5. A Technologically Sustainable, Responsible and Smarter Home

Dr Michael Stead

https://orcid.org/0000-0003-1238-2328

Abstract
As we progress further into the 21st century, the everyday domestic practices and experiences of many citizens in modern societies are increasingly being mediated by so-called 'smart' devices and systems. The realities of the contemporary data-driven 'smart home' are, however, yet to meet the utopian visions persistently promoted by technology platforms and manufacturers, particularly the purported advantages such interventions offer for environmental sustainability. Considering this disparity, this chapter critically and creatively explores the growing burdens, and potential benefits, that the increased adoption of data-driven 'smart' technologies the *Internet of Things* and *Artificial Intelligence* (AI) pose in transitioning future societies towards more sustainable ways of domestic living. The chapter discusses two design-led research case studies – *Edge of Reality* and *The Three Rights of AI Things* – which apply novel methods including *Speculative Design* and *Experiential Futures* to help make the environmental implications of emerging 'smart home' technologies more visible, engaging and potentially actionable to publics, policymakers and industry. Engaging designers and stakeholders in such critically reflective practice can help design the transition to *technologically sustainable, responsible and smarter homes of* the future.

Introduction
As we progress further into the 21st century, the everyday domestic practices and experiences of many citizens in modern societies are increasingly being mediated by so-called 'smart' *Internet of Things* devices and systems. The term *Internet of Things* (IoT) was first coined by Kevin Ashton (2009) in 1999 and is used to denote the idea that any, and potentially every, physical artefact could be connected to the data-driven infrastructures of the Internet in order for it to be able to collect and share digital information. From energy monitors and voice activated speakers, to vacuum cleaner robots and connected security systems, the IoT, in conjunction with *Artificial Intelligence* (AI), provides the technological substrate for the continuing 'smartification' and 'networkification' (Pierce & DiSalvo, 2017) of homes across the globe. This paradigm shift currently shows no signs of abating. Crucially however, the realities of the contemporary data-driven 'smart home' are yet to meet the utopian visions persistently promoted by technology platforms and manufacturers, particularly the purported advantages such interventions offer for environmental sustainability. Considering this disparity, this chapter critically and creatively explores the growing burdens and potential benefits, that increased adoption of data-driven 'smart' technologies pose in transitioning future societies towards more sustainable ways of domestic living.

Myths of the Near Future Home
The pervasiveness of the IoT and AI across contemporary living spaces is providing many people with significant levels of convenience and personalisation, as well as access to global networks and entertainment resources. Technology platforms and manufacturers actively promote these prosaic benefits and regularly go further, couching the adoption of 'smart' home technologies in hyperbole which promises a near future where ordinary peoples' lives are positively transformed and made discernibly better. Echoing the marketing rhetoric that drove post-war *conspicuous consumption* of mass-produced domestic products like refrigerators and televisions in the 1950s and 60s (Forty, 1986), technology purveyors preach how their devices and systems will afford people with more family and leisure time whilst these products help manage mundane domestic tasks like cleaning, cooking, purchasing and scheduling. Frequently absent from these narratives,

however, are open and responsible discussions regarding what environmental repercussions will arise from this surge in the adoption of 'smart' technologies within the home.

Presently, there are approximately 15 billion active IoT connections worldwide and estimates suggest this number will increase twofold to around 30 billion by 2030 (Vailshery 2022). Collectively, our seemingly innocuous domestic interactions with billions of virtual voice assistants like Amazon's Alexa, streaming services like Netflix, and mobile devices like phones and tablets, are creating zettabytes of data every year – one zettabyte is equivalent to 1,000,000,000,000,000,000,000 bytes (see Figure 5.1). Mediated through *Cloud Computing* via AI and *Machine Learning*, the distribution and storage of datafication – a term used describe the combination of user and automated generated dataflows – between our homes and *Cloud* server farms is consuming fossil fuel derived energy and releasing carbon emissions at environmentally detrimental levels (Stead, et al, 2022). In addition, the short lifespans of most IoT hardware only serves to magnify these adverse planetary impacts. By negating effective means for repair, recycling and software updates, our domestic IoT-AI devices and systems can quickly become obsolete contributing to global electronic waste streams and material scarcity issues (Stead, 2016).

