Flood resilience technology in Europe: identifying barriers and co-producing best practice

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Abstract

Flood resistance and resilience technologies hold considerable potential to limit the damage caused by flooding. Resistance technologies generally aim to keep water out of buildings, while resilient measures may allow ingress but create the conditions for a quicker recovery of individuals, communities and buildings. However, despite their potential contribution to flood risk management (FRM), their use remains uncommon. This paper draws on pan-European research of local communities at risk and their representatives, and professional stakeholders working at a more strategic scale, to explore the barriers to use and describe the co-production of new best practice. It interrogates the issues in terms of level of awareness, degree of acceptance and the integration into decision making. We found that even where awareness was high, there was a reluctance to use these measures. This is due to issues related to comparability, costs, installation, performance and maintenance. The research also revealed that FRM policy and practice has struggled to incorporate this emergent approach and that many individuals at risk are reluctant to take responsibility and protect their properties in this way. In response, this paper details how good practice guidance – the 'Six Steps approach' – was co-produced with key stakeholders to facilitate the wider contribution of FRe to FRM.

Keywords: Co-production; flooding; innovation; property level protection; resilience; technology.

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Introduction

Throughout Europe, recurrent flooding and increased understanding of the sources of flooding has led to a diversification of flood management approaches. While largescale engineered defences remain important, there is an acceptance that the risk cannot be managed solely by holding back water through a narrow focus on heavy civil engineering schemes (White, 2010; Zevenbergen et al., 2010). Instead, a more pluralistic, risk-based approach places the emphasis on understanding the interconnections between natural and human systems, with people increasingly expected to live with a degree of flood risk (Scott et al., 2013). Catchment-based partnership working that crosses traditional administrative boundaries is promoted. Additionally, adaptation is considered alongside mitigation, and structural measures are complemented by non-structural initiatives such as better planning and forecasting for floods. This shift is usefully described as a move from 'flood defence' to 'flood risk management' (FRM) (Johnson and Priest, 2008; Butler and Pidgeon, 2011) and has been accompanied by parallel narratives associated with the need to 'live with rivers' (Fleming, 2002), 'make space for water' (Warner et al., 2013) or for communities to 'be resilient' (O'Hare and White, 2013). Consequently, there has been a widening of FRM responsibilities beyond the state to encompass the private sector and citizens through, for example, the purchase of insurance or consulting publicly available flood risk maps when moving house.

As part of this more flexible and holistic approach, the use of flood resilience and flood resistance (FRe) measures at property and community scales has been advocated (Department for the Environment, Food and Rural Affairs, 2012; Jha et al., 2012; Garvin et al., 2013). These elements include mobile perimeter barriers, door guards or changes to the fabric of the building. The measures are particularly beneficial where it is difficult to justify expensive capital expenditure, to protect critical infrastructure, to limit the visual disruption in cultural and heritage areas and where traditional defences are inappropriate, such as in the case of flash flooding within urban areas.

The definition of resilience has prompted considerable debate within the professional and research community, with interpretations varying between disciplines and sectors (White and O'Hare, 2014). For example, structural definitions of resilience refer to the ability of a system to resist a hazard. In contrast, functional definitions of resilience focus on the capacity of a system to cope with a disturbance (Berkes et al., 2003; Lake, 2013). The understanding of FRe is similarly dependent on the context within which resilience is deployed as both resistance and resilience characteristics are captured by the term FRe. Here, structural resilience is seen in flood 'resistance' measures that attempt to keep water out of buildings, often referred to as dry proofing. These are directly applied to building apertures, such as door guards and air brick covers, and resist the entry of water to a property (usually to a depth of around 600 mm). Perimeter barriers may also be deployed to hold back and resist flood water at the community scale (see Figures 1 and 2). Alternatively, flood 'resilience' measures may allow water ingress and are designed to limit damage and to facilitate the recovery process. This more functional approach is also referred to as wet-proofing. Complicating this dichotomy, whilst FRe measures prevent floodwater from entering a property to certain depths, they can also slow the rate of water ingress, thus affording more time to evacuate buildings. In some cases, therefore, resistance technologies can increase the resilience to flooding. While this distinction between resistance and resilience is acknowledged within engineering and is widely deployed in the United Kingdom and the United States (for example, USACE, 2005; Bowker, 2007), both resistance and resilience technology may be used to manage localised flooding.

