Alternative future energy pathways: assessment of the potential of innovative decentralised energy systems in the UK

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Alternative future energy pathways: Assessment of the potential of innovative decentralised energy systems in the UK

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HIGHLIGHTS

- This paper examines four international urban decentralised energy initiatives.
- Drivers and barriers are found to be highly diverse but similar to the ones in the UK.
- Governance drivers play the most significant role.
- Increased implementation of DE systems can enhance social and governance benefits.

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ABSTRACT

In order to meet its 2050 target of 80% carbon emissions reduction, the UK is facing a challenge of restructuring its energy system, possibly by introducing more decentralised energy (DE) systems.

Following semi-structured interviews, four exemplar international cases have been critiqued in order to investigate the variety and interrelationship of the drivers and barriers involved during their implementation, and then compared with the barriers and drivers that can potentially affect the implementation of similar projects in the UK context. The impacts of the barriers on the outcomes of these projects were evaluated, and recommendations were presented on overcoming these barriers if replicating similar projects in the UK context.

Governance drivers play the most significant role, whereas financial drivers (commonly believed to be crucial), are deemed to play a lesser role. Social, governance and financial barriers rather than technological barriers constitute the central problem areas for the increased adoption of DE. The drivers and barriers experienced in the international cases were similar to those anticipated in the UK. The case studies present a high potential for replication and scaling up in the UK context and demonstrate that the increased implementation of DE systems could also enhance social and governance benefits.

1. Introduction

The UK Climate Change Act sets a legally binding target of reducing the UK greenhouse gas (GHG) emissions by 80% compared to 1990 level by 2050 (DECC, 2008). One of the possible ways to reach this target is by making a shift towards more sustainable forms of energy – thus the significant challenge of restructuring the energy system has to be addressed (GOS, 2008; Rydin et al., 2012). Currently, the UK energy system is characterised by a lock-in to centralisation (e.g. Walker et al., 2007; Bergman and Eyre, 2011; Unruh, 2000). There is, however, a potential to challenge this lock-in through the development of more decentralised energy systems based not only on technological but also on more innovative political, social and economic approaches. The main drivers for this transition are not only the necessity to reduce GHG emissions, but also to increase the share of renewables in the energy mix and to make the use of energy more efficient. Rising electricity demand and the price of fuel, liberalisation of the markets and increasing concern over energy security also play important roles in encouraging decentralisation of energy systems (ITRE, 2010).

Indeed, a number of towns, cities and communities in the UK and worldwide have already pioneered unique and effective approaches to more DE systems leading to enhanced GHG reductions. The implementation of these approaches, however, is a long and complicated process that requires not only financial investment but also support from authorities, community engagement and other interconnected factors, that, if underestimated, can negatively affect the outcome of the project (Goodier and Chmutina, 2013; Devine-Wright and Wiersma, 2013).

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The definition of DE often shifts depending on the context (e.g. BERR, 2008; Ofgem, 2008; Allen et al., 2008). DE systems frequently claim to be more resilient, reliable, efficient and environmental friendly, as well as more affordable and accessible whilst offering greater levels of energy security (Coaffe, 2008; Turcu et al., 2011).

An emphasis on the potential benefits of a more localised and distributed pattern of energy generation, and on the involvement of the community emerged in the UK in the late 1990s (Walker et al., 2007), and a variety of policies that may give an increased drive towards DE have been introduced in recent years, ranging from financial tools such as the Low Carbon Building Programme to local innovative planning policies and subsidies for the installation of new technologies, such as the Green Deal.

DE generation and supply is yet to play a significant role in the UK energy system (Bergman and Eyre, 2011), and its development in the UK is much slower when compared to similar economies such as Germany, Sweden and others. As this paper demonstrates, there is a mixture of financial, technical, social and governance barriers that often slow down the installation and application of these systems and the potential maximisation of energy savings and emissions reduction.

Despite significant interest, there is a lack of comparative insight into the barriers and drivers regarding novel DE initiatives, with focus often on existing literature rather than actual case studies (Michalena and Hills, 2012).

The main emphasis of the existing literature is often on the effectiveness of policy measures, technical performance (e.g. Walker et al., 2007; Allen et al., 2008), or the challenge of energy technology implementation, and frequently focuses on the financial and technical aspects on a national level. However, the complex socio-political context in which new technologies are to be employed is often overlooked.

We address this paucity via the discussion and comparison of four international innovative case studies, including examining contexts, stakeholder perception, and levels of social awareness regarding the risks and benefits of proposed technologies. The overall aim is to analyse the potential of these projects for implementation in the UK context, with *potential* defined as "latent qualities or abilities that may be developed and lead to future success or usefulness" (Oxford Dictionary Online, 2013). Verbruggen et al. (2010) argue that neglecting the potential is an equivalent of "lost opportunities".

In order to be able to analyse this potential and to address the main research question, we need

- to discuss drivers that may encourage DE project implementation: literature currently mainly focuses on barriers at the deficit of (equally important) drivers,
- to analyse the full range of barriers that may affect the outcome of the project, in contrast to the majority of literature that focuses mainly on the technical and financial aspects, and
- to suggest recommendations for addressing the barriers based on workshop discussions with UK practitioners, local government, and contemporary literature.

2. Methodology

2.1. Case study development

A case study approach was applied, as it is the most appropriate research method when questions *whether* and *how* are asked (Yin, 1994); it focuses on understanding the dynamics present within single settings (Eisenhardt, 1989).While they cannot offer generalisation, conclusions taken from case studies can be applied to the development of new theories and concepts, and the revision of existing ones.