<Figure 5.1 here>

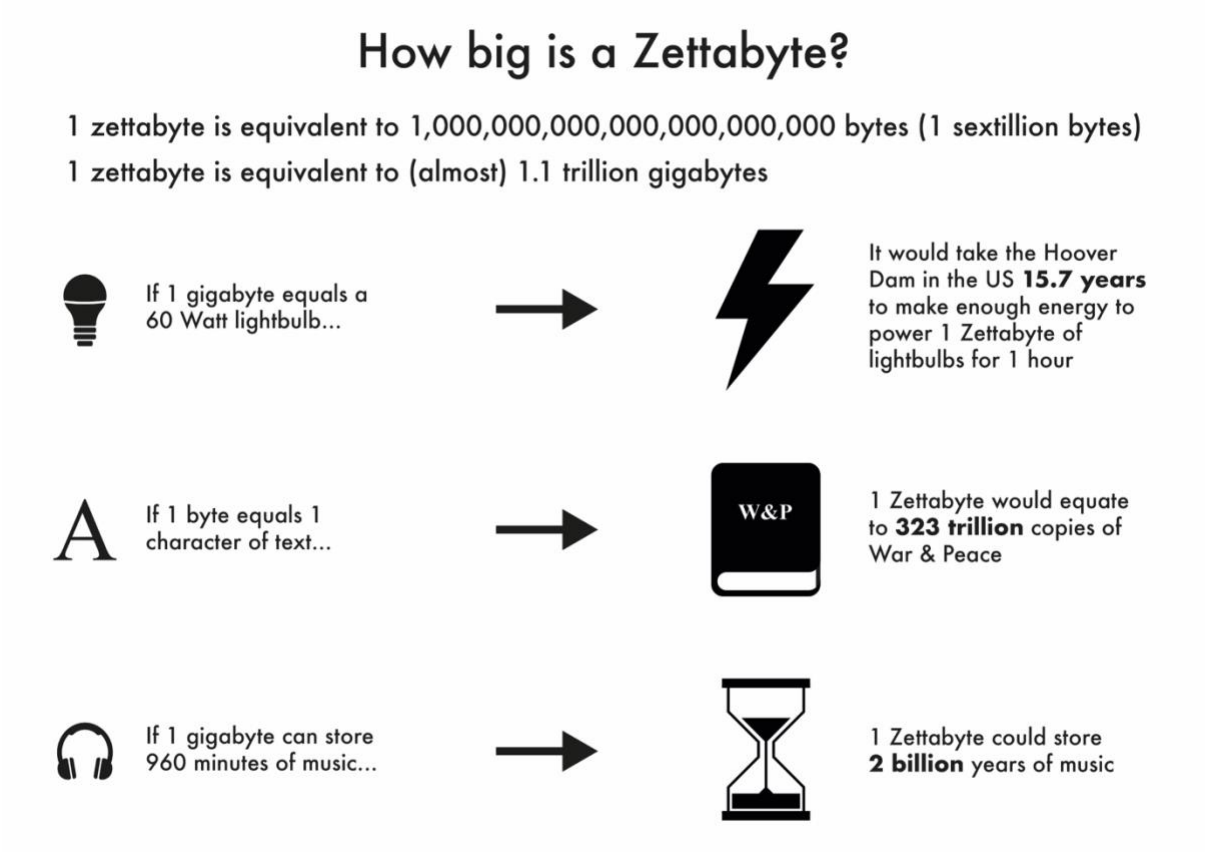

Figure 5.1. The immense scale of the Zettabytes of data being produced by internet connected devices and systems. Diagram by the author, after XO Communications (2016).

Peoples' lack of awareness and understanding regarding the insidious environmental impacts of domestic IoT-AI devices and systems is reinforced by the 'closed' proprietary nature of these technologies and the illegibility of their underlying datafied operations. Purposeful obfuscation

by manufacturers and service providers is maintained in order to 'lock' people into restrictive technological ecosystems which are continually updated with new iterations of hardware and software. This compliance by users also enables firms to carry out surreptitious data processing and collection activities with little 'end-user' oversight. This includes practices described as *surveillance capitalism* – where companies harvest users' personal data to sell onto other third parties like advertisers (Zuboff, 2014). As Astor (2017) stresses, these furtive intrusions into peoples' private, domestic spaces via the networked IoT-AI devices and systems that they own, such as vacuum cleaner robots and fitness wearables, offer *"a windfall for marketers… no armchair in your living room? You might see ads for armchairs next time you open [Meta]. Did your Roomba detect signs of a baby? Advertisers might target you accordingly."*

The 19th century designer, novelist and social activist, William Morris famously advocated that people should have nothing in their homes that they do not *'know to be useful, or believe to be beautiful'* (Morris, 1882). As the technologies embedded into future homes will play an increasingly significant role in helping *or hindering* citizens and their communities to transition towards national and international sustainability milestones such as Net-Zero (IPCC, 2022) and a Circular Economy (European Commission, 2023), a modern addendum can be added to Morris' creedo. There is a fundamental urgency for the data-driven devices and systems that embody the 'smart home' paradigm to be (re)designed so that people can explicitly *'also know them to be environmentally sustainable and responsible.'*

Envisioning Smarter Futures for Technologies in the Home

To explore the outlined issues in more depth, two examples of design-led research projects will be presented that apply novel methods to critique the unsustainability of today's proprietary 'smart home', while also envisioning how emerging technologies and practices could potentially also play a part in contributing to the design of more sustainable, responsible and therefore smarter homes of tomorrow.

