Preparing to Repair: Using Co-Design and Speculative Design Methods to Explore the Future of IoT Right-to-Repair with Citizens and Communities

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Abstract
In an effort to stymie electronic product obsolescence, the UK government introduced the *Eco-design for Energy Related Products and Energy Information* regulations, commonly referred to as the *Right-to-Repair*, in July 2021. Mirroring the European Union's 2020 *Circular Economy Action Plan*, manufacturers are now required to integrate a degree of repairability into certain electronic products sold within the UK, as well as supply their replacement parts for ten years after production. However, this still does not create an equitable form of *Right-to-Repair*, as the regulations capitulate to manufacturer sanctioned repair services, rather than helping to foster innovative, citizen-oriented cultures of repair.

Importantly, the *Right-to-Repair* also only applies to a limited range of household products and does not account for the rapid increase in the unsustainable consumption and disposal of networked or so-called 'smart' *Internet of Things* (IoT) devices. This is despite ever greater volumes of *electronic waste* being characterised as IoT – it is estimated that by 2030, there will be over 25 billion globally active smart electronic devices. Furthermore, smart phones, voice assistants and wearables can easily become 'bricked' when their physical hardware no longer supports digital updates such as the latest software.

This paper outlines initial research which begins to explore how design approaches can be harnessed to better understand how citizens' might be empowered to increase IoT device *Right-to-Repair* within their local communities. Our work was carried out as part of a funded design research project which seeks to identify sustainable and equitable pathways that challenge the top-down hegemony which currently characterises IoT *Right-to-Repair* policy and practice.

To investigate these possibilities, the research team collaborated closely with *The Making Rooms*, a community makerspace and the eminent creative hub for digital innovation and fabrication in the North-West of England. The paper firstly discusses how we designed and delivered two *co-design* workshops (Sanders & Stappers, 2014), during the second of which we introduced *Right-to-Repair speculative design probes* (Tsekleves, et al, 2017). Secondly, we use *thematic analysis* techniques (Braun & Clarke, 2006) to map the collated workshop data. Thirdly, we discuss an initial vision for a local IoT *Right-to-Repair* ecosystem as co-created with participants. We conclude that our initial findings begin to contribute to growing discourse calling for community adaptation towards *Circular Economy* principles (Ellen MacArthur Foundation, 2021) to redress national and international e-waste issues.

Author keywords
Right-to-Repair; Internet of Things; E-waste; Social Innovation; Circular Economy; Sustainable Futures

Introduction

As the consumption of *Electrical and Electronic Equipment* (EEE) continues to grow, so too does the volume of *electronic waste* (e-waste) reaching global landfill sites. In 2019 alone, the world generated 53.6Mt (million tons) of e-waste, a figure which is expected to grow to 74.7Mt by 2030 (Forti et al, 2020). Across Europe for example, less than 40% of e-waste is subject to sustainable recovery, that is, 'post-lifespan' processes such as material recycling and reusable component harvestry (EC.Europa.EU, 2021). This unsustainable growth is reinforced by planned obsolescence – which is to say that devices are purposely designed to have short lifespans and be quickly usurped by newer models and lack specification for long-lasting repair (Remy & Huang, 2015; Cooper & Salvia, 2018).

In an effort to stymie electronic product obsolescence, the UK government introduced the *Eco-design for Energy Related Products and Energy Information* regulations (Conway, 2021), commonly referred to as the *Right-to-Repair* (R2R), which came into effect on 1st July 2021. Importantly, the current R2R also only applies to a limited range of household products and does not take into account the growing environmental and social impacts that result through the unsustainable production, consumption and disposal of billions of networked and so-called 'smart' *Internet of Things* (IoT) devices like phones, fitness wearables and home voice assistants (Stead & Coulton, 2022).

This paper outlines initial research which begins to explore how design approaches can be harnessed to better understand how citizens' might be empowered to increase IoT device R2R within their local communities. Our work was carried out as part of a funded design research project which seeks to identify sustainable and equitable pathways that challenge the top-down hegemony which currently characterizes IoT R2R policy and practice.

To investigate these possibilities, the research team collaborated closely with *The Making Rooms*, a community makerspace and the eminent creative hub for digital innovation and fabrication in the North-West of England. The paper firstly discusses how we designed and delivered two *co-design* workshops (Sanders & Stappers, 2014), during the second of which we introduced R2R *speculative design probes* (Tsekleves, et al, 2017). Secondly, we use *thematic analysis* techniques (Braun & Clarke, 2006) to map the collated workshop data. Thirdly, we discuss an initial vision for a local IoT R2R ecosystem as co-created with participants. We conclude that our initial findings begin to contribute to growing discourse calling for

community adaptation towards *Circular Economy* principles (Ellen MacArthur Foundation, 2021) to redress national and international e-waste issues.