Despite FRe's potential, research into their practical integration is sparse. Studies tend to only consider financial issues within a discrete, recently flooded area, such as the potential cost savings compared to traditional practices (Joseph et al., 2011) or the willingness of homeowners to pay for measures (Kazmierczak and Bichard, 2010). This paper addresses this lacuna by discussing research in the wider context of FRe use in Europe: what factors, beyond finance and willingness-to-pay, inhibit the uptake of FRe technologies? How does this differ between various user communities? And how could these issues be addressed? Such questions permit a broad analysis of the social and political challenges of technologies along with an emphasis on those stakeholders with critical roles regarding decision making, from the individual homeowner to the flood risk managers operating at a municipal level. Significantly, the network developed during the research also enabled the coproduction of good practice guidance – the Six Steps approach outlined in 'The six steps: building capacity in an innovative sector' – to be developed. This was designed to support FRM professionals and property owners in deciding whether FRe is a feasible option. Before we turn to the specifics of the guidance, we explain the research approach and analytical framework. We then discuss the empirical findings that underpinned and shaped the production of the Six Steps.

Figure 1 Wet testing of a door guard. *Source*: Flood Angel®.

Figure 2 Demountables in action, Bewdley, Worcs, UK. *Source*: The Environment Agency.

Research Approach and Analytical Framework

Evidence is drawn from the 42-month European Union FP7-funded SMARTeST (2015) project, which involved partners from across Europe (see www.floodresilience.eu). The research was designed to explore FRe technologies, their integration into practice and the requirements for capacity building. This occurred in seven countries that posed a range of flood risks and sociocultural characteristics: Cyprus, France, Germany, Greece, Spain, the Netherlands and the United Kingdom (Figure 3). Two main user communities were engaged. First, we held workshops with local communities at risk as those were considered possible 'end-users' of FRe (community stakeholders). To complement this perspective, we also held workshops with more expert and knowledgeable stakeholders who may install, fund or recommend FRe technology for use within existing houses, new developments or to deploy mobile barriers to manage exposure at a neighbourhood scale. These included planners, engineers, insurers and wider decision makers, who work at a more strategic scale (professional stake- holders). In terms of the former category, in addition to local property owners and community members, local representatives were included as they are closely involved with, and advocate on behalf of, these groups. Two workshops of approximately 25 people each were held in each country to account for the two user groups (Table 1). Participants were shown photographs and drawings of FRe products, and a facilitated discussion was undertaken in order to identify and explain the barriers to their use.

The data was further enriched and validated through the establishment of National Support Groups in each country, who met biannually to advise the research team. These groups had members drawn from key stakeholders: government and municipal agencies; product manufacturers, installers and distributors; insurance companies; and property developers. The workshops and meetings were transcribed and thematically coded according to the analytical Flood resilience technology in Europe framework outlined below, with further codes developed iteratively between the project team (Braun and Clarke, 2006). Given the positioning of FRe as an innovation in managing floods, the framework draws on two main areas of scholarship: FRM and innovation studies.