The case studies presented here represent only a small proportion of all the urban DE projects currently employed. Four case studies were chosen from an initial list of 35, presenting a range of energy resources, technologies, end applications and types of project intervention; the main criteria being

- applicability and uniqueness of the project: i.e. the project/approach has not yet been applied in the UK or has only been applied on a very small scale, but could potentially be applied on a larger scale;
- usefulness for investigating various dimensions of the project: i.e. the way that governance stakeholders interact, consumer engagement with technology and how these influence implementation and outcomes;
- a range of different scales; and
- financial affordability for investigation and case study development.

An extensive web and literature research was initially conducted to identify any secondary data. Site visits were then conducted where possible, as this helps to obtain valuable insight (Lofland and Lofland, 1995) when discussing the projects and to understand the environment and the context in which the project is taking place. Finally, semi-structured interviews with the main stakeholders were conducted in person, as the stakeholders' perspective on the process of the project implementation provides valuable information on experienced drivers and barriers and the ways in which they are dealt with, as well as on their impact on the outcome of the project.

Three or four semi-structured interviews with a range of key project stakeholders were conducted for each case study (with 15 interviews in total), covering five main aspects: governance, finance, technology, social aspects and the level of potential replicability. The aim of the interviews was to gain first-hand information regarding the decision-making process and the implementation of the project, as well as the role of the stakeholder in the project and how it evolved over time; however no particular emphasis was placed onto the discussion of drivers and barriers The results presented in this paper emerged from the collected data rather than from opinion hypothesised beforehand.

The interviews were recorded, transcribed and thematically analysed using Nvivo 8.[1] Thematic analysis was chosen due to the complexity of the dataset and the need for a flexible analytical process to provide a structure (Howitt and Cramer, 2011). A coding framework was applied including 23 top-level and 47 subcodes, based upon the collected data and research questions, checked for reliability via the independent coding of two interviews by two different researchers, in order to clarify and refine the code definitions.

2.2. Industry workshops

After the case study data was analysed, four workshops were held in order to test the potential of the projects in the UK context. The aim was to facilitate a debate amongst practitioners, policymakers, consultants and academics regarding the potential for the case study implementation in the UK.

The number of participants ranged from 7 to 15. A series of short presentations began with the case study instigating

[1] For more information about Nvivo software and its benefits for analysing complex qualitative data, see: http://www.qsrinternational.com/products_nvivo.aspx.

stakeholder introducing the project and the drivers and barriers experienced during the project implementation, followed by short presentations by similar planned projects in the UK and a facilitated round table discussion around the potential drivers and barriers for similar projects within the UK, taking into account similarities and differences of the UK and international contexts, as well as the potential of the projects in 2050.

Following each workshop, a brief summary report was distributed to all the participants with the main findings from the discussion, with the aim of refining participants' comments and to check whether any important information has been missed or misinterpreted. All the presentations and discussions were video- and audio-recorded, transcribed, and analysed similarly to the interviews.

3. Results and discussion

To aid analysis, the barriers and drivers were classified into four pre-determined aspects: governance, social, financial and technical. While definitions of financial and technical aspects are clear, there are many definitions of governance (e.g. Never, 2011; Blumstein et al., 1980; Sovacool, 2011). The majority agree that it is about deciding who can do what, who will monitor it, and how rules are modified and changed over time, as well as referring to the way humans make decisions and form institutions that create rules shaping the behaviour of individuals.

By social aspect we understand not only the end-users, but also those "affected" by these projects, such as communities living in the area where the implementation of the project takes place and those engaged in public consultations.

Aspect classification is employed here to facilitate simplification and analysis – the actual drivers and barriers frequently do not fit neatly in to any one category, and the relationships between them are also important and taken into account in our analysis.

3.1. Introduction to the case studies and the UK situation in similar areas

An overview of the case studies[2] is provided in Table 1.

The case studies share some similarities in terms of governance, finance and aims; e.g. three of the case studies are public–private partnerships (PPP). This is not intentional, and as demonstrated below, some of the case studies are similar in one aspect but extremely different in others.

The City of The Hague has developed an innovative district heating (DH) concept consisting of a seawater central supply unit with a heat exchanger and heat pump unit that uses the nearby sea as a source of heating and cooling.

The BESP concept is an energy performance contracting project based on transferring energy management of state-owned properties to a partner, who self-finances the modernisation of building infrastructure necessary to cut energy use and CO_2 emissions. In return, the partner guarantees annual energy and cost savings for the state.

The Morris Model is a unique and cost-effective method of financing municipal RE projects for public facilities through low-interest bonds, traditional Power Purchase Agreements (PPA) and federal tax. It allows local government to receive access to RE at a price lower than they currently do, without any debt obligation.

Kungsbrohuset is a sustainable office building that was built using readily available materials and technologies in order to create a development where the environment and energy-efficiency are central considerations.

3.1.1. UK context

Some of the international projects described above have already been implemented in the UK to some extent, although they often operate in a different context.

For example, PPPs have been used in the UK – the RE:FIT Building Energy Efficiency Programme, a programme similar to the BESP, was introduced by the Greater London Authority in 2010 (Chmutina et al., 2012), and has been replicated in other UK cities, e.g. Leeds and Sheffield. There is obviously an appetite and opportunity for EPCs in the UK, particularly when considering the poor energy efficiency of much of the public and private building stock. Table 2 provides a comparison of BESP and RE:FIT and illustrates that although the UK has the potential for implementing ESPs (and significant efforts have been made in this area), the investment is still comparatively low compared with other ongoing successful ESPs.