Right-to-Repair

Legally and ethically complex, the current UK R2R legislation mirrors the EU's C*ircular Economy Action Plan* (2020). The legislation's key proviso is that manufacturers must begin to integrate degrees of repairability into certain electrical/electronic products that they produce and sell, as well as supply replacement parts for said products for at least ten years after manufacture. Whilst these stipulations might appear progressive, UK citizens' R2R and reuse the products they have purchased is still impeded as the legislation only sanctions 'authorised' third parties to carry out repair work. Furthermore, the R2R does not ensure that spare parts and repair services will be affordable nor that consumers will have access to the information they require to personally carry out repairs themselves (Peake & Vallauri, 2021).

Importantly, as illustrated in Figure 1, the law's focus is also restricted to six specific types of products (Which?, 2021). The legislation currently ignores the growing volumes of EEE being characterised as IoT products – physical electronic objects which have in-built Wi-FI, sensor and software capabilities. These products can connect and transmit data to and from internet platforms/services as well as with fellow internet-connected devices. It is estimated that by 2030, there will be over 25 billion physical IoT devices being actively used worldwide (Von See, 2021). Unfortunately, due to the way they are presently designed, IoT devices can easily become 'bricked' (inoperable), when their hardware physically breaks or they can no longer support digital updates such as the latest software (Stead, Gradinar & Coulton, 2020). Consequently, billions of IoT devices will likely end up in landfill sites as e-waste.

Thus, whilst the law requires manufacturers to begin to (re)design products for repairability, it does not create an equitable form of R2R. The regulations capitulate to manufacturer supplied parts and approved repair services, rather than helping to foster innovative, citizen-oriented cultures of repair. The latter, Perzanowski (2022) asserts, is crucial for modern societies because as *'we diagnose and fix the things we own, we are reconfiguring our interactions with the world around us… we are refining our understanding, developing new skills, and strengthening social ties within our communities.'*

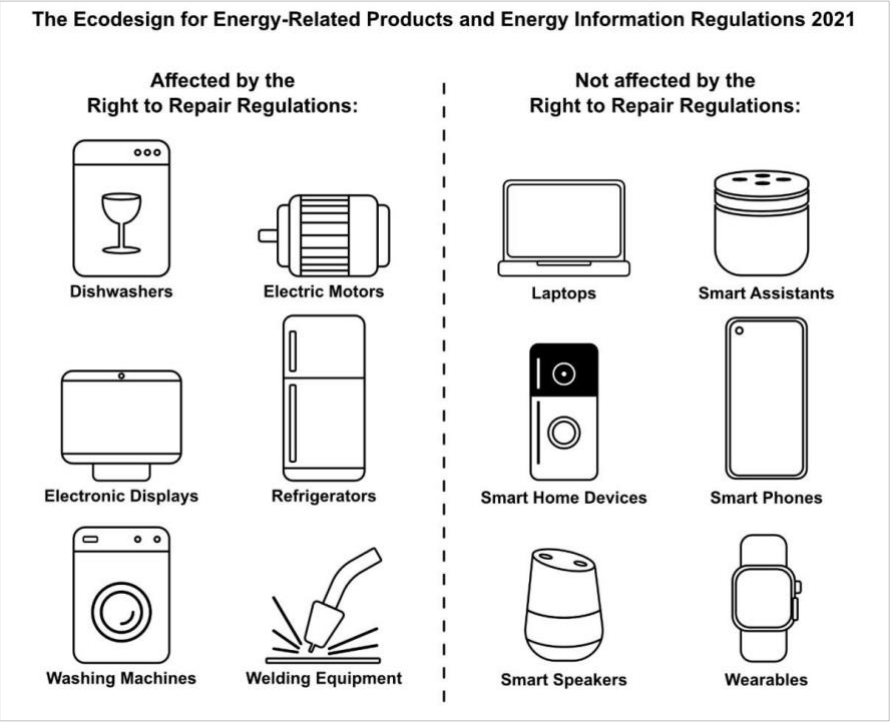

Figure 1: *The limited range of electronic products included in the current "Right-to-Repair' legislation (left) compared with the growing numbers of IoT devices not sanctioned for citizen or even professional third-party repair (right). (After Conway, 2021).*

Preparing to Repair

To curtail the Western trend of disposing of electronics in their entirety (Cooper, 2010), activist groups like *RepairEU* (2022) and *The Restart Project* (2022) have long highlighted the deleterious impacts of e-waste and campaigned on the benefits of product repair and reuse. Rooted in maker, hacker and open-source communities, this grassroots movement aligns closely with *Circular Economy* thinking (Ellen MacArthur Foundation, 2021). The introduction of the new legislation for EU/UK citizens is thus a step forward in tackling planned obsolescence and can undoubtedly be viewed as a positive outcome for the R2R movement.

