Beyond Behavior Change

Household Retrofitting and ICT

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***Abstract*— Sustainability research about using Information and Communications Technologies (ICTs) to reduce household energy consumption has recently focused on two potential strategies: "smart homes" that rely on sensors and technological innovations to automatically reduce the energy load, and tools that seek to persuade users to change their domestic habits, such as by using eco-feedback devices to raise awareness of the amount of energy used. We propose that there is another approach: support and encouragement of existing best practice within a community to spread it more widely. One such practice is household retrofitting: the installation of domestic environmental technologies (DETs) such as increased insulation, energy efficient boilers, or renewable energy that serve to permanently reduce energy use in a household. We have developed a smartphone application to be used in conjunction with retrofitting open-home events that assists organizers in tracking their event's impact, whilst also helping users in the decision-making processes that surround retrofitting. This paper provides an overview of the app development process and initial results from in-the-wild testing, whilst also identifying potential areas for future research.**

***Index Terms*—Retrofitting, smartphones, community learning, applications.**

I. Introduction

When considering how technology can be used for energy efficiency, it is not uncommon for thoughts to turn to "intelligent" devices, from smart meters [1] and thermostats [2], to overall smart homes [3], where it is the technology that is responsible for energy reduction. Coming at the problem from another direction, the discipline of human-computer interaction has increasingly turned to tackling questions of sustainability with a focus on altering aspects of behavior [4][5][6]. Such systems typically try to persuade individuals to change habits surrounding energy use [7], e.g. boiling only the water required rather than filling a kettle completely [8], or using awareness of energy expenditure to lower household usage [9][10][11]. Behavior changes such as this adhere to a philosophy of "every little helps"; for example, turning off radiators in unused rooms can save up to 4% of the energy used for space heating, and lowering a thermostat from 19 to 18^{o} C can yield potential savings of approximately 13% [11]. While such changes are certainly worth pursuing, De Young [13] and Brynjarsdóttir et al. [14] highlight the difficulty in ensuring that these behaviors are carried out on a long-term basis. In particular, Brynjarsdóttir et al. [14] argue that:

> "Although individual behavior change *may* be *one* means for instigating a sustainable society, it is not the only means. Turning off lights, unplugging unused appliances, and conserving water are all important. But focusing only on simple acts sidesteps more difficult lifestyle choices that may in fact be necessary to work toward a more sustainable society."

Indeed, we feel that there is a middle ground between these two strategies that can serve as a permanent way to reduce domestic energy use: retrofitting. In standard use, retrofitting is an amorphous term that encompasses a wide range of potential home interventions, from the relatively effortless and inexpensive (draught proofing, insulating hot water pipes and tanks), to the more costly and specialized: installation of high-spec double or triple glazing; insulation of solid walls, cavity walls, floors, and lofts; heat pumps; and solar thermal and solar PV systems. Once installed, these interventions can yield potential energy savings of 45-80% annually [15][16].

Unlike the isolated behavioral changes often tackled by persuasive technology [14], retrofitting is a one-time intervention in which the focus of energy saving shifts from an individual's behavior to the physical fabric of the building itself. As a result, it sits at the curious intersection of sustainability through product consumption, requiring present expenditure for future monetary savings, and trades current disruption and inconvenience for the hope of future thermal comfort. The installation of many retrofitting measures has more in common with the decision-making processes found in the purchase of "big-ticket" items: one-off decisions that are consciously considered and weighed up. Furthermore, retrofitting is an action that can be divorced from the behavior of the individuals who inhabit a residence, e.g. some local councils have installed solid wall insulation to improve their housing stock, which provides benefits to the current occupants in terms of lower energy bills and a warmer home, but it does not necessarily impact how they live within the space.

A number of community initiatives have sprung up across the UK in an attempt to help householders and builders learn more about the options involved and the retrofitting process itself. Many do this through "eco-home open days", where households who have already installed retrofitting measures

open their doors to the public, allowing visitors to see the measures in action and hear a first-hand account of both the benefits and potential problems involved in retrofitting. Such face-to-face, personal contact can undoubtedly be beneficial: personal recommendations have long been recognized as an important method of encouraging purchases or behavior as they can provide reassurance in a choice or present a way of life to aspire to [17] [18].