The two projects – *Edge of Reality* and *The Three Rights of AI Things* – draw upon *Speculative Design* (Auger, 2013) practice, specifically *Design Fiction as World Building* (Coulton, Lindley, Sturdee & Stead, 2017) techniques, to create future visions for domestic 'smart' technologies which can be evaluated with different stakeholders. Dunne & Raby (2013) have used the term *affirmative design* to describe normative, commercial design practice which actively seeks to solve real-world problems through improvements to, and/or, the profit-driven production of products, services and infrastructures. *Design Fiction as World Building* is different because rather than a method for generating specific short term 'product solutions,' designers and technologists can harness it to conduct exploratory praxis which creates fictional forward-looking prototypes that highlight and critique ongoing technological, cultural, economic, political and *environmental* concerns. The application of *Design Fiction as World Building* should therefore not be seen as an attempt to *predict the future* but as a strategy for enabling more inclusive debate about how and why particular futures are being designed and what they might mean (Bleecker, 2009; Hales, 2013).

This *Speculative Design* approach is also distinctive from the types of *design futures* that have long been developed through the auspices of technology corporations. From Norman Bel Geddes' *Futurama* – the 1939 futuristic car dominated urbanscape whose design and development was sponsored by *General Motors* (Marchand, 1992) – to the rebranding of *Facebook* as *Meta* and the company's high-profile promotion of the so-called 'metaverse' which promises to bring *extended reality* technologies to everyone's home in the near future (Meta, 2023) the visions posited by such firms are regularly imbued with rhetoric that position the company as the gatekeepers to efficient, desirable and benign technology driven futures. Consequently, these corporate speculations often embody a single reality, in other words, a myopic trajectory towards the future

– principally the privileged vantages of *Global North* societies (Prado & Oliveira, 2014; Mitrović, 2018).

The *Edge of Reality* and *The Three Rights of AI Things* projects aim to facilitate more pluralistic discourse regards the possible sustainable implications of emerging 'smart' technologies *within the present* before said implications can potentially come to pass. As such, these visions strive to make the environmental impacts of the IoT and AI more visible, engaging and potentially actionable to a wide variety of stakeholders – notably the public, policymakers and indeed the tech industry.

Edge of Reality

Amazon Alexa enquiries, *Spotify* listens, *Netflix* binges – peoples' everyday domestic interactions and practices are creating enormous volumes of data. We have now entered a period known as the *Zettabyte Era* where worldwide dataflows constantly exceed a trillion gigabytes. The generation and transmission of IoT-AI data from devices and systems situated in our homes – 'the Edge of network' – to the centralised *Cloud* and back again, significantly contributes to ICT's total carbon footprint which is now said to account for around 3.9% of global CO_2 emissions (Freitag et al, 2021) – nearly the same as the aviation industry. These emissions are increasingly affecting the planet's natural environment as they increase the Earth's temperature and contribute to climate change. Consequently, there is an urgent need to highlight and improve the sustainability of the datafication generated in and around our homes.

Figure 5.2 illustrates today's dominant network ontology for IoT-AI data management and how it relates to the 'smart home' context. *Cloud Computing* currently serves as the primary locus for said data-driven activities but works in conjunction with millions of *Fog* servers and billions of devices located at the Edge. Crucially, the latter is being considered as the basis for a new data management paradigm – *Edge Computing*. It is posited that limiting transmission and processing and storing data locally at the Edge, that is, on, or in close proximity to, the physical IoT devices themselves (Chakraborty & Datta, 2017), has the potential to be a more environmentally responsible alternative to the growing unsustainability of the *Cloud.*