Yet, in the long term, the efficacy of the new R2R law will ultimately be reliant on citizens and their communities availing themselves of this right. Given that repairing and maintaining devices often requires specialist knowledge, skills and tools, it will be difficult to assess how effective this right may prove to be in practice. Furthermore, due to their complex, physical/digital nature, it is more difficult to maintain and repurpose IoT devices than conventional non-connected counterparts (Stead & Coulton, 2022; Perzanowski, 2022).

Initiating Partner Collaborations

Rather than choosing to investigate the above issues through a broad lens like, for example, a national framework, at this early stage of our research we wanted to focus on a localised, situated context for future R2R. This, we posited, would help us to start to better assess and

understand the effectiveness of current R2R legislation amongst citizens and communities, as well as consider how far the law must evolve to include IoT repair, which stakeholders should be involved in such developments, and to what extent. In addition, this approach enabled us to begin to consider the role that design can make in facilitating such social and environmental transitions – both in practical and theoretical terms.

Partnering with the well-connected community makerspace, *The Making Rooms*, afforded us the opportunity to directly engage with a wide range of key stakeholders. This engagement took the form of two foundational workshops, which will now be discussed.

Design methods for engaging with stakeholders

Doos et al (2016) determine the common method for exploring the benefits and challenges that new technologies and their regulatory policies pose for future society, is to converse with 'experts' drawn from industry, academia and government. Tskeleves et al (2017) stress that this approach can be problematic as it regularly excludes citizens from the development phases of technologies/policies that will ultimately have direct effect upon said citizens when implemented. Thus, as Irvin et al (2004) assert, increasing the type of stakeholders included in these important dialogues should be seen as an 'ethical opportunity'. These arguments are highly pertinent to the ongoing implementation of current R2R legislation, as well as to how it might be expanded to include IoT. These perspectives therefore informed the planning of our two workshops.

Firstly, to gauge *informed* perspectives regards current R2R law and the likely drivers, barriers, risks and benchmarks that need to be considered to potentially expand the policy for IoT, we chose to hold an initial workshop with 'expert' industry, academia and local government stakeholders. Our workshop delivery was built around six key research questions:

1. *What is your opinion of the current R2R legislation and its scope?*
2. *Have you seen any changes or impacts following the introduction of the legislation?*
3. *What do you think of existing support for repair or e-waste collection/recycling?*
4. *How accessible are current repair infrastructures?*
5. *What are your thoughts on smart devices and their capacity for repair?*
6. *Who do you think are the key stakeholders required to create a local smart device repair ecosystem?*

For our second workshop, we wanted to collaborate directly with citizens to explore the relationship between R2R and IoT. The democratic approach of *co-design* (Simonsen & Robertson, 2013) was the most appropriate method for us to utilise. Steen et al (2011) emphasise that through co-design techniques, citizen participants are essential to the design process. Empowering them in this way means that they can creatively contribute their personal experience, knowledge and expertise to generate new insights within the collaborative environment (Sanders & Steppers, 2008).

Following Sanders & Stapper's (2014) 'co-design framework', to help facilitate valuable discussion regards our six key questions, we incorporated a series of *design probes*. Sanders & Stappers (2014) contend that this approach allows researchers to create a 'generative space' for both *'designing with'* and *'designing for'* their participants. For the creation of our probes,

we drew upon *speculative design* practice (Auger, 2013), specifically that of *design fiction* (Bleecker, 2009). Bowen (2009; 2010) argues that speculative interventions are extremely useful as they help multiple stakeholders to begin to collectively think prospectively and critically about possible future alternates to the present-day status quo. Baumann et al (2017) emphasise the potential of such probes to facilitate participants in considering timely social, ethical and legal debates. Speculative design probes can take many forms including, but not limited to, tangible 3D objects, 2D visualisations, drawings, games, scenarios, installations, storytelling and written documents, as well as integrate techniques from art, literature, film, psychology, philosophy, anthropology and ecology (Tskeleves et al, 2017).

Workshop 1 – Engaging Informed Stakeholders (WS1)

Our first workshop was held virtually in April 2022. Nine participants were in attendance and represented a variety of sectors – technology design and manufacturing, local government, consumer rights organisations and academia. The 2-hour workshop was staged and audio/visually captured using a combination of the online video conferencing platform *Zoom* and the interactive whiteboard platform *Miro*. The decision to run the workshop online was twofold: the effects of the Covid 19 pandemic were still present in the UK at the time while virtual attendance also made it easier and quicker to bring participants together who were dispersed geographically across the country.