Although the personal contact experienced during the open days is the driving force behind such programs, there is a gap that can be filled by ICT to enhance and support the work of these local initiatives. Partnering with one such organization, Bristol Green Doors, we sought to explore how digital technology could be used to benefit the visitors and organizations themselves through a project called Digital Green Doors. This paper provides an overview of two strands of research: (1) in order to understand the barriers to the uptake of retrofit technology we conducted interviews with environmentally-motivated individuals who had not retrofitted their homes; and (2) the development of a smartphone application that seeks to help overcome these barriers and encourage the adoption of retrofitting. The app was tested in the wild at an open home event, and some of the initial findings are also presented here.

II. Barriers to Retrofitting

Seven individual householders responded to requests placed in the online newsletters of local sustainability and transition groups that asked for the participation of those who had considered installing retrofitting measures, but had not yet made any firm plans or purchases. They were interviewed about why they were unable to proceed with the retrofit, despite being strongly motivated to do so. The reasons given for the inability to proceed are similar to findings discussed in a working paper for the Tyndall Centre for Climate Change Research [19], which identifies three general categories of barriers: informational, cognitive, and financial. This section will discuss the following barriers:

1. Lack of reliable information (informational);
2. Information processing (cognitive);
3. Difficulty in finding a trusted builder to carry out the work (informational);
4. Uncertainty regarding the householder's living situation (informational);
5. Disruption (informational);
6. Cost (financial);
7. Social norms (informational).

Being aware of what options are available and which will have the desired impact for a given property were frequently mentioned. As one interviewee stated, "I think that the main challenge for me has been knowing what sort of retrofitting would make a difference." In a related vein, participants cited trouble finding clear, non-technical information.

This is similar to responses in a 2010 Refit West survey [20] in which participants commented, "We found the gathering of information a headache, as detailed guidance was not readily available," and "We had been racking our brains (i.e. trawling the internet!) trying to find out how we could deal with the walls. Unfortunately we were just getting more confused by the technical stuff which came up." This highlights the cognitive burden that is associated with searching for and processing the resulting information [19].

Participants also mentioned that they had trouble finding contractors they had confidence in. Because many of the techniques and technologies are new or seldom employed by builders, there is confusion regarding which is the "right" method and who can be trusted to carry it out:

- "There is a lot of information on the web, but it is difficult to take in and to know what is good advice and what's not. You can talk to contractors and some do seem to have a lot of knowledge but you can talk to three different contractors and get different takes on the situation."
- "Where can I get advice on what to do regarding retrofitting? Unbiased advice that I can trust from a reputable source, advice that makes it easy for me, doesn't take me too long, doesn't cost me or doesn't cost me too much, and won't lead to recommendations I can't afford. Is this asking the impossible? Maybe, but that could be what it takes for me to getting round to a retrofitting project right now."

The rational choice theory states that behavior is "the outcome of rational deliberations in which individuals seek to maximise their own expected 'utility"' [21]. A form of this was expressed by householders despite their environmental leanings: if the payback period was too great, householders did not feel that retrofitting was worth carrying out. This was often coupled with uncertainty about how long the householder would remain in the home; if they believed they would potentially move, householders expressed reluctance to plan a retrofit project.

The final barriers—disruption and finances—are perhaps the most difficult obstacles to overcome as it is not possible to avoid the installation process and costs involved. PlanLoCaL (Planning for Low Carbon Living), a division of the Centre for Sustainable Energy, refers to the disruption and inconvenience that retrofitting can cause as "the hassle factor". Minimizing this can lead to greater uptake; for example, trials run by the Cabinet Office Behavioural Insight Team (COBIT) found that offering a loft clearing service lead to four times as many installations of loft insulation [22]. It was found that the importance of "making things easy" could not be underestimated, and this was also borne out in the participant interviews:

- "As someone who works in the sustainability field, knows a lot about climate change, etc., it is amazing how little I have done to reduce my own carbon footprint. The principal reason is probably financial; I don't have money to spare."
- "Cost and disruption/inconvenience are the two factors which by far outweigh any other considerations. Even with sufficient knowledge and information (gained from research online and in person) to make the decision it's difficult to justify spending the capital to insulate. And then, if we could bring the costs right down (particularly as I'm not in favour of financing) it's difficult to see how we

> could overcome the huge disruption involved in undertaking the work. It's the kind of thing I could see doing if I had just purchased a property and where renovating it but not otherwise."