While programmes similar to the Morris Model cannot be replicated in the UK in its pure form due to legal and regulatory differences, there is potential and interest for encouraging the implementation of similar hybrid PPPs, as UK local authorities are faced with the challenge of reducing both carbon emissions and financial outlay.

DH is a mature technology deployed effectively in many Northern European countries, but is used sparsely in the UK (Macadam et al., 2008). Currently, UK DH coverage is around 4% of the UK building stock, mainly in hospitals, universities and industrial sites, although it is dwellings that account for 70% of heat demand and therefore could benefit the most from DH (Upham and Jones, 2012). SWH systems implemented in The Hague are new to the UK and have been used only in the Continental Ferry Terminal building in Portsmouth. SWH was selected due to its financial viability, and would seem to have significant future potential in the UK due to the large bodies of available water, both coastal and inland (Goodier et al., 2013). The comparison of the systems is presented in Table 3.

In past decade, demand for "greener" office buildings has increased dramatically, particularly in London where many of the contemporary office buildings are BREEAM Excellent or Outstanding. However, in the UK context the main focus is on the building's technical performance rather than the sustainable behaviour of the occupiers. The demand for "green" buildings in the UK is often driven by an eagerness to enhance corporate social values and reputation rather than by a willingness to save energy (Chegut et al., 2011). Nevertheless, potential exists for improvements in the performance of "green" office buildings in the UK.

All the case studies presented therefore have a theoretical potential to be successfully implemented in the UK, and in many cases the first steps have already been made. The following sections discuss similarities and differences in the drivers and barriers that may impact upon the implementation of similar projects.

3.2. Drivers: a UK and international comparison

The Oxford Dictionary defines "driver" as "a factor which causes a particular phenomenon to happen or develop". We take drivers as factors that potentially contribute to the development of DE; they can be specific to a particular location, or general to the context; and also internal (organisational) or external (related to society) (Chmutina et al., 2013b).

Despite the increasing amount of literature available on DE, comprehensive empirical analysis on drivers remains scarce.

[2] More information on the case studies can be found at http://www.ucl.ac.uk/clues/structure/wp5 and in Chmutina and Goodier, 2013.

Table 1
Overview of international case studies (adopted from Chmutina and Goodier, 2013).

	Seawater district heating	Morris Model	Energy saving partnership (BESP)	Kungsbrohuset office building
Location	The Hague, Netherlands	Morris County, New Jersey, USA	Berlin, Germany	Stockholm, Sweden
Technology/area	Seawater heating	PV	Building retrofit	Eco-smart building
Focus	Heating and cooling	Financing	Financing	Profit
Date started	1999	2009	1997	2010
Scale	800 houses	19 municipal buildings; 3.2 MW	1400 buildings	1 building, 27,000 m^2
Investment	€10m	$30m (In bonds)	No initial investment	€120m
Funding body and instigating party	Vestia (housing corporation)	Morris County Improvement Authority	Berlin Energy Agency	Jernhusen
Energy/CO_2 reduction	50% Of CO_2 reduction	51,500 MWh over 15 years	60,400 t of CO_2/year	50% Of energy consumption reduction
Aim	Sustainability	Financial savings for the local government		Profitability

Table 2
Comparison of the BESP and London RE:FIT results.

	BESP	London RE:FIT
Number of contracts	26 Pools (~1400 buildings)	42 Buildings (145, 852 m^2)
Guaranteed savings (all contracts)	£9.6 m/a (Including €2.7 m/a savings in Berlin public budget)	£1 m/a
CO_2 reduction	67,900 t/a	7000+ t/a
Investment (all contracts)	£42.6m	£7m
GDP per city	£59b	£356b

Table 3
Comparison of the seawater heating/cooling case studies.

Location	The Hague, The Netherlands	Portsmouth, United Kingdom
Date started	1999	2006
Scale	750 Houses	Ferry terminal building
Investment	€10m	£10m
Funding body and instigating party	Vestia (housing corporation)	Portsmouth City Council
Energy/CO_2 reduction	50% Of CO_2 reduction	Not available
Aim	Sustainability	Profit/sustainability

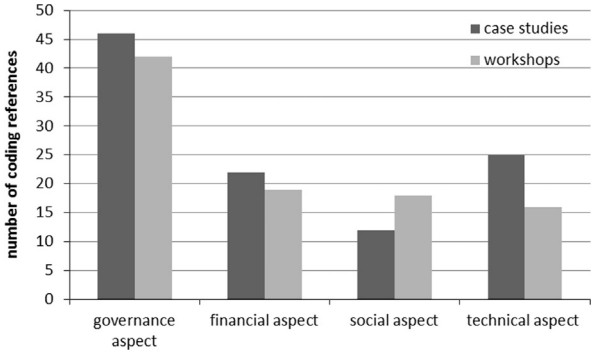

Fig. 1. Number of coded references to drivers during the four case study interviews and UK workshop discussions.

Table 4
Main drivers for the DE case studies and for potential similar projects in the UK.

Driver type	International case studies	UK workshops
Governance	Carbon reduction targets	Carbon reduction targets
	Interest/support from local authorities	Energy security
	Belief in sustainability	New business opportunities/ creation of jobs
Financial	Financial savings	Financial savings
	Good business opportunity	Business opportunity
Social	Show one can do it	Prosumers
	Make area sustainable	Fuel poverty
Technical	Improve building sustainability	Improve building sustainability
	Location	
	Interest in technology/ performance	

Marques et al. (2010), and Marques and Fuinhas (2011) investigate the recent drivers promoting RE in the EU, and Watson and Devine-Wright (2011) discuss drivers for moving towards DE. Many argue that financial drivers such as policy instruments and procurement mechanisms play the most crucial role in promoting DE (e.g. Alagappan et al., 2011; Foxon et al., 2005). Fig. 1, however, shows that this may not be the case here, and we argue that governance drivers play the most important role in DE initiatives. This will be discussed further in Section 3.2.1.