The aim of this first workshop was to gauge *informed* perspectives and attitudes regards the current R2R law and to also ensure that the research team's understanding of the existing practicalities and challenges for possibly repairing and reusing electronic devices were accurate. The six questions posed to the workshop participants (page 5) were designed to provoke responses on the technical design requirements of current IoT devices, the existing repair infrastructure that surrounds the end of life of IoT and helps/hinder sustainable IoT reuse, and whether the recent legislation caters for an inclusive, equitable society.

Participants were logged into *Zoom* and *Miro* at the same time and could interact with both platforms in real-time. We therefore encouraged them to actively make use of the *Miro* platform as a location to note down any additional thoughts or comments related to the main line of discussion that was taking place on *Zoom*. To facilitate this, each of the six key questions was given its own individual 'mini-board' on *Miro*. The six 'mini-boards' were also divided into four future-focussed quadrants – *Driver*, *Opportunity*, *Risk* and *Barrier*. Participants were asked to place their virtual *Post-It* note(s) into the quadrant that they felt best corresponded with their comments and ideas. Prompts and 'agreeance markers' were also included as part of the activity – the latter could be used by participants' to signify their agreeance with another participant's comment. We felt this 'semi-structured' process would help the research team to identify deeper levels of data granularity during the post workshop analysis process.

Examples of participant Miro 'mini-board' responses to the questions *'2. Have you seen any changes or impacts following the introduction of the legislation?'* and *'3. What do you think of existing support for repair or e-waste collection/recycling?'* can be seen in Figure 2.

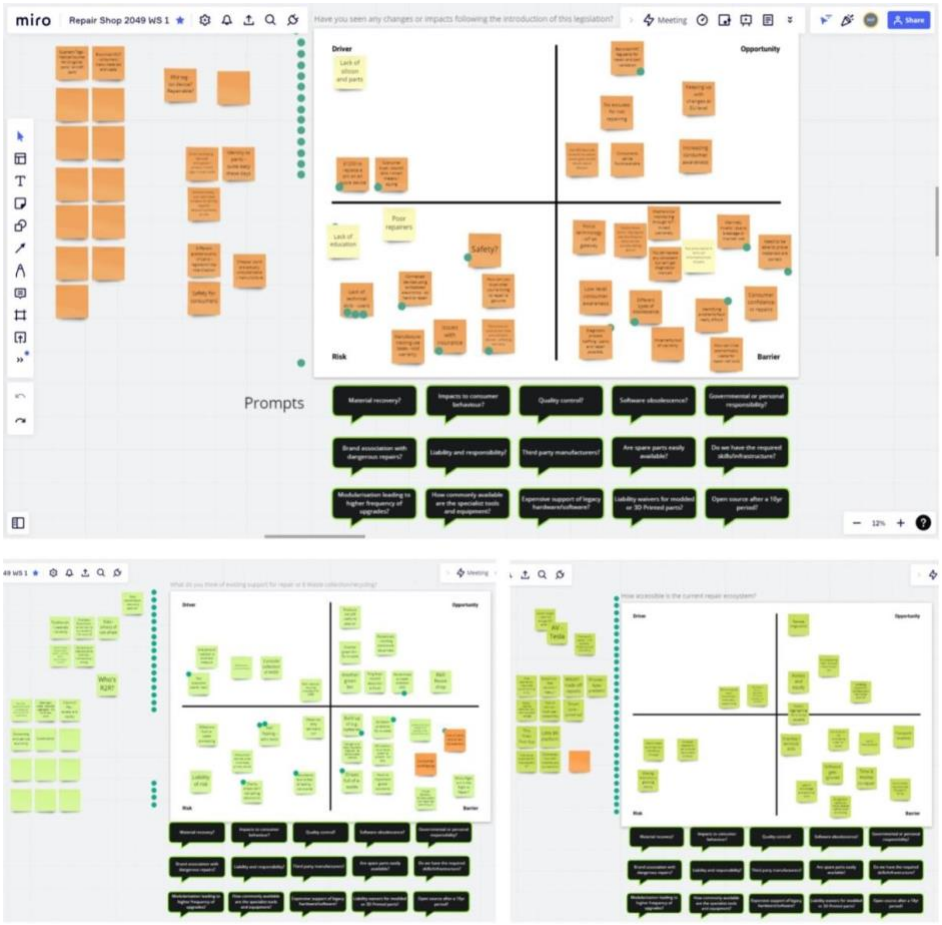

Figure 2: *The 'mini-boards' designed for each of the six key questions on Miro and used by participants during the virtual workshop to share insights. Question prompts and 'agreeance markers' (green dots) can also be seen.*

Workshop 2 – Engaging Citizen/Community Stakeholders (WS2)

The second workshop was an in-person event held in Blackburn town centre at the start of May 2022. There was a total of twelve participants in attendance who represented local repair professionals, repair enthusiasts, makers, community group members alongside the research team. Like the first event, the workshop was audio/visually recorded but this time via a video camera and digital voice recorder. The objective of this workshop was to open democratic and inclusive dialogue directly with members of the local Blackburn community who likely experience regular issues with the existing R2R framework and who could potentially benefit from positive changes to the legislation – including its embrace of repairable IoT hardware and software. For delivering this workshop, *The Making Rooms* digital fabrication lab granted the research team access to a vacant retail space sited opposite the lab in Blackburn town centre.