A general obstacle among the wider population, e.g. those who are not intrinsically motivated by the environmental benefits, is that retrofitting is not seen as a "normal" home improvement [19]. This particular barrier leads to the lack of uptake in retrofitting to become a self-fulfilling cycle: retrofitting is not viewed as being a mainstream home improvement, and therefore it is not carried out on a regular basis, preventing builders from gaining experience and reducing its visibility within a community.

ICT has the potential to assist users in overcoming many of the informational and cognitive barriers discussed. This is discussed further below regarding the design of the Greendoors app.

III. The Greendoors App

Bristol Green Doors has arranged open home events in Bristol since 2010, running an open weekend approximately every 18 months. The third event was held 28-29 September 2013, and the first iteration of the Greendoors app was developed for testing at this time. The Digital Green Doors team presented at a householders' meeting several weeks prior to the event to explain the purpose of the app and to encourage householders and event volunteers to familiarise themselves with it.

The app was advertised through existing Bristol Green Doors and University of Bristol publicity channels prior to the event, and leaflets explaining the app were also available at all of the participating houses. As a result of these methods, 46 users downloaded and registered the app before the event, and 44 during the open weekend itself.

We did not wish to distract from the event itself, and therefore evaluations (28 online questionnaires and 7 semi-structured interviews) were conducted afterwards with consenting participants. Members of the Digital Green Doors team were also available during the weekend to provide assistance and made note of initial comments from visitors. A full analysis of the results is currently underway, but initial qualitative comments are discussed in the individual features below.

A. A Note on Privacy

All of the participating households apply to take part in the Bristol Green Doors open weekend, and those who are accepted for inclusion agree to their house address appearing on a printed leaflet. However, some hesitation was expressed about appearing on an app. To ensure that the privacy needs of householders were met, inclusion in the app was done on an opt-in basis, and two houses chose not to take part. The remaining 30 householders were given the option to appear on the app for the duration of the event and either a month or a year following. Householders were given the same options regarding whether users could contact them via the app's anonymous messaging system. This raises several points in need of further investigation: how and why do trust levels vary between virtual and physical media, and what methods can be utilized to increase trust?

TABLE I.

Householder Participation in the Greendoors App			
	Opt-out	*One Month*	*One Year*
Map	2	6	24
Contact	8	6	18

IV. App Design

At its heart, the Greendoors app is a mapping application that allows the user to pinpoint the location of participating houses and gain an overview of the prevalence of retrofitting within a community. The additional features—favorites, filtering, notes, messaging, and scanning and saving—were selected based on brainstorming sessions with key stakeholders, which included event organisers and householders. PlanLoCaL's exhortation to "make things easy" was also at the forefront of the design process. For example, the filtering and saving functions allow users to quickly focus on the houses they wish to visit during the weekend.

A reoccurring theme of the brainstorming sessions was the desire for Bristol Green Doors to do more to get its message to the public beyond the open weekend. This is especially important due to the nature of retrofitting and open home events. Householders often decide to investigate the potential for energy saving technologies during existing home improvement projects, but most events are held on an annual basis. Householders in the middle of renovations who wish to gather personalized information have nowhere to turn if they do not know anyone with retrofitting experience. Being able to contact another householder, or simply see what retrofitting has been undertaken at nearby homes, can be a valuable starting point.

A. Registration

The app could be used without registering, but only basic functionality was supplied in this instance: users could access the list and map view, and the filters. Those who registered with an email address were able to bookmark houses, take notes, contact householders via email, and scan QR codes to produce a personalized report.

B. Map/List/Detail View

The primary form of publicity for Bristol Green Doors is a locally distributed map leaflet that provides the addresses of the participating houses and an overview of the measures they contain. However, it is schematic rather than functional for navigation. Therefore a mapping application pinpointing the houses served as the base for the Greendoors app, and users could also view a list of the houses and their addresses, as well as a list of the measures each house had installed (see Fig. 1).