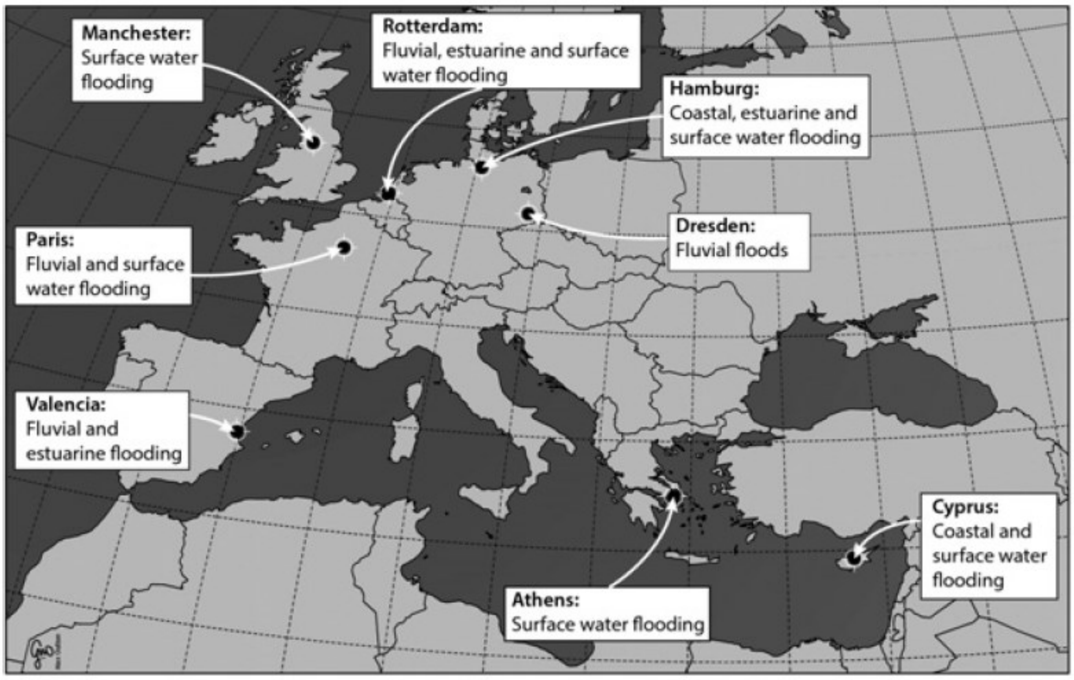

Figure 3 Location and risk profile of the case study areas.

There are a number of FRM approaches that help to contextualise the use of FRe. For example, the Scottish Executive's '4 As' approach to flood management is a linear process ranging from awareness, alleviation, assistance and, finally, avoidance. The delineation is designed to focus attention on specific key points, such as the initial awareness of flood risk amongst the general public, professionals, and decision makers to an appreciation of the potential alleviation measures that could reduce or avoid risk, for instance, decisions concerning the implementation of FRe. A comparable model can be found in European Commission documents that advocate the 3Ps and E and R: 'Prevention, Protection and Preparedness, Emergency Response, Recovery and Lessons Learned' as well as the '4 Capacities' in the Netherlands, which has a focus on adapting to the flood risk (see Ashley et al., 2010). All of these approaches similarly capture critical stages in managing floods: from promoting public awareness and improving risk literacy to providing a range of possible managerial options and enabling stakeholders to take meaningful remedial action (European Commission, 2007).

The literature on innovation diffusion provides further insights regarding the mainstreaming of FRe technologies and how the actors and agencies that will make decisions on their use can be supported. Innovation, in its broadest sense, refers to new or improved materials, services or the method of producing them (Edquist, 1997), and FRe is a good example of a recent innovation in managing flood risk. Many conceptual models have been developed to understand innovation diffusion. For example, Rogers' (2003) S-curve highlights how implementation is dependent upon four main factors: the innovation; how it is communicated (from innovators through early adopters and onto general adopters and laggards); time; and the relevant social system. Eventually, an innovation may reach ‘saturation point’, where it becomes widely accepted. The S-curve applies in instances such as those relevant to FRe, where benefits are not always immediately realised but can avoid unwanted consequences at some future time (Rogers, 2002). As such, a range of variables may inhibit or facilitate the route to market of any new innovation, from raising awareness of the option to the gradual acceptance of the measure to the effective incorporation into decision-making processes. Underpinning the insights is an assumption that society and technology co-evolve and that the acceptance of innovation is found in the interplay between a range of practices, including user behaviours, markets, governance structures and cultural values (Vigar, 2000; Petts, 2004).

Community stakeholders	Professional stakeholders
- People who have recently been flooded. - People who have been flooded but not recently. - Local businesses or business advocacy organisations, such as a Chamber of Commerce. - Local political representatives. - Local community forums, such as flood action groups, neighbourhood associations or public advocacy organisations.	- National and regional political representatives. - Spatial planners. - Engineers, including drainage, civil, municipal. - Consultants. - Utility companies. - Major building owners. - Insurance industry representatives. - Representatives from statutory bodies (e.g. local council social services, etc).