To ensure consistency across both workshops, we asked the participants the six key questions we posed to 'informed' stakeholders in the first event. As the discussion flowed, the participants were similarly encouraged to write and share any comments and responses in note form onto a

whiteboard, but this time physically, using *Post-It* style memo squares which they could place onto a large sheet of paper split into the four quadrants. Each time the discussion regards a particular question had drawn to a natural close, the quadrant sheet containing all the corresponding comments was removed from the table and pinned on the retail space's wall (Figure 4 – Top row – page 10). This created a visual record of the workshop's progress.

Significantly, the use of the retail unit also granted the research team the time and space to introduce at various points, three speculative design probes (Sanders & Stappers, 2014; Tskeleves et al, 2017:

- *Smart Device Bingo game* (Figure 5 – page 12) – designed to 'kickstart' conversations regards IoT R2R, we introduced this 'ice breaker' probe at the beginning of the workshop. We wanted to better understand what types of IoT devices were owned by the participants and which electronic products they believe to be covered by the current R2R.
- 3D printed modular smart phones (Figure 3 – Top left) – with their modular hardware, *Fairphone's* smart phones (2022) are, to a degree, repairable. The brand and its devices have yet to become a mainstream choice amongst end-users however. Other precedents for smart phone repairability are *Google's Ara* modular phone concept (2022) and the *PhoneBloks* project (n.d.). Using the latter's open-source design files, we 3D printed tangible models which participants were able to interact with and discuss in the context of future IoT device repair.
- *Self-Service IoT Repair Station* (Figure 3 – Top right and bottom) – to begin to demonstrate the range of equipment required as well as the expertise needed to carry out localised repair, we installed a fictional future IoT repair station in the retail space.

Our probes were used as a means to provoke discourse and ideation practices amongst the workshop participants (Knutz et al, 2014). As Huusko et al (2018) emphasise, such probes can be *'used as a workshop tool [but] while the workshop context creates certain needs for the tool,* [the probes] *can help in building the workshop.'* Originally scheduled for 2 hours, such was the enthusiasm and engagement of the participants, that the workshop continued for around 4 hours.

Analysis

To analyse the data, we employed *thematic analysis* techniques. Braun & Clarke (2006) explain how this technique can be utilised to interrogate and interpret the participants' qualitative feedback as collated via the workshop activities. We followed their process of 'data familiarisation' and iterative coding to identify recurring themes – *'patterns of shared meaning underpinned by a central concept'* (Braun & Clarke, 2006) – within the collated data. These themes are outlined in detail in the following sections.

Figure 3: *Top Left: 3D printed modular smart phone prototypes. Top Right and Bottom: participants engage with the speculative Self-Service IoT Repair Station during the workshop.*

Results

Informed Insights

The prevailing sentiment towards the current R2R amongst the first workshop's participants was one of disappointment. They argued that it denies the decentralised and democratic repair of IoT devices in the UK. The participants were not only critical of the narrow scope and reach of present R2R but also lamented the manner in which IoT device/service manufacturers and electronic product producers in general, continually push back against intergovernmental, activist and citizen-led attempts to make the industry more environmentally and socially responsible, accountable and sustainable – through the conception and implementation of such regulations as the R2R. To this end, three key themes emerged during our analysis of the first workshop's discussions.

Figure 4: *Top Row: The range of participant comments collected during the second workshop. Bottom Row: the combined 'thematic mapping' (Braun & Clarke, 2006) as carried out during the post workshop analysis process.*

The Difficulties of Repair

There was no shortage of criticism levelled at the lack of existing networks and infrastructure available for repairing IoT. Participants persistently pointed out that very few manufacturers are supportive of the R2R and that these entities hold dominion over the transition to IoT repairability. This hegemony is demonstrated by the way manufacturers continue to release products that are not designed to afford effective and efficient repair and reuse. Examples included how it is regularly difficult to carry out simple forms of fault diagnosis on IoT devices and when parts are eventually replaced, there is a stringent requirement for these to be validated by the original manufacturer, or if very lucky, a registered third-party supplier.