Although Fig. 1 does not represent statistically significant results, it shows the number of occurrences a particular driver was mentioned in an approximately similar period of time, thus providing an indication as to the level of interest and debate in each of the drivers during the workshops and interviews.

The main drivers stated by the case study stakeholders and the UK workshop participants are presented in Table 4 and show that the diffusion and promotion of DE cannot be attributed to one single driver – it is encouraged by an arrangement of several complex and interrelated factors. It is particularly difficult to allocate policy incentives into the individual categories as they incorporate both policy and financial drivers. For the purpose of simplification, policy incentives and similar financial regulations will be discussed under the financial drivers section.

The drivers that encourage the potential implementation of DE projects in the UK share some similarities with those of the case studies, although some aspects are driven by very different forces.

3.2.1. *Governance drivers*

Governance drivers can be divided into organisational (stakeholder-related) and political (regulations and political will). Several studies (e.g. Del Rio and Unruh, 2007; Menz and Vachon, 2006) support our argument that particularly in the case of the DE initiatives, governance drivers may play a more important role than financial drivers. For example, highly supportive institutional

frameworks allow the stakeholders to ensure that the schemes enjoy a stable and certain environment – institutional factors such as compliance with international agreements (e.g. Kyoto Protocol) can lead to a push towards low-carbon energy generation and energy consumption reduction. Marques et al. (2010) however, showed that generally "environmental concerns appear not to encourage the use of RE" and that "the larger CO_2 emissions, the smaller are [the] RE commitments", as the countries with high CO_2 emissions levels have large proportions of energy generated by fossil fuels; this traditional energy generation benefits from the strong support of industrial lobbying groups that restrain RE deployment. Government regulation and legislation act as an important driver for energy initiatives because of the necessity to comply with them (Walker et al. 2007), e.g. the compliance with regulations encouraged the implementation of the Morris Model and BESP. Compliance with the regulations was also mentioned at the UK workshops

> "Policy will drive Local Authorities or central government in saying "You have responsibility for delivering *X* per cent or your share of that 80% [of CO_2 reduction] by 2050"". (UK workshop participant).

Political motivation and long-term commitment also drive the promotion of DE systems

"A project's going to work where there's serious political will to do it. You need cross-party support so a project doesn't just vanish 3 years later when there's a change in power structure" (UK workshop participant).

Most of the cases enjoyed the support of local government

> "They [The City of Berlin] are doing information work. They did workshops and information about EPC, and today I think everybody knows in Berlin about [BESP]".

Support and interest from the local authorities were particularly valuable when partners shared the belief in sustainability – e.g. in The Hague, where both Vestia and The City of The Hague believed that a "Sustainable Duindorp is possible" and supported each other financially and in terms of project implementation

> "As a business you can't do it and as a public office you can't do it on your own. You have to do it together. You have to share the risk, the knowledge and the attitude and commitment".

Motivation can be driven by personal belief or by the willingness to improve the reputation and green credentials of the local government.

Energy security was discussed widely at the UK workshops. Literature suggests that the larger the dependency on energy imports, the higher the investment in RE sources (Chien and Hu, 2008; Watson and Devine-Wright, 2011). The participants of the workshops argued that the role of energy security as a driver for promoting DE will increase gradually in the future, parallel to the increase in oil and gas prices

> "[Energy security and resilience is] always high on the agenda of national government, play the security card and then people start to pay more attention".

Energy security was never raised as a driver for any of the case study project implementation – the actual project drivers were more simple and practical.

3.2.2. Financial drivers

Financial regulations generally favour RE and most of the countries have recently adopted these (Marques et al., 2010). The Morris Model was created based on the New Jersey State regulations that made installation of the PV profitable. Financial regulations, however, did not play a part in any of the other case studies, but during the workshops they were seen as one of the main drivers for encouraging the wider application of DE systems

> "The only real way to get this to work is to have it legally binding. It's got to be law and legislation to put it in place to do it en masse" (UK workshop participant).

Cost reduction is a common driver for energy initiatives, even more so when it incorporates emissions reductions, and is important for businesses as well as local authorities. In the case of the Morris Model, cost reductions were important for the county government and for the buildings that took part in the model

> "For us it was this huge accomplishment to be part of this project because we're a school district that really doesn't have a lot of money".

BESP had cost reduction as the main driver

> "… highly ambitious climate targets for the city of Berlin, but at the same time a tight budget situation, so there was no money for energy saving measures on public buildings and so it was clear that there must be some kind of third party financing".

Cost reduction is believed to play an important part in the UK too

> "I think everything's driven by cost fundamentally. I mean everything else matters, but if you really broke it down, then cost would be where you'd end up. There are other people driven by carbon and polar bears, which doesn't affect us all, but cost [does]" (UK workshop participant).

The fear that the price of the energy will rise dramatically in the next decade make stakeholders – particularly local authorities – look for solutions that allow the cost to decrease. The workshop participants agreed with the case studies findings – they were particularly concerned about price volatility and suggested that the willingness of businesses to control energy prices can encourage the deployment of RE

> "For some businesses it's the potential volatility of energy costs – so being able to get more of a fix on your energy costs is important. It's fear of an even greater economic recession" (UK workshop participant).