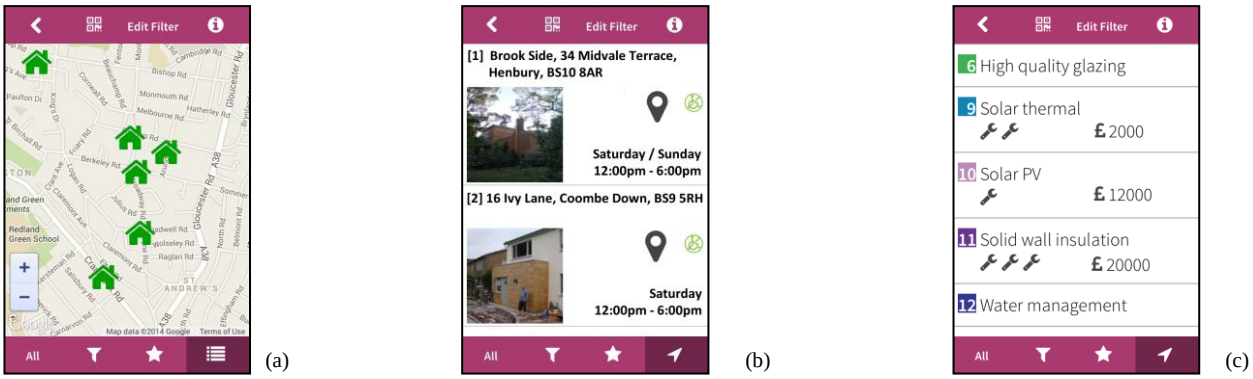

Fig. 1. The mapping view (a), list view (b), and over view (c) in the first iteration of the Greendoors app. The map marker icon seen in (b) centers the map on the chosen property. The user interface design adheres to Bristol Green Doors branding in order to provide a consistent experience across paper leaflets and the existing website.

- "I thought the list and info provided was excellent. It enabled me to be selective and visit the houses where the house and / or improvement was relevant to me."

In addition to navigation, there are a number of advantages to providing a digital map. From a practical perspective, the app can be easily updated at the last minute with the most current information; for example, two houses dropped out after the map leaflets had been printed, which may have confused some visitors. It is not possible to tell simply by looking at a house whether it has installed energy efficiency measures, and the mapping functionality also serves to make retrofitting visible in a community in a way that it may not be otherwise.

This could potentially be expanded to include previous Bristol Green Doors participants to help illustrate the growth of retrofitting as new houses are added annually. Doing so would help show that retrofitting is becoming a mainstream home improvement, which may encourage greater uptake. Using social norms to promote environmental behavior is well established [23][24][25][26][27], and future research may involve whether drawing explicit attention to such norms can also encourage retrofitting actions.

The screen shown in Fig. 1 c provides an overview of the retrofitting measures installed at a particular house, along with the level of disruption (1-3 spanners) and installation cost. While the level of disruption is based on the householder's subjective assessment, this information is a starting point to help visitors realistically assess the installation of retrofitting measures. Although not pictured in the above illustration, the overview also provided details about the property such as age and size to allow users to see what is possible at a particular type of house. Such features are a step to help lower the informational barriers would-be retrofitters encounter.

C. Bookmarking

Users had the opportunity to "star" or bookmark specific houses to create a shortlist. Positive feedback was received during the event, with app users reporting that they used the feature to save the houses they planned to visit. This feature is a simple way to allow users to focus on specific houses and "made things easier" for visitors during the event itself.

- "This enabled me to make a shortlist of houses to visit."

A common suggestion for improvement regarding this feature was to ensure the user could identify their saved houses as a glance, rather than through a separate listing. This modification will be added to future versions of the app:

- "I think it would be helpful if it was possible to quickly identify saved houses when looking at the list of all houses (without the necessity of going to the list of saved houses) just so that you know which of them have already been saved."

D. Filters

In a similar way, a basic filter function allowed users to select which measures they were interested in and only view the houses that contained those measures. Preliminary feedback from visitors during the weekend was favourable as it allowed them to focus on the specific retrofitting technology they wanted.

- "This was the best bit about the app - it gave me an easy way of sorting through the information and displaying it in a way that was easy to interpret."
- "Brilliant! I know I was looking for floor solutions this year. This enabled me to do just that."