Participants also confirmed that in many instances, a device's warranty often becomes void should any repair work be attempted by anybody other than the original manufacturer. This annulment can often be triggered even through initial diagnostics to ascertain the root of the problem – not through any actual repair work. This led to discussions regards third party repairers increasingly becoming risk – and therefore repair – averse due to the fears of evoking liability and negating customer warranties through the work they attempt to carry out.

Further criticism was also levelled towards the current legislation since it does not include repair support for device/network firmware nor for wider, yet operationally essential forms of software. *Participant 7 (WS1)* opined that this design *and* policy flaw was increasingly to blame for IoT devices becoming inoperable (or so-called 'bricked') when they are no longer supported by the manufacturer and/or associated service platforms, regardless of whether the devices' hardware remains functional. Interestingly, a key point raised by participants was that there

was also growing concern amongst policy-makers and end-users, that should devices become more easily repairable, they could consequently become less reliable and durable due to changes or even deterioration in their physical and digital specifications.

Changing Attitudes

Crucially, participants also countered the above criticisms with a number of optimistic contributions regards our relationship with IoT technology and its impact on the environment. *Participant 2 (WS1)* stressed that there has been a perceptible shift in greater consumer adoption of professionally refurbished products in recent years. They noted how more and more consumers are deciding that they do not always need to purchase a brand-new device nor the latest 'throwaway gadget'. The participants collectively determined that the impetus for this shift is likely to be the result of increased public awareness surrounding the global challenges that modern societies currently face, principally climate change and the need for Global North countries in particular to transition to more sustainable ways of living.

The prospect of the EU possibly broadening their R2R legislation to include IoT devices was also actively raised. All participants agreed that such a change would result in a positive impact across Europe as it would help to start to reduce e-waste streams. It was also posited that such a move could also force the hand of the UK government to follow suit and make similar amendments.

Opportunities for Education

The final key theme that emerged from the first workshop is the potential to improve *knowledge and education of repair*. The discussion around this particular subject was led by two participants who were representatives of the local council. *Participant 5 (WS1)* and *Participant 9 (WS1)* explained that there are plans currently being drawn up by the local educational authority to improve schooling and run specific lessons regarding basic electronics repair and reuse/recycling processes. This led to further discussions around the capacity for introducing electronics repair and reuse as fundamental and applied skillsets across UK STEM subject curriculums (STEM stands for *science, technology, engineering* and *mathematics* – these four subjects are considered critical, inter-related disciplines in the UK education system). It was felt that such developments presented a considerable opportunity which could feed into wider attempts to educate the UK public about the R2R legislation, their technology consumer rights and sustainable social, environmental and technological transitions in general.

Citizen/Community Insights

We commenced the second workshop with our 'ice breaker' probe, *Smart Device Bingo*. Each participant was asked to mark on their game sheet which of the depicted 'smart devices' they owned, and which they thought would be covered by the existing R2R legislation. The collected responses are shown below in Figure 5. The figure indicates that there is a low level of awareness amongst our citizen participants regards the R2R. This was affirmed following the bingo game. The majority of participants stated that they had not even been aware of the new legislation prior to attending the workshop.

Significantly, the second workshop's discussions, whilst similarly critical of the practices of IoT device manufacturers and the insufficiencies of current repair infrastructures, were primarily centred the unsustainable behavior and ongoing attitudes of consumers. Having analysed the workshop's data, a second set of three key themes emerged.

Distrust in the System

The community participants displayed an evident 'distrust in the system' when discussing both IoT manufacturers' ongoing unsustainable practices, and the current lack of local IoT repair/recycling infrastructures. Similar to discussions in the first workshop, participants found manufacturers untrustworthy when it came to providing continued hardware and software support for their devices. Several agreed that they feared the wider introduction of restrictive software by manufacturers in particular which was designed to artificially impinge upon – or 'throttle' – their devices' capabilities and consequently limit their hardware and battery lifespan over time. It was also suggested that manufacturers are unethical in their approach to the design of current IoT devices as there is little to no support for their long-term durability and repair.

Figure 5: *The collated results of our 'ice breaker' probe – Smart Device Bingo, depicting the number of participants that own the featured IoT devices alongside which electronic products they believe to be covered by the R2R - the correct devices are highlighted in orange.*

Participant 6 (WS2) bemoaned how, in previous generations, electronics and electrical goods used to be 'socially valuable' and actively repairing such products was part of everyday life. They felt that these repair practices, businesses and mindsets have all but been eroded over recent decades as technology has become widespread, cheaper and therefore more disposable. There was further distrust and disappointment amongst the participants regards what they consider a poor standard of local e-waste collection and recycling services/facilities. Several participants expressed their anger towards the nefarious practices exercised a number of privileged Global North nations who strive to offset the problem of e-waste by shipping it to the Global South countries rather seeking to improve repair or sanction manufacturers and retailers.