Table 1 Typical attendees of each workshop

By combining an understanding of the often uneven route to market for innovations with current FRM strategies that emphasise decision-making processes, three aspects of the FRe innovation journey were identified in order to help analyse public and professional understandings of the technologies and enable thematic analysis across the case study sites. These were awareness, acceptance and decision-making ability. Awareness of FRe is the extent to which workshop participants were cognisant of innovative FRe technologies. If awareness was low, the approach was unlikely to be mooted as an option. Acceptance of technologies interrogated the extent to which stakeholders appreciated the potential of the FRe approach as a solution, including accepting the responsibility to act. Lastly, the decision-making ability of actors and agencies was investigated in order to identify the factors affecting the practical implementation of FRe. For example, even if people were aware of FRe and willing to use it, they may be reluctant to do so due to a lack of certainty regarding product performance, the lack of clarity relating to the possible discount on insurance premiums or concerns such as reliability, affordability or aesthetics. The analytical framework additionally allowed the identification of specific areas that would benefit from increased information and capacity building, informing the good practice guidance described in ‘The six steps: building capacity in an innovative sector’.

Results

Awareness of FRe – an active sector and direct experience of floods

Awareness of FRe technologies differed across nations and between communities and professional stakeholders. Two key factors framed the community stakeholders’ awareness: direct experience of floods and a manufacturing sector that is active in promoting FRe technologies. In those case studies where a considerable length of time (circa 8–10 years and over) had passed since the last flood event, the community stakeholders’ awareness of flooding and the possible strategies that may be taken to counter flooding was noticeably lower. Conversely, individuals who had experienced recent flooding were more likely to have some broad awareness of FRe technologies. Community stakeholders drew attention to the private sector manufacturers and installers who actively marketed products to potential customers in the wake of a flood event. Consequently, awareness of technologies amongst the public was relatively higher in countries with an active flood FRe sector (the United Kingdom, Germany and France). The Netherlands seems to be an exception. Despite flooding being a concern, a reliance upon large-scale structural flood defences and strategic planning to manage flooding meant that technologies designed to manage smaller-scale floods of less than 1m depth were much less relevant.

Amongst professional stakeholders, awareness of FRe technologies similarly reflected distinctions between nations. In the United Kingdom, Germany, and France, professionals tended to have a relatively high awareness of FRe as a mechanism to reduce risk and the differing types of products available. In the United Kingdom, this was because of technical (research and development) efforts as well as policy initiatives that have resulted in an active manufacturing sector, some of whom had voluntarily formed an association to improve standards throughout the industry. In Germany, certain municipalities were aware of FRe for cultural or aesthetic reasons. For example, Cologne has mobile flood protection to prevent spoiling tourist views with permanent defences (Gabalda et al., 2012). In the workshops held in Spain, Greece and Cyprus, knowledge of flood FRe technologies was almost non-existent, and, by consequence, workshops and National Support Groups reported that they were rarely considered an option to manage flood risk.

Acceptance of technologies – resistance to change

Beyond awareness of FRe technologies, specifiers and end users must also accept their use as a possible solution for their situation. This challenge is directly related to the expansion of FRM responsibilities as outlined in the introduction, a transition that has taken place in the context of broader shifts towards neoliberal governance (Harvey, 2007) and societal narratives that normalise and commodify risk management (Beck, 2009). However, the data indicated a resistance to the argument that citizens and communities need to take responsibility for managing their own flood risk. While other aspects of personal protection, such as insurance and consulting risk maps, were seen as common sense, both the community and professional stakeholder workshops revealed that the general public were reluctant to accept responsibility for the purchase and installation of these technologies. Such a response was most strongly elicited in the French workshop and, to a lesser extent, in those carried out in Germany, the Netherlands and the United Kingdom. Research participants in the community workshops reported that this was due to long-held expectations regarding flooding as a complex technical exercise carried out by experts in the public sector combined with other more pragmatic issues such as a lack of guidance, knowledge and capacity. Not only did people resist becoming responsible for managing their own flood risk, but the workshops revealed that citizens tended to prefer action to be taken at a scale well removed from their home. Fears were expressed that if FRe technologies were fitted to properties, 'upstream' hard defences would be less likely.