However, several expressed a desire for finer gradation, and it is intended that future versions of the app include further options such as age of house, number of bedrooms, and location (i.e. specific neighbourhoods). This will allow users to see what retrofitting measures are possible in houses that are similar to their own.

- "Would be good to be able to pick an area, e.g. Henleaze, and list all properties in that area and then maybe a further list of properties in neighbouring areas. That would make it easier to see properties in our area without travelling too far."

E. Contact

Householders from previous Bristol Green Doors events have reported that visitors have stopped them in the street or appeared on their doorstep with queries after the event. While

many are happy to provide help, it was preferred that contact be less obtrusive. Weeks' et al.'s "Power Law of Engagement" [28] highlights the vital role that Validators and (Energy) Masters can potentially play within a community to encourage retrofitting, and therefore providing a platform to connect such householders with others was deemed necessary. As a result, an anonymous messaging system was set up within the app to allow users to email questions to householders who agreed to be contacted.

Despite interest in the feature, it has only been used once to date. Initial results are pointing to a simple lack of understanding that the feature remained available after the event. While not face-to-face, it is hoped that this would allow the mission of Bristol Green Doors—connecting householders to those interested in retrofitting—to continue beyond the open weekend.

- "I didn't need it on the day or since but would have used it if I wanted clarity about something."
- "I downloaded the app just before the event and thought it was too late to use this function."
- "I might use it to contact one of the householders now you've drawn my attention to it."
- "I would have [used the contact feature] if I'd known about the app earlier. It's a great idea!"

F. Notes

Visitors had the opportunity to write and save notes about the house and its measures for later reference. This was also an underutilized function during the initial trial, with only one visitor taking advantage of it. However, the response was favourable:

- "It was an easy way of recording interesting info provided by the home owners, and the fact it was then included in the report meant it formed part of the overall info on each property. Excellent function."

Initial evaluations indicate that there are two contributing factors to the lack of use: the difficulty in typing on smartphones, and a lack of awareness about the function:

- "Next time I'll use the iPad I think because it's much easier to use and easier to take notes as well."
- "Typing on the phone is tiresome."
- "I wish I had realised there was one - I could have note the useful contact details I was given there, instead of on a scrap of paper which I lost."
- "I'm still a bit of a Luddite so would be more likely to take a pen and pad with me, but would use it if I had forgotten my pen!"

This highlights an issue that must be taken into account for future developments of Greendoors or similar apps: different purposes may require different platforms. The size of the average smartphone can make conducting in-depth research difficult, and instead smartphones may be better suited to collecting data for later perusal on a laptop, desktop, or tablet.

Fig. 2. An example of a QR code used during Bristol Green Doors. The number on the right refers to the house's event number.

G. QR Codes (Scan and Save)

Increasing post-visit engagement has long been a goal of venues such as science centres and museums [30]. It was decided to trial similar techniques in a home setting by utilizing Quick Response (QR) codes. QR codes are becoming increasingly common as a method of advertising, and have also been employed as a way of collecting location-based information [31]. Yet rather than quick, we sought to provide a delayed response: the information associated with the scanned code would be collated and provided to users to peruse in their own time after the weekend. This filled the dual purpose of making information gathering easier for visitors by serving as a post-event reference, and also measuring the impact of the Bristol Green Doors weekend by providing trackable hyperlinks to products and suppliers.

Each retrofitting measure at the participating houses was given a specific QR code (see Fig. 2). When scanned by the Greendoors app, it is saved to the user's account. A personalized report containing information about the scanned measures is then emailed to the user after the event. During the trial, this included data about the measures–the cost, the level of disruption, and the supplier or product–and details from the householder, such as what difference the measure has made or what they wish they had done differently when it was installed (Table II). Links to general information about the category of measure were also included as a way of presenting a "pre-approved" shortlist of references to prevent users from feeling overwhelmed by the number of available sources. All of the links were trackable in order to measure visitor's actions after the event. Of the 90 who registered the app, 37 used the QR codes to generate a report (41%), and 12 of these followed at least one link from the report. Additional research is needed to determine whether any of those who produced a report subsequently made a retrofitting or energy efficiency purchase.