Recent research (e.g. Bolinger et al., 2006; Berry, 2005) recognises that DE can be a good protection against unstable fossil fuel prices. This hypothesis, however, was tested by Marques et al. (2010) and it appears that the small price increase is not sufficient to encourage the switch to greener forms of energy, and that the price increase in oil stimulates more the use of coal rather than RE, though this study was pre-2006, hence pre-energy price hikes and pre-global recession.

3.2.3. Social drivers

Social drivers encourage end-users and communities to accept and get involved in DE initiatives. Despite the fact that the case study projects did not directly involve end-users and communities in their implementation, they did have an element of behavioural change and awareness raising at the operational stage of the project. Society and communities were considered when the projects were proposed – "we want to make a difference both for the environment and [the] people" (Kungsbrohuset case study) – but the ideas were carried out without public involvement.

The workshops showed that social drivers may play an important role in the UK – public awareness about climate change has dramatically increased in last decade (Gan and Smith, 2011). It creates a great opportunity for businesses to promote DE and

focus on non-financial benefits, such as thermal comfort and climate change mitigation. Local acceptance and support for the initiatives encourage their implementation, particularly when the community associates these initiatives with the benefits of employment and development opportunities

> "You could involve them [communities] in it and make them part of it and that could help them to accept or even embrace the idea" (UK workshop participant).

Peer influence and word-of-mouth can be a driver for DE and as a way to enhance "green" behaviours, particularly with the assistance of understandable information (Dennis et al., 1990; Paladino and Pandit, 2012). The expectations of those who have never used DE systems are strongly influenced by the direction and success of other users – for example, technologies that have been seen in the neighbourhood and have received positive feedback from the neighbours inspire the confidence of others

> "It was when they saw their neighbours who had agreed to have it done that they suddenly changed their mind and you got the up-take very quickly" (UK workshop participant).

One of the most interesting drivers discussed in the case studies and workshops was the concept of place attachment

> "The social background of the people who live in Duindorp was with fishermen families and there was an old combination with the sea and in some marketing we used that old combination in the new combination with the sea" (The Hague case study).

This was also perceived as a potential UK driver

> "Authenticity, local produce, freshness…. If you said to somebody "Well would you rather have heat out of your local sea or lake or would you rather have some gas which Mr. Putin pumps down the pipe in Russia?" – most people would find that a very easy decision to make". (UK workshop participant).

3.2.4. Technical drivers

Technical drivers were more significant in the case studies than the UK workshops. Technical drivers can have a positive effect on financial barriers through economies of scale and improved efficiencies, but it is sometimes difficult to separate technical drivers from other governance and financial drivers, as they can be interrelated.

An important driver is interest in technology – none of the case studies feature new technologies but instead innovative ways of applying existing technologies

> "We had no research in this building. This is all purely made with normal stuff that you can find everywhere. And put together in a very delicate way, thereby showing people that you can do it as well if you just put your effort in it" (Kungsbrohuset case study).

During the workshops it was commonly agreed that in the future there will be more DE available in the UK at a lower cost, the issue being that DE has to be integrated into the built environment. Currently, most of the UK building stock need retrofitting to improve their energy performance and reduce emissions, but changes in the built environment, particularly those related to community scale DE technologies, may be opposed by the local residents. To avoid this, public engagement needs management – public will accept the disruption and switch to different power systems only if the high level of trust is developed in those implementing the change (Watson and Devine-Wright, 2011).

3.3. Barriers: what can we learn for DE projects?

It is often stated (e.g. Blumstein et al., 1980; Painuly, 2001) that DE initiatives face barriers during their implementation, and sometimes operation. The diversity of the potential barriers is significant and varies from structural to behavioural (Shove, 1999).

It is believed that the main barriers for the implementation of DE projects are financial and technical, and this opinion is reflected in the policies and regulations, which are aimed at economic opportunities, such as financial and regulatory mechanisms and technical challenges (Michalena and Hills, 2012). Fig. 2 shows that although financial barriers play an important role and may prevent the project from happening or slow it down, the most

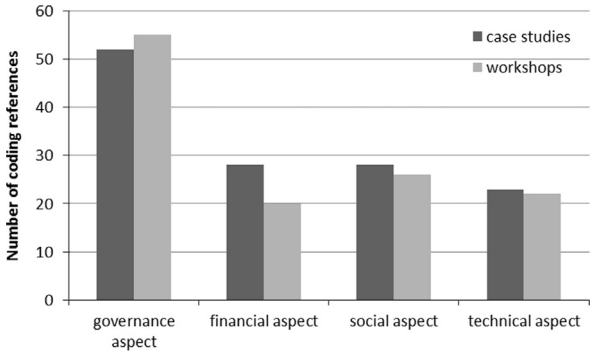

Fig. 2. Comparison of coded references for barriers during the case studies interviews and UK workshop discussions.

Table 5
Comparison of the main barriers experienced by the case studies and the potential barriers for similar project implementation in the UK.

Aspect	International case studies	UK workshops
Governance	Planning permissions Lack of qualified labour Lack of support from national government Dealing with and coordinating many parties are the same time	Planning permissions Lack of qualified labour Lack of support/resistance from national government and utilities Lack of clear guidance
Financial	Financial constrains	Financial constrains/lack of incentives High price of RET and EE Low fossil fuel prices
Social	Hard to change habits Lack of understanding/interest Association of RET and EE with high costs and inconvenience	Hard to change habits Lack of understanding/interest RET and EE is seen as inconvenience
Technical	RET are not mature enough	RET are not mature enough Old infrastructure Lack of link between RET and EE

debated barriers are often governance-related, and social barriers may play as important a role as financial.

Table 5 presents the main barriers discussed during the interviews and workshops and shows that barriers experienced in the case studies were very similar to those anticipated in the UK.