Amongst professional stakeholders, there was a greater tendency to accept that FRe technologies, in principle, were a possible solution, notwithstanding the need for greater surety regarding their effectiveness and value for money. Decision makers are led by their policy priorities, budgets and procurement processes, and the explicit advocacy of FRe technologies in policy was rare, only emerging in a limited fashion in the United Kingdom, Germany and France. As such, there was a view that there is limited scope to consider it an option. Yet, in principle, the view was positive. Even where FRe awareness was low (Spain, Greece, Cyprus), professional stakeholders overwhelmingly viewed the technology in a positive fashion when it was demonstrated to them, suggesting that if awareness was higher and the policy framework was more conducive, acceptance would be less of an issue for strategic decision makers. However, mirroring the discussion in the community workshops, there was still a degree of debate amongst professional stakeholders, particularly in Germany, France, Cyprus and Greece, as to whether property scale initiatives, such as FRe, should be part of the remit of municipal authorities or the prime responsibility of the homeowner. Additionally, in countries where the state provides some sort of compensation against flooding, such as the Netherlands, the extent to which property owners could be held responsible to install FRe was strongly questioned.

Turning to the technologies themselves, participants were shown both manually and automatically deployed technologies. Acceptance of manually operated FRe was detrimentally affected by a lack of faith in the efficiency of weather warning systems to allow time for their deployment and practical issues, such as usability for the elderly. Professional stakeholders in the German workshop also noted the added costs associated with the deployment of mobile barriers over permanent flood defences. In general, flood risk professionals – and the insurance industry – across all of the workshops preferred automated products. That said, concerns were also raised against the performance of these devices. For example, UK professional stakeholders (most notably a representative of the insurance industry) noted that the colloquial labelling of automated products as 'fit-and-forget' is often taken too literally, which instils a false sense of security in the end-user; all technologies require maintenance.

Making decisions – the consequences of an emerging technology

Even in cases where decision makers were aware of FRe technology and accepted it, in principle, as a potential solution, the research revealed several factors that inhibited the ability of key actors to take action. A key finding from stakeholders in all countries and at all scales was that there was not enough information or experience to confidently make a decision on using FRe. Related to this, there was consensus within the National Support Groups that no case study country possessed a regulatory framework that could integrate FRe technology into FRM. This was considered to have critical implications for perceptions of technologies; community and professional stakeholders in all countries felt unable to place trust in products that were, for the most part, absent from official policy or wider sources of information. As such, all workshops reported that participants asked recurring questions centred on issues connected to confidence in an innovative technology; how were they developed, are they accredited by a standards body, how are they installed and maintained?

Further concern was expressed regarding the difference between the various FRe products available, with queries ranging from the technical to the very practical, including how products could be compared on cost and performance, their aesthetics and how they might be deployed if the homeowner or user was away from the property. There was also evidence, particularly from the United Kingdom, that communities were worried that FRe may mark their property as being at risk and thus possibly affect its saleable value. During the course of the research, manufacturers were refining products in response to these concerns, for instance, by developing flood doors that could resist floods yet looked like other doors on the market.

Community stakeholders indicated that they trusted 'expert' organisations, such as the government and the academic sector. However, their first introduction to FRe technologies was commonly through a product sales representative. Many community stakeholders were sceptical of the independence and veracity of the information provided by companies marketing FRe technologies. In this regard, research participants at both scales and National Support Groups identified a need for independent guidance regarding product procurement and use to help innovation reach maturity. Related to this knowledge vacuum, institutional fragmentation and unclear governance was identified as a significant barrier to action. It was widely suggested that there was a need for a leadership role, with an agency firmly given the remit and ability to coordinate, demystify and support the integration of FRe technologies.

The process of enabling innovation was also touched upon. Here, the emergent nature of the market led to a finding from most workshops and National Support Groups that the state should play a stronger role. This encompassed a number of suggestions, such as subsidising property owners to install FRe technologies and supporting the manufacturers through reducing the costs of product development and testing. An effective flood risk assessment was also identified as a key stage to effectively match the risk to the technology.