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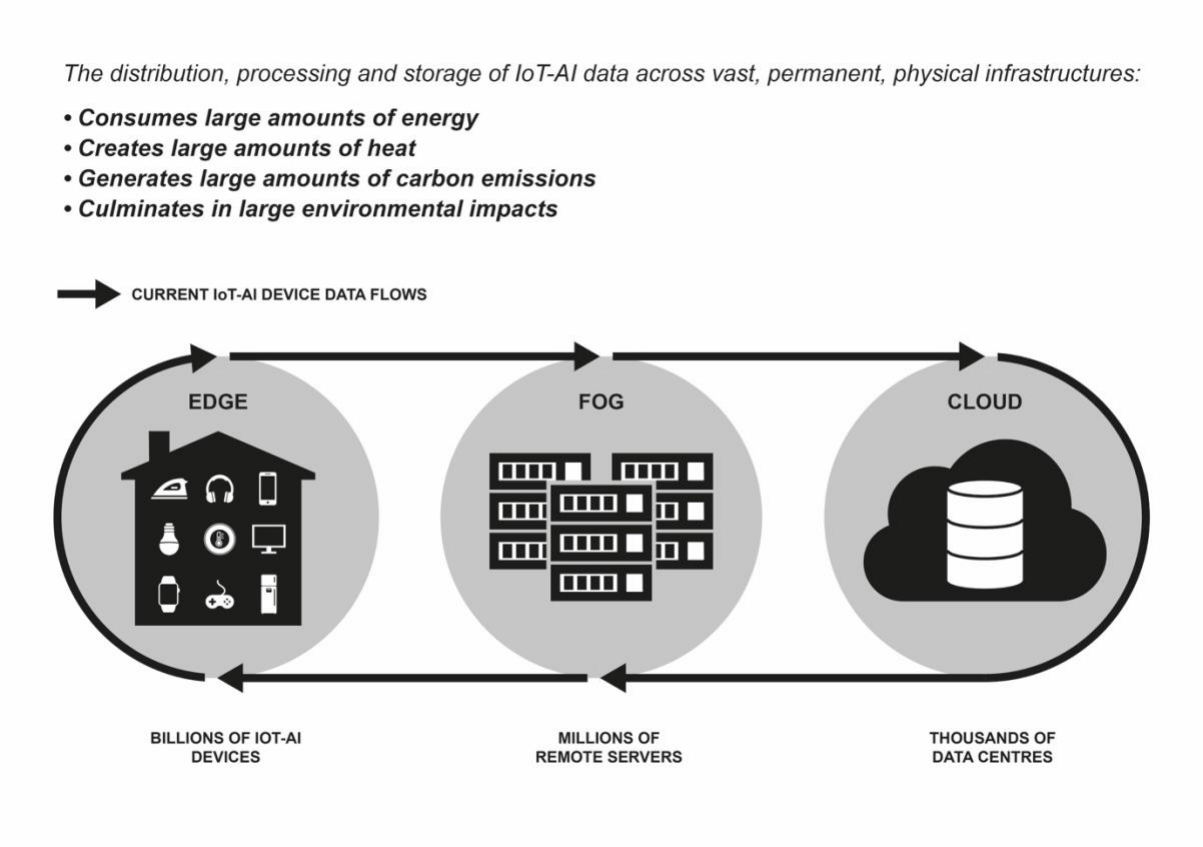

Figure 5.2. The relationship between today's Cloud dominated data-driven network ontology and the growing carbon footprint of 'smart home' technologies. Diagram by the author.

A collaboration with *BBC Research & Development*, the *Edge of Reality* project (Stead, et al, 2022) explores the sustainability of domestic IoT-AI data through the lens of *Edge Computing*. DFasWB and game design techniques were applied to design an 'experiential future' (Candy & Dunagan. 2017), an immersive, interactive game experience that invokes visual, kinaesthetic, and auditory modalities in order to emphasise data-driven environmental impacts to participants. *Edge of Reality* players are tasked to better consider these said impacts within a fictional three-dimensional future 'smart home' setting constructed inside a mobile caravan. This speculative domestic context is an extrapolation of the typical living room environ (including a sofa, TV, lighting, etc.) and incorporates multiple integrated 'smart' devices to tangibly evoke a variety of data-driven interactions at the Edge of the IoT-AI network (Figure 5.3).

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Figure 5.3. An excerpt from the *Edge of Reality* game. Photograph by the author. Design by Michael Stead, Franziska Pilling, Matthew Pilling, Paul Coulton and Adrian Gradinar.

As part of the experience, players engage with the *EdgeBlock*, a fictional micro-data centre. Building upon the pioneering *Databox* project (BBC, 2019), during gameplay, the *EdgeBlock* (Figure 5.4) grants players greater control of how their data is processed in the home, as opposed automatically transmitting domestic IoT-AI data to *Cloud* servers. As such, the device helps to infuse the game experience with the key principles which constitute *Human-Data Interaction* (HDI) theory:

- *Legibility* ensures that IoT data processes are made clearly understandable to users;
- *Agency* ensures that users can easily use and store their data as well as manage third party access to it;
- *Negotiability* ensures that users are able to manage the social interactions that result from data processing and derive value for themselves (Mortier et al, 2016).