Similarly to the drivers, there is a considerable interaction between the different categories, and understanding the relationship between them is important in order to address and overcome them.

3.3.1. Governance barriers

Theoretically, the main purpose of the mandatory national targets, such as EU Energy Directive 20-20-20 (EP, 2009) or the UK Climate Change Act (DECC, 2008), is to provide certainty for investors, to stimulate the development of RE technologies, and to reflect the local reality and needs (Michalena and Hills, 2012). This is not, however, the case for all policies, and their discontinuity and uncertainly are often the main cause of limited development of the RE, as was identified at one of the UK workshops

> "The regulation's to bring up the struggle and not to create new innovation".

Political aspirations are not seen as "bankable" by businesses and do not send an investment-inducing signals to them (Allen et al., 2008). The policies were named as one of the most crucial barriers faced by the energy initiatives

> "We wouldn't invest in the feed-in tariff system because we don't trust the government in this regulatory environment" (UK workshop participant).

Another shortcoming of energy policy is that it does not address and encourage the importance of information exchange and collaboration

> "There is a lack of good quality data and also best practice information. So lots of businesses are learning from their own experience and mistakes rather than learning from the collective experience of collective mistakes" (UK workshop participant).

In addition, many of the workshop participants raised the point that "we'd do better with energy if we didn't have to meet all the regulation", partly attributed to the fact that regulations focus on a particular aspect of a project rather than the project as a whole.

Energy policies and energy market regulations are also developed and changed at different speeds using different decision-making processes (Szatow et al., 2011). Institutions developing energy policies often coevolve with energy markets and are likely to be (more) sympathetic to the incumbent energy systems, creating inertia, which makes policy instruments not as effective as they could be as they threaten the viability of the existing energy systems

> "There is absolutely no incentive whatsoever for utilities to support local RE. They will get in the way of smart meters and the reason for that is if you give the customer more intelligence they can start to vary their usage and it's just not in their interest. No-one is blaming the utilities but just the structure of it. They have shareholders and they have to maximise profits" (UK workshop participant).

Planning policy, although created with good intentions, was addressed as a big barrier for both case studies and UK workshops

> "At some point the buildings may not be affordable to be heated because of this curse of being in a conservation area because it looks so nice". (UK workshop participant).

Current planning permissions are characterised by the unnecessary level of complexity and the time it takes to get permissions

> "We had to go through all the red tape because the State wants you to do this, but it puts up all these barriers so you can't do it." (Morris Model case study).

Timing is crucial as slight changes in the business environment might influence investment decisions

> "I think the time for this [Kungsbrohuset office building] was perfect. We'd never do that again now. That time has passed".

Dealing with and coordinating involved parties are seen as a barrier that might create unexpected difficulties

> "The main challenge is to get everybody to cowork with these goals of getting it as energy efficient as we wanted. Some people just said "Why are we going to do this? Can't we do it like we've always done it? You're not going to earn many per cent on that…". That was one of the hardest parts – to keep the line, to keep the focus on the target" (Kungsbrohuset case study).

For example, in The Hague, a stakeholder dropped out at the very last minute

> "Eneco didn't believe it [the system's efficiency] and they caused us quite some trouble because they made all kinds of objections against the system, and once we had solved their objections they came up with new ones".

During the workshops and case studies the performance of the installers and RE developers was also discussed

> "The workforce is clearly inadequate at the moment. There are huge training needs to deliver the level of skills" (UK workshop participant).

Installation of DE systems requires highly trained specialists; they are crucial as performance expectations will only be met if the installations are carried out correctly. UK workshop participants also claimed that the cost of the qualified labour is high, and this increases the overall cost of the project. In addition, many of the installers focus on one particular type/aspect of technology rather than considering a building as a whole system, and therefore cannot provide information for consumers on how to use the newly installed systems in their individual context efficiently.

3.3.2. Financial barriers

A common financial barrier was the lack of initial funding – while it did not affect the outcomes of the projects, the lack of finance did not allow the achievement of better economies of scale or taking projects onto a new level. BEA is planning to start BESP Plus in order to take energy efficiency measures further and offer clients energy saving solutions with higher payback periods, such as insulation and windows replacement

> "We have the contract for this and we want to do this with some pilot projects, but we still have to find the financing. The ESCOs cannot finance this" (BESP case study).

Workshop participants emphasised that energy prices and fossil fuel subsidies are a big problem for the deployment of DE technologies and that they actively discourage customers from seeking cleaner alternatives and encourage overconsumption

> "We're in a situation where fossil fuel prices are still lower than they should be arguably and renewable technology's still more expensive and less efficient than it should be. So we're all fighting to close an economic gap and all the

financial engineering that's going on with incredible innovation and intensity is basically trying to close that gap, jumping on any subsidies that are available". (UK workshop participant).

High capital costs of RE technologies make them unattractive, as markets are seeking short payback periods.

Another barrier is the absence of reflection of the value of improvements on the property sale price

"If you spend £10,000 on your house, is your house worth £10,000 more? No! If that were the case the economics for an awful lot of this would be very different and the energy savings would just be the bonus on top of the fact that you've just increased the value of your house" (UK workshop participant).

It is not entirely clear why the value is not reflected and may arise from the lack of understanding of the benefits. In addition, property buyers are often more interested in the physical appearance and location of a property, rather than in "invisible" energy savings and thermal comfort.

Financial barriers did not play the primary role in these cases and present possibilities for improvement rather than failure. Taking the financial barriers experienced in these cases into account, it has been noticed that innovative DE initiatives require high initial investment and a strong financial background. Thus, due to the fear of financial failure that can be caused by unsuccessful investment, many stakeholders fail to understand that there is more to sustainability than just financial profit.