In all of the case study countries, the insurance industry was identified as a particularly important agent. Insurers benefit from flood defences (Penning-Rowsell and Pardoe, 2012), a situation that logically may be replicated with regard to FRe technologies. Yet participants from the insurance sector on National Support Groups were sceptical about factoring these technologies into risk calculations, primarily due to ambiguity regarding how they may perform. Insurers wanted longer-term evidence of their effectiveness and potential contribution to loss reduction before determining the degree of discount they should warrant. They also indicated a need to instil greater confidence in the installation and maintenance of products; while they may work once fitted correctly, how could they be certain this would be consistent over time? In addition, while there was a broad agreement that where FRe was effective, it would be likely to reduce the costs of flooding, there was a lack of adequate cost-benefit analysis upon which decisionscould be based. For example, will it ensure a property remains completely dry or will there still be some ingress and associated (albeit limited) damage? Or which technologies are cheaper to purchase, install and maintain or are more reliable across an extended period of time? A final finding with regard to insurance was that in countries with state level comprehensive flood insurance, such as Spain and the Netherlands, a reliance on central compensation served as a clear disincentive to FRe product innovation and implementation (see O'Hare et al., 2015).

Discussion: enabling trust and best practice in an emergent sector

When compared to one another, certain case study countries from our sample could be said to be more comfortable with the use of FRe technologies, depending on issues such as their specific risk profile and institutional contexts. For example, flooding in the United Kingdom has become rapidly more skewed towards surface water events (Douglas et al., 2010; White, 2010, 2013), which has highlighted theneed for resistance and resilience in the urban area and helped FRe permeate professional discourse (e.g. Bowker, 2007; Entec et al., 2008; Ogunyoye et al., 2011). In addition, there is an active and vibrant product sector reflected in the marketing of technologies at expositions in both these countries.

Cultural and social factors are also at play; the public would much rather have protection away from their homes, and determined by the state, but can see how FRe can be useful, particularly for surface water events. In a related fashion, many community stakeholders preferred flood preventative measures to be located away from their properties. This reinforces similar research in the United Kingdom that demonstrated how institutional cultures can help large-scale engineered FRM approaches (Harries and Penning-Rowsell, 2011) or that the general public tend to prefer traditional hard defences over 'softer' schemes that work with nature (White and Richards, 2007).

Whilst the acceptance of FRe technologies as a theoretical option varied across the case study countries, practical doubts over when and how they should be used were universally expressed. There was a view from a number of professional stakeholders that the increasing use, and accuracy, of risk assessments is one of the factors that could facilitate an increased engagement with FRe, whether targeted at individual homes or as part of a wider strategy. This can ascertain factors such as the height and flow of a flood event, both of which can affect the optimum performance of FRe technologies. However, to be effective, they must be supported by an excellent local understanding of flood risk combined with knowledge of the application of FRe technologies. Furthermore, in a step that goes beyond the current scope of flood risk assessments, they should also consider social factors to ensure that the recommended options can be matched to the capabilities of users.

The development of standards and testing regimes for FRe technologies were considered a vital quality assurance mechanism for professional stakeholders and the general public alike, and attention was drawn to the British Standards Institution's (BSI) Kitemark in the United Kingdom or the Deutsches Institut für Normung in Germany that could provide assurances to homeowners, insurers and flood risk managers in charge of public funds (Connelly et al., 2015). In practice, however, there was confusion over which FRe technologies had been tested and the effectiveness of technologies when deployed in practice.

Reflecting on the data collection, it is clear that there are a number of factors inhibiting the small scale FRe technologies becoming integral to managing flood risk. Overall, the variety of challenges is indicative of an innovative technology that has only recently emerged and is struggling to fit into accepted governance structures and practices. For example, there is still a strong emphasis on floodplain and catchment management, with wider options such as retrofitting resilience less common. Critical aspects of FRM, including legislation, regulation and insurance practices, have been slow to incorporate the FRe approach. This may be due to existing practices and protocols derived from collective experience and learning (March and Olsen, 1984); powerful 'regimes' often maintain the existing status quo and, when they change, do so at a much slower pace than that of innovation (Geels, 2002; Smith and Stirling, 2007). Strategic decision makers, for example, voiced concerns about spending public funds effectively and needed to be confident that, if they do advocate FRe, it works. Significantly, both communities at risk and professional stakeholders tended to be unsure of the process to be followed. They were not confident about the correct uses of specific products, particularly given how risks and needs, from both a technical and social perspective, alter with time.