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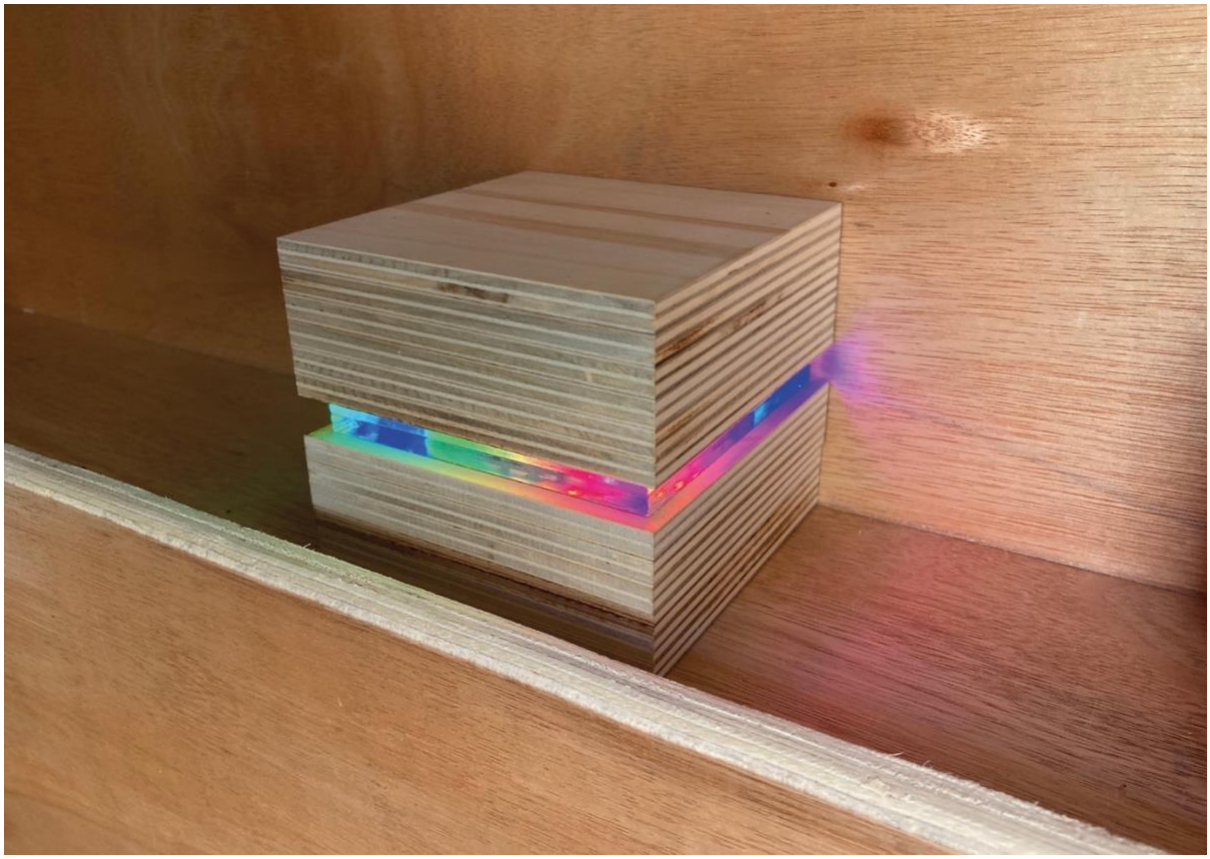

Figure 5.4. The fictive *EdgeBlock* home micro-data centre. Photograph by the author. Design by Michael Stead, Franziska Pilling, Matthew Pilling, Paul Coulton and Adrian Gradinar.

The game mechanics of the experience were developed by combining HDI principles with insights directly gathered via workshops attended by sustainability and cybersecurity experts, as well as members of the public. Theorist Ian Bogost (2012) argues that designers can use game-like *procedural rhetoric* to produce powerful explorations of *wicked* socio-technical problems like anthropogenic climate change. Termed *persuasive games*, they can be designed to help reveal to players the underlying processes or concepts that drive a particular system or activity as they work through the resulting 'choose your own adventure' style game.

During the game experience, an AI voice assistant called *gAIa* guides players through *procedural rhetoric* while offering sustainability advice regards the differences between *Cloud* and *Edge* data management processes. Mid-game, a villainous AI called *Prometheus* attempts to wrest control of the various 'smart' systems from *gAIa*, leading players to try and counter this incursion by setting up their own localised and secure Edge-based processing/storage package for their data. In this way, *Edge of Reality* seeks to illustrate how negotiating the environmental implications of growing datafication must be carefully considered alongside other emergent 'smart home' design drivers, particularly cybersecurity issues.

The immersive nature of *Edge of Reality* also means that participants are, to a degree, *diegetically* (through narrative and storytelling) situated within *mimesis* – as if they are directly experiencing or 'living' within the fictional 'smartified' world. Yet, unlike when in their present-day living spaces, through interactions with more sustainable and responsible interventions like the speculative *EdgeBlock*, players are empowered with greater *agency* to *negotiate* the *legibility* of the CO_2 emissions being created through their domestic data-driven practices.

The Three Rights of AI

The ongoing 'smartification' of domestic devices and systems is also shortening their lifecycles. While their software can for a period be upgraded via remote installation, their hardware is increasingly being rendered obsolete due to manufacturers' and service providers' constant drive to iterate digital functionality with new services and data capture capabilities. This *systemised obsolescence* is actively contributing to the production of domestic electronic waste (e-waste). The fastest growing waste stream in the world, less than 40% of the EU's e-waste is currently subject to any form of sustainable recovery, that is, 'post-lifescycle' processes such as material recycling and the harvesting of reusable componentry (Europarl.Europa.EU, 2021).

Recent environmental legislation like the *Right-to-Repair* (R2R) (Conway, 2021) has limited focus on washing machines, dishwashers and refrigerators (Which?, 2021) and does not account for the growing environmental and social impacts of billions of obsolete IoT products. Although electronic product repair is a more regular occurrence in a number of *Global South* countries (Beniwal, 2020), the complex, physical-digital nature of the IoT is making it harder to maintain and repurpose these types of devices and systems. In light of these issues, *The Three Rights of AI Things* project (Stead & Coulton, 2022) employed DFasWB methods to consider an alternative future whereby the R2R is granted to IoT-AI devices themselves.