Friction

Building upon the above conversations, *Participant 8 (WS2)* introduced the term *friction* to describe the barriers faced by consumers when trying to handle and dispose of their e-waste in a sustainably appropriate manner. The participants' consensus was that there is a collective 'want to do the right thing' regards the e-waste they were generating but it was often unclear what this positive move could or should be and how they might initiate such a shift. It was suggested by *Participant 3 (WS2)* that a main contributing factor to this inertia was a lack of education regards the impacts of e-waste on the planet and societies. *Participant 4 (WS2)* strongly concluded that this was in large part a cultural problem – specifically a Western mindset – as in other parts of the world they have very different attitudes towards the economic and social benefits of repair, with devices' ongoing repairability being a major factor when making the decision to purchase a particular product or not.

Improving public awareness and education was consequently raised as a method for better equipping UK citizens and local communities with basic knowledge for understanding both their repair rights under the legislation and how to discern if an IoT device is likely to be repairable or requires further investigation and support from expert repairers/repair services. Subsequently, several examples of 'repair hacks' were discussed which had been completed by online community members to fix hardware/software issues that had been identified by other members. Whilst the group agreed that the 'hacking' of technology and devices was a 'good thing', they collectively concluded that people should not be in a position where this is necessary in the first instance, as device repair support should be now provided by the manufacturers/service providers.

Local Solutions

Given the community-oriented pedigree of the participants, they were eager to highlight how to both 'localise' repair and reuse of IoT and emphasise that the solutions to do so were already present and correct within the community. A primary idea put forward was collecting e-waste from residents and/or refuse centres for refurbishment and materials and components recovery. Renewed devices could then be sold in charity shops, while harvested parts could be dispersed for appropriate reuse or recycling. This network could run in conjunction with existing local council and charity network schemes. Anecdotal stories from participants who had experience of attending and using the services of local 'Repair Cafés' were also offered. Importantly, *Participant 8 (WS2)* and *Participant 2 (WS2)* noted with excitement that solutions such as these could also provide means to engage with and include disadvantaged communities and groups in repair and reuse practices.

Co-envisioning A Localised IoT Right-to-Repair Stakeholder Ecosystem

The mix of optimism and urgency that is required to instigate effective sustainable transitions informed the final task we requested our second workshop participants to complete. Lyckyi et al (2018) discuss how participatory activities can also be employed to facilitate '*the creation and use of* [further] *design fictions.'* Indeed, for the final task, participants were asked work together to speculate regards what a future local IoT repair ecosystem might look like – specifically *could they collectively envision who the key stakeholders in such an ecosystem might be?*

This collaborative process led to the creation of a 'low-fidelity' *socio-technical imaginary* for a future local R2R IoT ecosystem. Figure 6 depicts a graphic iteration of this speculative vision. The participants' imaginary aims for the minimum amount of e-waste to be dispersed to recycling centres, or worse landfill, by integrating a combination of sustainable channels and

responsible stakeholders. This criticality is significant as it identifies our participants' main concerns regarding the relationship between R2R and IoT devices.

Using *socio-technical imaginaries* as a design frame is an effective approach for creating a shared vision of the social, technological, economic, political, and environmental impacts that must be negotiated to achieve constructive, collective change (Jasanoff, 2015; Speed et al, 2019). This method also corresponds with Ceschin & Gaziulusoy (2016) who argue that while the sustainability of individual products and services is important, we must start to design more holistically for the wider infrastructures and *ecosystems* that give rise to problems like e-waste. This is so that we can one day collectively *transition* beyond these issues.