In sum, all of the stakeholder concerns can be considered to be centred on the meta-theme of trust (or lack thereof). This manifested itself as trust in the independence of manufacturing companies, trust in product performance and trust in risk assessments. Clearly, emergent FRe technologies (and other innovations that address disasters and climate change) need an operating structure to help them standardise and develop alongside capacity building for communities and professionals (Hedger et al., 2000; Tippett and Griffiths, 2007). The last section of this paper thus turns to the key output of the research: a framework to support FRe technologies as part of a holistic FRM strategy.

The six steps: building capacity in an innovative sector

Whilst there is a lack of trust in various issues relating to FRe, the research revealed that this is related to its rapid emergence. Promoting trust is a key component of building general societal capacity towards resilience (Lebel et al., 2006; Bach et al., 2015), but this may take time and requires careful appraisal of the role of experts working at the science–policy interface (Jasanoff and Wynne, 1998). A strong theme emerging from the research was that independent and trusted agencies can prepare guidance documents aimed at a range of stakeholders to help address the barriers to use. This finding supported the view of previous research into the factors that motivate people to play a role in managing their own flood damage prevention in Germany, which emphasised that clear communication of consequences and the opportunities to take precautionary measures was essential to enable change (Grothmann and Reusswig, 2006). In the United Kingdom, a voluntary Code of Practice was mooted to be a pragmatic solution that could take account of the political difficulty in pushing new regulation and the fear expressed by manufacturers that regulation could stifle innovation. Both local and strategic stakeholders cited the need for impartial guidance to help demystify the appraisal process and raise standards, expectations and knowledge.

Participants indicated that in an interdisciplinary research project (with commercial, policy and community partners), academic partners could be considered a trusted and independent organisation that could mediate between different stakeholders, their languages and concerns. This role may be regarded as a 'critical friend' (O'Hare et al., 2010) or to provide leadership (Bach et al., 2015). Given the complexity of integrating FRe into practice, there was a need to collaborate with a wide range of stakeholders, including governmental and local regulators and flood risk managers, product manufacturers, community flood resilience forums and the general public, with a view to coproducing good practice guidelines applicable for both the general public and strategic user communities and drawing upon both local and expert knowledge (Lane et al., 2011; Jasanoff, 2013).

Based on the UK workshops, and with the assistance of the National Support Group in the United Kingdom, six sequential steps were identified that encompassed the process of installing FRe measures for both project designers and end-users (Figure 4). Each step is underpinned by a recognition of the analytical framework outlined in 'Research approach and analytical framework' and is designed to increase awareness, acceptance and the decision-making capacity of actors involved in the procurement process. Step one provides guidance on understanding the risk, giving links to official maps and the nature of the threat in any particular area with caveats around their interpretation and fallibility. If this element suggests that there is a risk from flooding, then step two helps people plan a scheme, find out about the products and think about individual requirements. The following steps extend this process, providing support for the survey, design and installation stages of procurement, ending with a discussion of operation and maintenance. Though presented as a linear process, step six suggests a reassessment of the residual risk of flooding that provides a 'feedback' link back to the initial considerations.

At the request of research participants, the guidance is simple, neutral and, via web links, provides more detail and references if required.[i] Since launching in the United Kingdom, the Six Steps to Flood Resilience has been endorsed by the Association of British Insurers, the Department for the Environment, Food and Rural Affairs, the Environment Agency, the Flood Protection Association (then the sector's industry and trade representative), the Local Government Association and the National Flood Forum. It has also influenced policy and practice, including the 2014 update of FRe standards by the BSI (BSI, 2014).