QR codes were initially chosen as the method of saving details about retrofitting measures because they are easy and inexpensive for eco open home organisations to generate, and were thought to be familiar to smartphone users. This was borne out, with 60% of users reporting that they had previously used QR codes. However, on the weekend itself, two problems developed. First, familiarity proved to be a double-edged sword as those who understood the purpose of QR codes tried to save them with their normal QR scanner,

rather than the scanner incorporated within the Greendoors app. This was then incompatible with the production of the personalized reports. As a result, initial feedback has been mixed, and better user education is needed for this feature to live up to its true potential. Future versions will offer an invitation to the user to download the app if a Greendoors QR code is scanned with a standard scanner.

Another issue that may have affected users' responses to the reports is the amount of information provided at particular properties. Not everyone was willing to share details about their house, leading to gaps in the report that may have caused users to have a negative perception of this feature. This is discussed further in the "Unexpected Obstacles" section below.

TABLE II. This is an example of the details provided through the personalized reports. Feedback from the householders was collected prior to the event, and links to the products, suppliers, and general information were trackable.

Solar PV	Product / Supplier	Cost	Disruption
House 2 "Our site is shady and hasn't generated much electricity (2500kwh in 3 years). My sister installed a slightly more expensive system on her roof at around the same time (us 8 panels; £8.5k; her 16 panels; £11k) and has now generated 7500kwh! So don't install PV panels on a shady site. Long story as to why we did, but it wasn't worth it."	Tigo Optimiser / Dulas, the commercial arm of the Centre for Alternative Technology	£8500	Low
House 8 "Get as big a system as your roof can take. Be careful about inverter as kids get annoyed by the high frequency sound."	Navitron / Solar Sam	£9000	Low
For more general information about Solar PV, please see the following websites: • Bristol Green Doors: http://www.bristolgreendoors.org/next-steps/solar-energy • Centre for Sustainable Energy: http://www.cse.org.uk/advice/renewable-energy/solar-pv • Energy Saving Trust: http://www.energysavingtrust.org.uk/Generating-energy/Choosing-a-renewable-technology/Solar-panels-PV Concerned about finances? You might also be interested in: http://www.energysavingtrust.org.uk/Generating-energy/Getting-money-back			

V. Findings

The overall response to the app was positive, and many of the features worked as intended to simplify and support the user's visit:

- "Excellent app (and excellent event). Didn't have time to explore it properly as only found out about the event the day before. Also fairly new to a smartphone so not using it to its full potential yet. Hope it will be available next year."
- "Impressive app that I think will prove to be a big benefit to the Green Doors event. Looking forward to trying app again next year now that I understand what it does."
- "As a complete novice it seemed great and easy to use. I am sure I could have got more out of it had I been more 'app' literate although it seemed pretty intuitive even for me!"

Yet complicating the Digital Green Doors project is the demographics of the householders and many of the visitors: they tend to be older individuals who do not have smartphones. As hinted at in the comments above, those with smartphones during the event tended to admit unfamiliarity with their device, including one user who had never previously downloaded an app. However, this should not be viewed as a barrier, but rather an opportunity to ensure that the technology is perfected before a greater number of would-be retrofitters attend eco-home events.

A. Unexpected Obstacles

To be successful, eco-home events like Bristol Green Doors are reliant on members of the public willing to open their homes to visitors and share their experiences about the installation of retrofitting measures. In a similar way, the Greendoors app requires householders to share information– the app and reports are only as good as the data provided by the householders. Yet one unforeseen problem that occurred in the app's development was the difficulty in obtaining these necessary details. Whilst the initial brainstorming sessions involved vocal, enthusiastic proponents of retrofitting, getting data from *all* participants, such as level of disruption, cost, and a sentence or two about each measure, proved very time consuming and, at times, impossible.

Indeed, one householder dropped out of a subsequent eco-home event when asked for information, saying that there was no "consideration for participants' own priorities." Another threatened to do likewise after completing an online data collection form, despite the questions being similar to those asked by visitors during the event: "If I had known I had to do this [form], I might not have offered to open my home." The underlying assumption that householders are intrinsically motivated by a desire to share their experience must be re-examined, and there is a need for further investigation about how ICT can be used to potentially motivate householders and collect the vital data.