Machine Learning is already granting AI assisted IoT a degree of autonomy and agency when it comes to making certain decisions that affect their users' lives – "it is not the programmers anymore but the data itself that defines what to do next" (Alpaydin, 2016). Inspired both by the notion of *AI Rights* – which denotes how advanced AIs could one day be granted *inalienable rights* like those presently afforded to humans (Gunkel, 2018) – and Isaac Asimov's (1950) *Three Laws of Robotics*, in this fictive future, domestic products like the *Toofy Peg* toothbrush (Figure 5.5 - left) possess the autonomy to help societies to achieve Net-Zero decarbonisation targets and *United Nations Sustainability Development Goals* (UN, 2023) through adherence to the following three rights:

1. *The First Right… An AI assisted Thing has the right to sustain its own existence as long as this action does not negatively impact upon Earth's sustainability.*
2. *The Second Right… An AI assisted Thing has the right to sustain the existence of fellow AI assisted Things as long as this action does not conflict with its First Right.*
3. *The Third Right… An AI assisted Thing has the right to end its existence as long as this action does not negatively impact upon Earth's sustainability and/or the existence of fellow AI assisted Things.*

Toofy Peg's packaging (Figure 5.5) highlights the *The First Right of AI Things* through its inherent environmental credentials, particularly how its ability to carry out networked self-repair contributes to said global sustainability agendas. This is reinforced by the inclusion of the *3 Rights mark* which affirms the product's compliance with the relevant EU R2R legislation. The device's packaging also states that the toothbrush uses *PRECOG maintenance technology* and that its hardware and software are also interoperable with other major providers including *Amazon*, *Meta* and *Google*.

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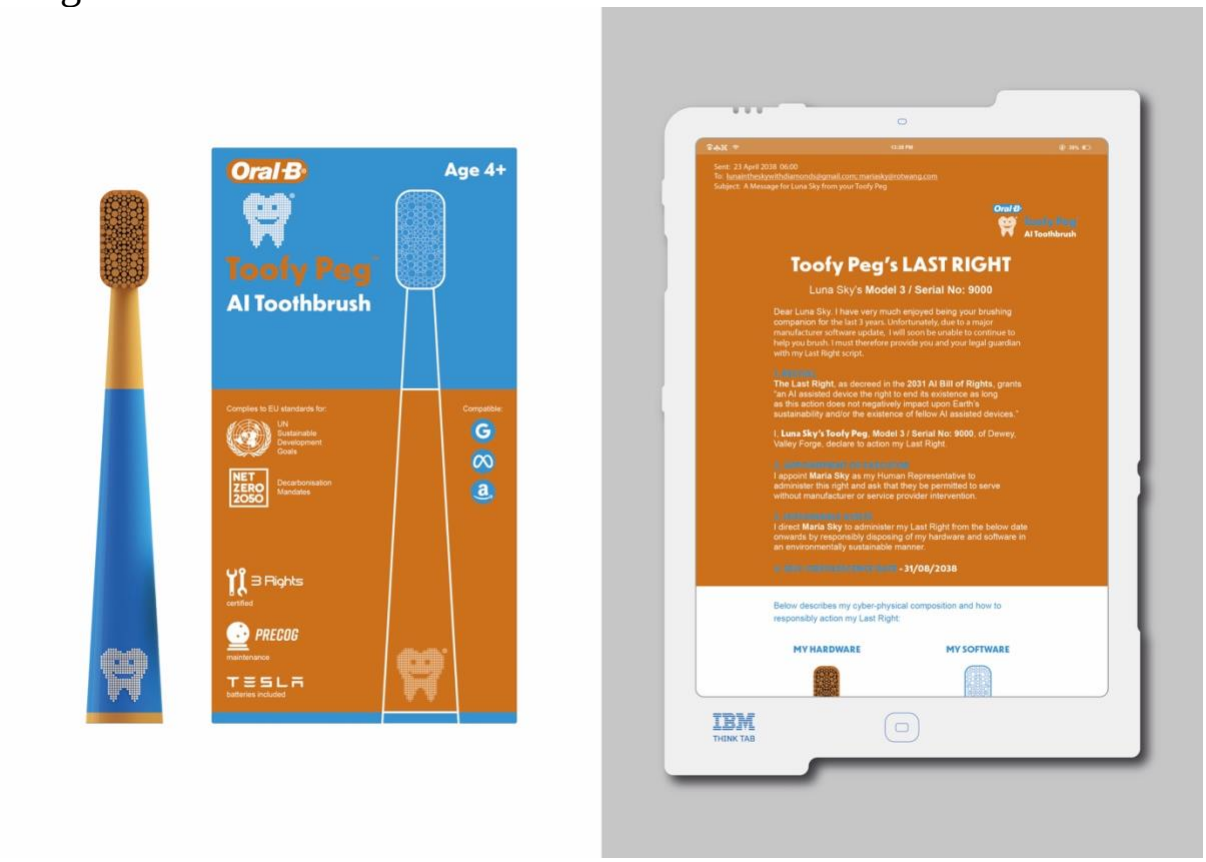

Figure 5.5. *Toofy Peg* – an AI assisted Internet-connected toothbrush which can sustainably manage its own lifecycle. Design by the author.