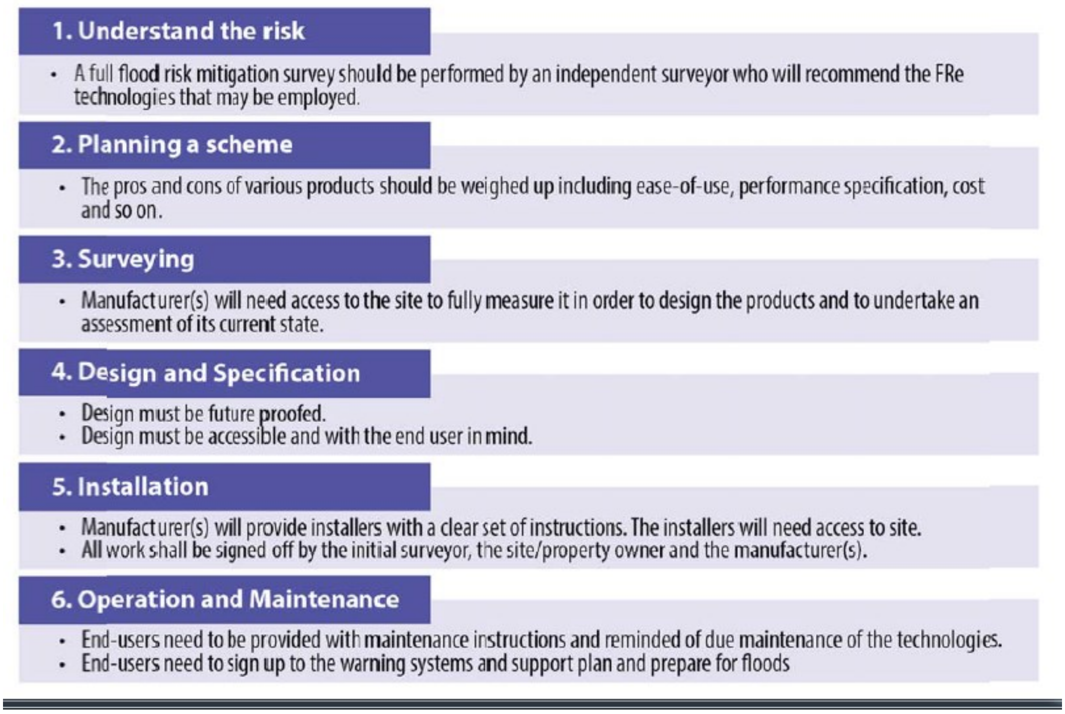

Figure 4 The recommended 'Six Steps' process for FRe (White *et al*., 2013).

Beyond this guidance, a number of further measures could be taken to help instil trust in the efficacy of flood protection products and the sector more generally. This includes the continued collection of the best available data for risk assessment that, given the wider responsibility of new actors and agencies, should be freely available and easily understood. Furthermore, products need to be presented in a way that allows decision makers and end-users to easily compare their performance and appropriateness for given circumstances. This should be combined with the continued sharing of good practice on surveying and installing features. Responsibility for maintaining and financing technologies should be negotiated and articulated in a clear and transparent manner. Finally, social equity issues may also be a factor. Where capacity to install property owner resilience is found to be lacking (for instance, because certain sectors of society are less able to install, maintain and use products), support could be provided in order to manage this vulnerability (Bichard and Kazmierczak, 2011). The guidance was developed for the UK market; however, the core concept (based on the Six Steps) may be transferable to other national contexts.

Conclusion

FRe technologies hold considerable potential to contribute to the management of flood risk by mitigating its weaknesses at smaller spatial scales and contributing to managing specific vulnerable locations or buildings. Its benefits are related to three interconnected reasons: the ability to address uncertainty; its potential to minimise impacts; and in facilitating the capacity to adapt to flood risk. That said, it should also be noted that FRe clearly faces a number of constraints, perhaps even related to the entire premise and justification for the use of technology that may require payment by homeowners. There is, therefore, a need to not just demonstrate the performance and maintenance of products but also to reconcile the reluctance of actors and agencies to assume ownership of, and responsibility for, managing risk. Across the countries surveyed there is a strong perception that flood defence should be provided by the state, a situation supported by the general lack of policies in support of FRe. The research also confirmed a general lack of incentives by key agencies, such as municipal authorities, planners, flood risk managers and the insurance industry, to promote the development and the deployment of these innovative technologies. Moreover, both FRM professionals and the general public lack awareness and are in broad agreement on the need for education and capacity building with regard to FRe.

Ultimately, while technologies exist and, in some cases, have been brought to market, greater emphasis must be placed upon understanding their integration into local and strategic contexts. Innovation needs support in order to break through cultural and managerial norms in managing flood risk. The guidance discussed here has attempted to demonstrate how a collaborative approach can identify and explain the key steps. Such coordination is also required to ensure that disadvantaged members of the community benefit from these measures and that FRe measures avoid creating unintentional impacts downstream.

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[i] 1More information on the Six Steps, including downloads of the guidance, is available at http://www.smartfloodprotection.com