VI. Next Steps

Evaluations and interview transcripts are to be further analyzed, but these have already uncovered unexpected results. For example, one user described that while she was

unable to visit the houses over the Bristol Green Doors weekend, she turned to the app as a reference tool when a relative's boiler broke down. She saw that the majority of the low-energy households used a combi-condensing boiler, which she recommended and her relative then purchased. This clear connection between the use of the app and the installation of an energy-saving measure highlights an unintended benefit, and one possible option will be to investigate how the app's potential as a reference tool can be enhanced.

During the Bristol Green Doors open weekend, some visitors were observed using their smartphones to photograph the information provided by householders and the retrofitting measures. This was supported by a visitor requesting "Maybe a voice recording option? Ability to capture pictures?" on the online questionnaire. Future versions of the app could include camera functionality, as well as greater crossover with web services to allow users to collect information about their potential retrofit in one place. Such use would fit well into Wilson et al.'s approach of a "one-stop shop" to help ease the barrier of cognitive burden [19].

Based on the results of the trial run at the Bristol Green Doors, a new iteration of the app is currently under development for testing at a second event, Frome Open Homes. This latest version seeks to polish and refine the original app, both in terms of practicalities such as app speed, as well as the addition of further features based on the initial user feedback. For example, a key new feature desired by users was routing so that they could see directions from their current location to the house they wished to visit. Whilst this was originally discussed in the brainstorming session, there was no time to implement it before the September event:

- "I think it would be very useful if the app could navigate the user to a house."
- "Be able to give directions from your current location to your chosen house. Be able to tell you which house with your chosen feature is closest to you."
- " 'Direct me to…' option."

Some users also expressed confusion about the existing features of the app, such as misunderstanding the icons; however, these users also admitted not looking at the instructions for further assistance. The latest version of the Greendoors app attempts to negate this by providing users with a brief tutorial when they first sign in. It is hoped that such changes will ensure that the Greendoors app is able to successfully appeal to a larger audience at future eco-home events and on a national level.

VII. Conclusion

VIII. Sustainability through ICT in the field of HCI often centers on using technology as the sole intervention, typically with the goal of changing behavior by raising awareness or being persuasive. Yet there is a need to look beyond using technology in only these ways, and instead see it as a highly adaptable tool that can be deployed in a variety of ways, from assisting existing programs to eliminating barriers to sustainable practices. This paper has shown how one such approach, the Greendoors app, has been used to support visitors to eco-home events in collecting information about retrofitting, while also helping the organisation track the event's impact. In this way, the technology has become part of a supporting framework, rather than a device single-handedly trying to achieve the aim of energy reduction. Pro-environmental organisations can benefit greatly from such an approach, whether through crowdsourcing [32] or sharing current best practice as outlined here.

However, our work has also shown that there is still much research to be done. For example, obtaining the support of householders who have already installed retrofitting measures was initially thought to be "preaching to the choir." However, our investigations have shown that a holistic approach is required if ICT is to be successfully deployed at an open home event; in this case, methods are needed to ensure that householders are fully on board with the technology and that data collection is as painless as possible. Increasing the level of trust in digital methods of disseminating information is also required, and consideration of privacy concerns must be kept paramount.

For retrofitting to move beyond these early adopters, it needs to be seen as just another home improvement. Having a smartphone app about a retrofitting event may not only make it appear normal, but can also serve as a way to make retrofitting visible within a local community. The effect that this illustration of social norms may have, and how to positively enhance the effect of such norms, is also worth exploring further.

By trying to make the information gathering process as easy as possible, the Greendoors app may allow the identified informational and cognitive barriers to retrofitting to be overcome, or at least minimised. In this situation, doing so does not necessarily involve changing behavior or changing minds, but instead harnessing the power of technology to turn intention into action:

- "It was the difference between me taking part in the event and not. I wouldn't have had the time to engage with the booklet or read through information online. This made everything simple for me."

Acknowledgment

This work was funded by UK Research Council Digital Economy grant number EP/K012509/1. We would like to thank the householders, visitors, and event organizers for their contribution in helping the Greendoors app take shape.

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