3.3.3. Social barriers

Social barriers play as important a role as financial in both the UK and abroad (Fig. 2). This is not reflected in policies however, which focus mainly on financial and technical barriers.

Although it is generally believed that society enjoys environmentally healthy surroundings and that many are supportive of good causes, there are still very few who are willing to "sacrifice" – as DE is often associated with "sacrifice" and "disruption" – too much on an individual basis for the benefit of wider society (Wustenhagen et al., 2007). In the case of the Kungsbrohuset office buildings, stakeholders believed that social aspects act as barriers

"People don't want to change and they just want to have it the way that they've always had it, and if they're going to change it has to be something better or easier".

Many opinion polls indicate that the majority of people tend to agree with the idea of public support for renewables (EORG, 2003; Wustenhagen et al., 2007). This positive overall picture is what possibly leads policy makers to believe that social acceptance is not an issue. However, when looking into more specific local examples, many agree that the problem of social acceptance does exist (e.g. Wustenhagen et al., 2007; Owens and Driffill, 2008). One possible explanation is that people support RE as long as it is "not in their own backyard". Duarte et al. (2012) suggest that the energy behaviour of the household is determined by social, cultural and demographic factors – such, high income households are responsible for the greatest volume of emissions. This creates a paradox when consumers with the highest spending power do not invest in RE generation as they are not interested in reducing the costs of the energy they consume. Conversely, those affected by fuel poverty and high energy prices would normally want to reduce energy costs, but cannot afford to do so due to the high costs of RE technologies and the implementation of energy efficiency measures

"If you look across at Nottingham, the areas that are affluent have much higher [energy] consumption per person than places like social housing. Social housing is great but people who live in [more affluent areas] waste heat. They have big houses and they probably leave things on because they can afford it and it's a small portion of their income" (UK workshop participant).

The biggest social barrier described in all four cases and workshops was lack of understanding and interest in how the technology works. This can affect the performance and in some cases leads to rises in energy consumption when not supervised by the specialists

"If the building owner is getting back all the saving measures but he doesn't have the technical staff to take care of that or he doesn't know about energy management so much, of course the energy consumption then starts to rise up again" (BESP case study).

Lack of understanding also triggers financial worries

"They [community] didn't really believe that we weren't spending any money. So it required me to do more of a line-by-line budget description for the community so that they trusted and believed that this was not embedded in our budget" (Morris Model case study).

Habits play a crucial role in creating social barriers

"You don't put some carpet on it which is very highly [heat] resistant. … You have to be aware because when you do something like that on the floor it doesn't work" (The Hague case study).

In order to overcome this barrier, project stakeholders used different ways of engaging the users and explaining how the systems work. The idea of these educational campaigns was that the awareness would encourage behaviour change towards the more sustainable behaviour. "…habit and behaviour are not the same" however (Hodgson, 2007: 106), and "energy – consuming behaviours […] are often guided by habits, and … deeply ingrained habits can become counter-intentional" (Marechal, 2011: 1104). Therefore it is important to make users aware of their habits and convince them that change of habits could lead to financial as well as non-financial benefits. It is important to bear in mind that the crucial question is not about having the information but about its effective application. Information is needed on costs but also on technology-specific details, as well as on broader issues such as household energy use (Bergman and Eyre, 2011). The issue with the information is further complicated by ongoing mixed messages on energy usage and lifestyle from both government and media.

3.3.4. Technical barriers

The main technical barrier discussed was that the DE systems are still considered as "innovative". The problem of maturity is complex – it incorporates barriers related to governance, finance and social acceptance. It is described here under the technical aspect as innovation is firstly seen as a technical notion. Innovation was mentioned in both case studies and workshops, and although it is observed that innovation plays an important role in decarbonisation, it does not attract investment and trust – rather innovation is associated with risks and uncertainties

"We don't want to be first with anything because we don't want to take the risk" (Kungsbrohuset case study).

Workshop participants agreed that although the UK government makes efforts in supporting new technologies, this support needs to go further

"The key thing is to support a wide range of innovation, and in the case of PV we should be supporting it by installing some of it, not by just looking at it at the university".

Old infrastructure was also raised as a barrier

"We're taking 19th century technology and we think we're going to use it in the 21st century". (Morris Model case study).

Technical barriers cannot be removed on their own as they frequently highly entwined other aspects (Goodier and Chmutina, 2012); indeed, often once governance, social and financial barriers are removed, technical barriers may often disappear without any specific direct action.

4. Recommendations for removing barriers in the UK

The four workshops investigated and debated drivers and barriers for a variety of potential DE technologies and schemes, including their applicability and appropriateness for the UK context. A variety of recommendations for the encouragement and increased deployment of DE in the UK emerged, which are outlined here. The recommendations are not prioritised or exhaustive, nor were they unanimous, but instead represent the spectrum of thinking and suggestions to be taken as a starting point for pushing forward and enabling solutions on how to increase the potential of various DE approaches within the UK.

