system; and social, rather than technological, entrepreneurs are likely to play a key role in these experiments and action-mobilising framing may vary among them. As we show in Section 4, social innovations, drawing on local grassroots activism and deploying a multi-stakeholder collaboration, are at the core of the Worcester experiment. In the next section we examine a group of municipal energy retrofit projects from the perspective of our emerging conception of the types of organising principles a potentially successful programme should have.

4. Small-scale experiment in Worcester, Massachusetts

With 175,000 inhabitants, Worcester is the second largest city in Massachusetts (after Boston), located in the central part of the state. Worcester has a vibrant community life, which could be branded as an emerging sustainable economy. An emerging vision of revitalising the Worcester economy takes a broader view of sustainability, beyond the green technology cluster, to include social development, and community participation and visioning. Like the green energy cluster, this vision also embraces multi-stakeholder collaboration, but its boundaries are wider, including grassroots and social services organisations, and it draws on the well-established community engagement of Clark University.

The area immediately surrounding Clark University, known as the 'Main South' neighbourhood, is generally poor, is known for petty crimes, depends on various social programmes and has a high proportion of immigrants. Since the 1980s Clark University has deeply and successfully invested in developing that community through educational programmes, youth development programmes, infrastructure development and other initiatives.

Several initiatives have sprouted in the Main South neighbourhood and beyond around housing retrofits and creation of green jobs, triggered by state-level and national policies and subsidies as well as the City's success in being designated by the State as a 'Green Community' under the Massachusetts Green Communities Act of 2008. Grassroots organisations are very visible initiators of many of them. These include: the Regional Environmental Council (REC), the Worcester Energy Barnraisers, the Worcester Roots project (and affiliate programmes as Toxic Soil Busters and Youth in Charge), EMPOWER Energy Coop, Stone Soup, and the Worcester Community Action Council (WCAC) (see also Stephens and McCauley (2012) for a more comprehensive description of grassroots and other institutional energy activities in Worcester).

Several of those groups have started or have been involved in various weatherisation programmes, and/or are active in mobilising citizens to engage in free energy audits. The Green Jobs Coalition – a coalition of grassroots activists, entrepreneurs, students and individuals from environmental organisations – also promotes housing retrofits, along with other social objectives, such as local ownership, community empowerment and healthy, living-wage jobs that contribute to the sustainability of the environment. Its mission statement is to organise '. . . a local movement for green collar jobs for all. We work for resources to create sustainable jobs that are in sync with our community, culture and needs'.

One of the most focused collaborative and self-organising initiatives built around the idea of upgrading the energy performance of homes is the WoHEC group. It came together through the initiative of faculty members and researchers at Marsh Institute at Clark University as a way to engage diverse local stakeholders in a community project. In this case 'community project' denotes one with multiple framings and objectives. The objectives are: to design and facilitate a large-scale energy-retrofitting of residential houses to a level that would significantly reduce energy use for heating and cooling; create a wide range of jobs; employ local at-risk unemployed youths; enhance vocational training programmes; improve the quality of life in the community; improve the market value of houses; and improve indoor air quality (including eliminating lead where necessary).

In short, in this vision housing retrofits would be a sustainable community development. The underlying premise here is that framing the project as energy conservation and climate change mitigation *alone* would not mobilise a community facing a plethora of more urgent social and economic problems. The researchers also saw it as a challenging socio-technical experiment, and possibly as a 'grassroots innovation' of the type described by Hielscher et al. (forthcoming): a community-led energy project. Whatever the conceptual heading, the project would entail higher order learning among the participants; a reframing of the meaning of community energy-related projects. For researchers, it offered an opportunity to study the learning processes and to contribute to the development of new conceptual frameworks for studying the impact of local energy projects, initiated by the civil society, municipality, business community or a combination of those.