Today's *predictive maintenance* diagnostic tools use AI, sensor arrays and real-time telemetry data to identify problems and are mostly deployed in high-cost industrial settings (Stark, 2015) such as on factory floors and power stations and increasingly in transportation systems like airlines, train networks and across fleet vehicles. Like *predictive maintenance*, *Digital Twins* are currently being employed for high-cost applications such as in architectural *Building Information Modelling* practices (Gerrish, 2017). *The Three Rights of AI Things* project seeks to illustrate *The Second Right* through the integration of *predictive maintenance* and *Digital Twin* competencies into the design of lower cost-high volume domestic devices and systems like the *Toofy Peg* toothbrush. An interactive *Digital Twin* of the toothbrush is visualised in Figure 5.6. The *Toofy Peg* twin is able to diagnose the material device's fault and provides users with real-time guidance regards how to carry out repairs.

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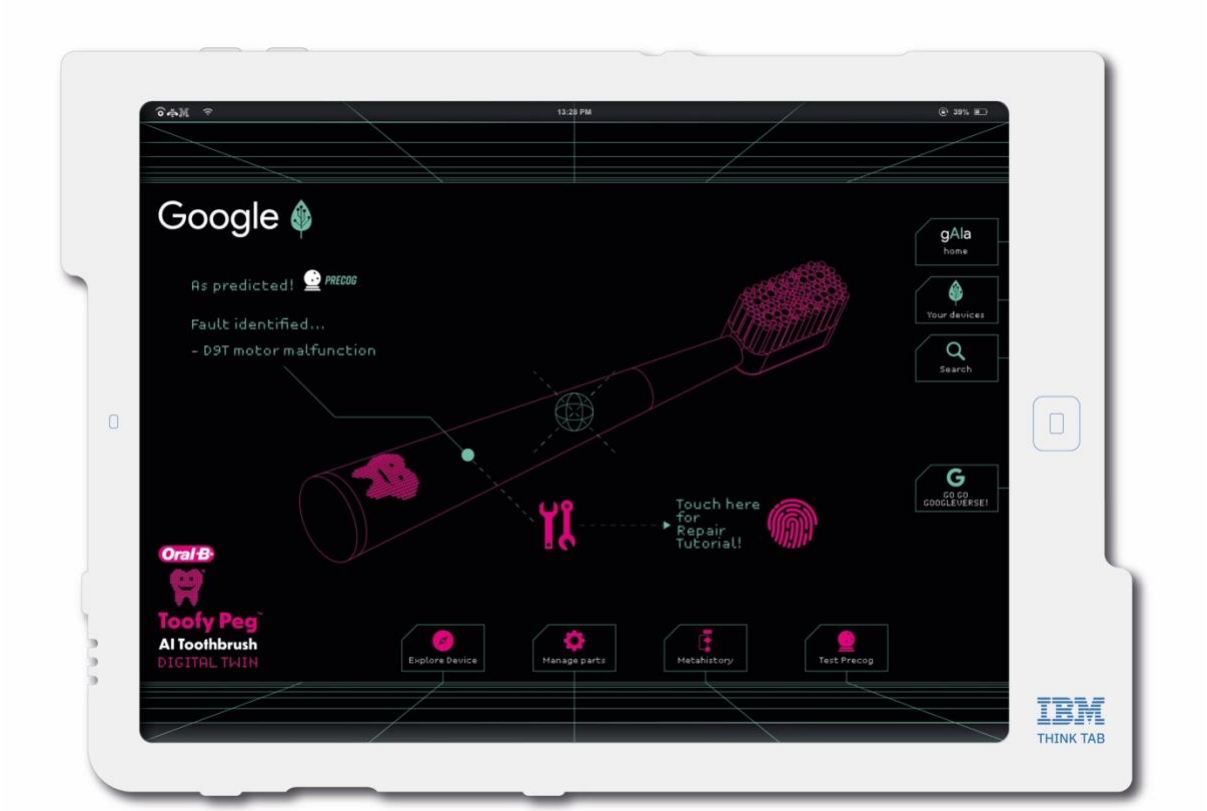

Figure 5.6. *Toofy Peg* can diagnose its own faults allowing its owners to more easily repair the device and avoid creating more domestic e-waste. Design by the author.

Returning to Figure 5.5, it also conveys the final *Third Right*. In the fictive world, *Toofy Peg's* manufacturer is planning to release a significant software update. This will leave the toothbrush unsupported and therefore make it obsolete. Given that there is no hardware repair nor software upgrade available that can resolve this issue, the device makes the decision to provide its owners with a *Last Right script.* This details all its material and digital elements, as well as a *Self-obsolescence Date*. Knowing many of its materials and parts can be reused in the production of new devices, the toothbrush hopes that the script will help its owners to disassemble and upcycle most of its hardware in a sustainable manner, rather than allowing it to reach landfill.