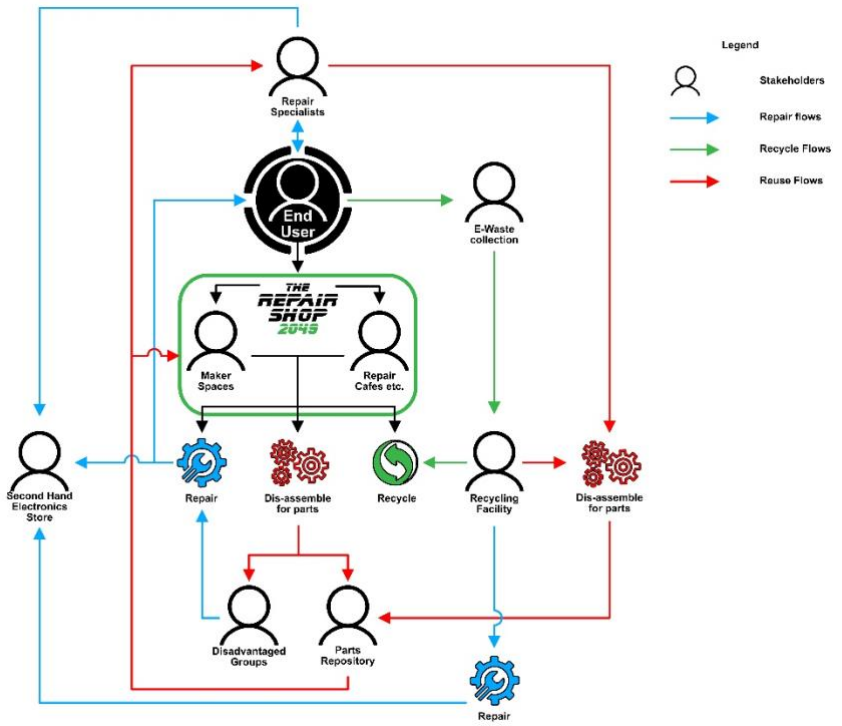

Figure 6: *A speculative closed loop local IoT repair ecosystem as co-envisioned by the citizen/community workshop participants.*

Repairing the future

This preliminary research has helped to lay the foundations for impactful follow-on work (in the form of further funded research) through which we will continue to explore the convergence between IoT R2R ecosystems, sustainable socio-technical development and citizen-driven innovation. At the close of the second workshop, participants were invited to join a *Whatsapp* group to be kept up to date with the research's progress. This has resulted in an active group who have been regularly sharing ideas and relevant repair case studies. Trust has been built between the research team and *The Making Rooms*/Blackburn community. Our work with the workshop communities will hopefully help us to 'recruit' further stakeholders to be part the forthcoming research activities.

Future work will include new workshops to further solidify the granular connections between key stakeholders, supply chains and physical-digital resources. To aid this process, we will also produce more advanced speculative design probes that critique the limitations of today's R2R legislation, while at the same offer potential visions for more sustainable and equitable repair futures. We also plan to run practical workshops with partner *The Making Rooms* to upskill local publics in basic IoT device fault diagnosis and repair.

Conclusion

Through this research, we have revealed a number of the drivers and opportunities that both of our stakeholder groups foresee as necessary efforts to scale up IoT R2R practices and infrastructures. Equally, several barriers and risks were also outlined, a key issue for both groups is the lack of public awareness of the current R2R and how it falls short with regards to supporting better repairability of existing IoT and the volumes of devices that will proliferate society in the years to come. Both groups acknowledged that, although consumers are becoming more galvanized around certain sustainable practices such as low carbon travel and ethical food choices, a throwaway electronic device culture still persists across society. However, they also highlighted how this lacuna creates an opening for education – increasing public awareness of the need for, and training in relation to, IoT device repair, as well as improving access to knowledge and tools. This, our participants felt, is an opportunity to be actively seized and that such education could also commence early in communities during school years so that succeeding generations possess the innate competencies to complete device repair.

Our participants also spoke of a 'distrust in the system' and that power dynamics regarding repair currently favour manufacturers and service providers over device owners. This leads to what was described as 'friction' where, due to the said power hierarchy and lack of an available IoT repair infrastructure, it is exceedingly difficult to carry out and/or solicite effective repair at a local or wider levels. As Mattern (2018) stresses, 'repair' is regularly framed through negative rhetoric, that is, it is a sign of a decadent and decaying society, yet it should, she contends, be considered more as a positive reflection of societal agency and a driver for change. Both groups also highlighted further concerns, including the need to ensure that next generation IoT devices are designed so that repair is a safe to practice, that their software is (to a degree) repairable alongside their hardware, and if future repairs are carried out by citizens'/communities directly or through third parties, producers evolve device warranties so that they are still preserved. This said, overall, our participants also shared a similar positive perspective to Mattern. They were steadfast in their collective enthusiasm and drive for making positive steps toward a more sustainable and equitable form of IoT R2R. Indeed, for both groups, localised, democratised repair and reuse of IoT was posited as a genuine, feasible route forward. This is reinforced in the co-envisioning of the localised R2R stakeholder ecosystem (Figure 6).

Fundamentally, there is a need to develop new ways to extend and improve the lifespans of billions of IoT devices. E-waste generated via IoT is a significant contributor to the rise in harmful carbon emissions which are global climate change. Resultantly, we contend that our findings, although emergent, begin to contribute to growing discourse which calls for community adaptation towards *Circular Economy* principles (Ellen MacArthur Foundation, 2021) to redress e-waste as well as wider international imperatives to achieve *Net Zero 2050* decarbonisation targets (Global Climate Action, 2020; IPCC, 2021).

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