The group convened for the first time in May 2009 at Clark University, bringing together the grassroots and social service organisations already active in the Main South area, Worcester Polytechnic Institute, Worcester State College and the City of Worcester (in the person of the new Energy Manager). Over the next two years WoHEC kept monthly meetings, supported by the efforts of Clark researchers, who served as conveners, facilitators, idea entrepreneurs and monitors of the learning processes. WoHEC defined its mission as 'a shared interest in community development built around upgrading existing housing stock; through retrofits pursue multiple agendas; drawing on bottom-up developments and new funding opportunities and policy developments'. The group kept open boundaries, which allowed new individuals and organisations to enter. The meetings largely consisted of information exchange, coordination, building bridges and leveraging the new links and knowledge to seek federal and state funding for energy and community development projects. In some cases, the information exchange led to new collaborative activities outside WoHEC. WoHEC has thus become a learning group whose members represent several (but not all) elements of the socio-technical residential housing system in Worcester, with all its complexity; but it also extends beyond that system, bringing into its deliberations sustainable community development. During discussions, participants increasingly evoked the systemic nature of the challenge of retrofitting houses and use multiple framings to discuss strategies for pursuing it. It engaged with the issue of house retrofits from a wider perspective. In short, it became a learning group.

The success of WoHEC has been limited so far. For instance, early in 2011 the City of Worcester received funding from the State of Massachusetts for a community-based energy retrofit project under the Massachusetts Green Communities Act. This created an opportunity to implement WoHEC's vision of a retrofit campaign as community development as well as a multi-stakeholder coalition-based approach to designing such a project. It also created almost immediately a tension between this and a more traditional vision for the project. From the start, the City began to lean toward the more traditional approach that has been taken by many other communities around the country: to mobilise residents by lowering two barriers: the costs and access to information about how to implement a retrofit project. It does so through modest subsidies and through direct outreach and web-based information dissemination. There has been much less interest in community-led and community development-focused initiatives or multi-stakeholder participatory process in the project design or implementation. The municipality has difficulty in re-framing the project as anything more than technical upgrades of buildings toward greater energy efficiency.

Nevertheless there is a growing interest in the 'WoHEC approach', as exemplified by WoHEC being invited in April 2011 for a hearing for the Second Climate Action Plan. WoHEC is also in the process of creating links with the local business community and utilities, as well as with NESEA and with local developers. Being a 'learning community' it still struggles to develop a coherent long-term strategy, as well as significant showcases.

5. Conclusions

The ongoing community-based energy retrofit projects around the country are built on a certain set of assumptions about the main barriers to change. These assumptions evolved through hard experiences and through disappointing progress among the pioneering projects. The initial leading assumption was about the high costs and lack of easy financing; over time, the collective wisdom has identified other barriers, such as the lack of knowledge among homeowners about the retrofit projects and potential savings from energy efficiency measures, the burdensomeness of retrofit projects, and lack of access to trustworthy and competent contractors. Among the municipal retrofit projects we have reviewed, most are structured to address some of these barriers (rarely all of them in one project).

Our analysis of the socio-technical system for the residential housing stock suggests that it may not be enough to focus on these barriers; that a collective learning process about achieving success in retrofit projects requires more experimentation with framing of these projects and with the process, and that grassroots organisation can potentially play a significant role in affecting systemic change. Worcester, with its history, and strong traditions of multi-stakeholder collaborations, including business, universities, local institutions and grassroots movements, offered an opportunity for such an experiment.

In this paper we have presented a conceptual framework which might inform ongoing and future energy-retrofitting projects in residential housing stock and grassroots innovation projects. Most important is that changes need to address all elements of the system in a concerted way; just addressing one element has led to disappointments. Grassroots innovations and small-scale experiments do not only offer the opportunities for addressing multiple elements, but also for reframing and higher-order learning, which are, in our view, necessary preconditions for successful socio-technical system change. In this sense it offers enrichment to the literature on niche development in the context of socio-technical transitions. The case study on WoHEC offers an example of how to address such a challenge in practice. More research is needed to study factors in the success and failure of similar experiments.

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