- *Decarbonisation as the goal*: a consistent goal of decarbonisation should be constituted in all institutions at all levels from single household to national (and global) government. The prevailing values and decision-making processes should be informed by the increasing awareness of institutions and individuals around carbon reductions and enhanced energy efficiency. Systematic and long-term approaches should be promoted in the decision-making process, led by energy specialists and sustainability champions from public and private institutions, as well as from the communities themselves in which the DE will be embedded. It is clear that decarbonisation on a local or project level will often meet initial opposition, but it is likely to shift as more information becomes available regarding the benefits, both direct and indirect. In addition, policy should not only alert, but also operationalise this goal and provide the guidance on the possible means of achieving it.
- *Improvement of the policy instruments*: a wide variety of complementary and coordinated policies should be introduced. Policy instruments should incorporate (but are not limited to) equity, efficiency, scientific validity, consensus, frugality and environmental effectiveness as well as take into account financial, social and legal implications of policy implementation. They should be coherent and integrated with both existing and other new legislation in order to avoid conflict between the objectives of different policies. They should also incorporate long-term action plans and tangible measureable targets.
- *Institutional changes*: currently there is a lack of institutional flexibility when dealing with issues of sustainability. Many institutions, both local and national, have fragmented, disconnected policies and do not optimally employ various mechanisms (e.g. PPPs, subsidies, supervision and monitoring) to resolve sustainability-related issues. Short-term planning approaches and inappropriate application of incentives are commonplace. Many institutions lack the knowledge and understanding of sustainability issues and are slow in responding to new information and values. In addition, information is rarely freely shared or disseminated, especially regarding the more problematic schemes – which frequently provide the best learning opportunities –- thus stunting scientific, data-led decision making. Most of these problems are the result of embedded institutional bureaucracy, therefore institutions need to be more flexible, open and accessible. Utilities need to shift from being pure energy producers to becoming service providers, thus generating new business opportunities.
- *Research into sustainability feedback*: it is important to recognise how the preferences of institutions and individuals impact on the success and failure of decarbonisation policies and projects. The understanding and evaluation of these effects will allow the improvement and refinement of policy instruments. Comparable benefit/cost analysis should also be encouraged that allows consideration of the market as well as non-market benefits and costs.
- *Redistribution of economic incentives*: fees, subsidies and taxes should be gradually employed to change the economic price of activities that interfere with or impact upon energy efficiency and sustainability (e.g. use of fossil fuels) and of those that are attuned with them (e.g. energy generation via RE technologies). While elimination of fossil fuel subsidies altogether is unlikely, the government needs to find ways of sending strong financial signals to customers and the market with regards the more rational use of energy. This could also stimulate increased competition in the electricity industry.
- *Incorporation of social aspects into policy instruments*: current legislation fails to incorporate and address household behaviour and its associated emissions. Policies should take into account the different consumption patterns based on the types of household, including incomes. Policy should represent a mix of institutional support and penalties, despite the obvious political and social sensitivity of this. Currently, although the energy consumption of dwellings is relatively high in the UK, there are no regulations that require energy users to reduce their energy consumption or personal carbon footprint, either in the home or in their daily lives.
- *Education and awareness*: media awareness regarding sustainability and climate change should be improved to avoid inaccuracy and inconsistency in reporting and hence public awareness and understanding. Examples such as educational campaigns, public demonstrations of exemplar initiatives, free energy audits of domestic and non-domestic buildings and industry training sessions would all help. To be effective, this information would need to be tailored to the audience – generic distribution should be avoided and education should not be aimed at overspecialisation and disciplinary isolation.

The majority of the drivers discussed in this paper have already an impact towards removing the barriers and addressing the proposed recommendations. Crucial drivers, such as belief in sustainability and willingness to act on it, play an important role in making the projects successful (Chmutina et al., in press-a, in press-b), and can challenge most of the barriers when employed effectively.

5. Conclusions

The UK government acknowledges the potential for DE to contribute to carbon emissions reduction and provide energy security. There is a potential to implement a variety of DE projects in the UK, but many issues need to be addressed. The implementation and operation of energy initiatives are often associated mainly with the financial opportunities, but in actuality it is also linked to local governance issues and social concerns and motivations. Technological challenges are mainly seen as research challenges which hence can ultimately be satisfactorily overcome,

but they should also be allied to financial opportunities. Similarly, planning concerns are commonly linked to environmental issues, but they should also take into account the governance and financial aspects of their impact.

This paper investigated the complexity and interconnectivity of the drivers related to DE. Governance drivers play the most significant role, particularly in the form of regulation, whereas financial drivers – that are typically believed to be crucial – are deemed to play a lessor role. As highlighted by the variety of drivers in our discussion, there are a variety of interconnected pathways to the increased development of DE in the UK.

Social, governance and financial barriers rather than technological barriers constitute the central problem areas for the increased adoption of DE, indicating multidimensional complexity associated with implementing and operating DE projects. Furthermore, the barriers cannot be simplistically divided into individual aspects. Therefore, in order for these barriers to be addressed, there is a need for developing an integrated approach that takes into account all aspects of project implementation as a whole, as many barriers are interconnected and cannot be dealt without considering the wider context. Currently there is a lack of coherent policy that can deal with the complexity and multiplicity of these interconnected barriers. A comprehensive approach should therefore be developed, aimed at a certain suites of barriers rather than individual – e.g. removing subsidies from conventional energy, but which may hurt the poorest and lead to higher levels of fuel poverty; distributing information regarding energy efficiency will be inadequate if associated energy efficiency measures are not available.

The drivers and barriers experienced in the case studies were similar to those anticipated by practitioners for similar projects in the UK. There is potential therefore, that the increased implementation of DE systems in the UK could also enhance social benefits and governance practice. The case studies examined present a high potential for replication and scaling up in the UK. There is a need however, for additional empirical evidence and research examining the deployment of specific DE technologies to enable the characterisation of the complex interactions among the plethora of interrelated socio-political actors and enablers that influence implementation of DE in the UK. Such research is needed in order to provide an in-depth understanding of the potential barriers and drivers for DE technologies and their potential contribution to the UK national carbon reduction targets.

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