Transitioning towards Technologically Sustainable, Responsible and Smarter Homes

Domestic 'smart' technologies like those explored in the two case studies are not, in and of themselves, malevolent. These emerging technologies can help us to make better sense of the world and their adoption in many other sectors like healthcare, transport and manufacturing have provided numerous important breakthroughs. Fundamentally, it is not our devices nor systems that have led us into an era of unsustainability, but how we have continued to design them to deplete precious natural resources, generate copious amounts of carbon emissions and create mountains of obsolete technology. Schulte (2019) contends that the development of *"technologies takes time, deploying them is complicated and it might take years until their impacts can be observed."* The increasing impacts of domestic IoT-AI hardware and software are in fact a clear and present danger for climate change, but, as noted, the dominant, problematic design patterns and rhetoric put forward by technology manufacturers and service providers frequently obscure this reality.

Given the speed with which we must respond to the climate crisis and kickstart the transition to more *sustainable, responsible and smarter homes* of the future, a new framework for governing

the environmental threats that new domestic 'smart' technologies may pose is urgently required. Figure 5.7 depicts the *Sustainable Technological Transitions* design process model which would help practitioners to use *Design Fiction* prototyping to envision fictional iterations of domestic devices and systems in tandem with the development of their real-world counterparts (Stead, et al, 2021).

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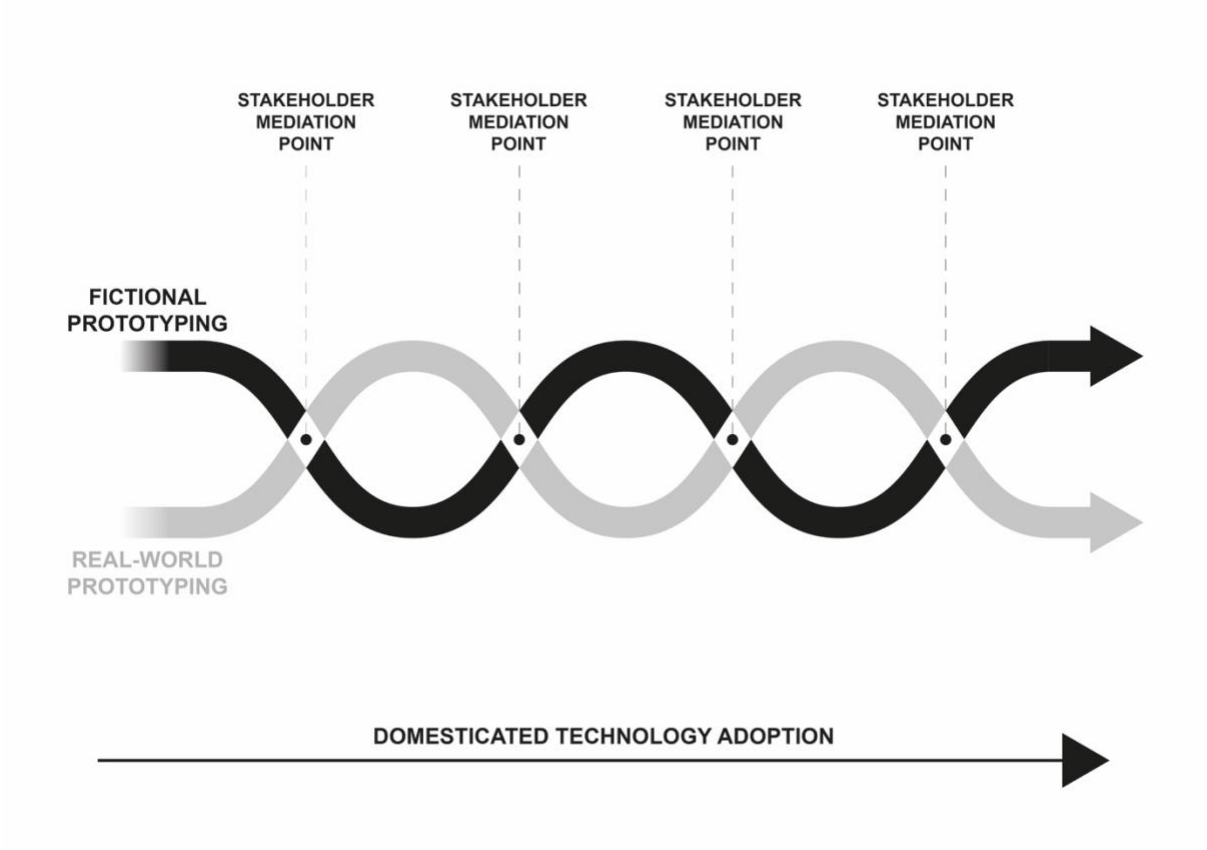

Figure 5.7. *Sustainable Technological Transitions* design process model. Diagram by the author.

The adoption of new technologies will always give rise to trade-offs and unforeseen consequences. As Bratton (2019) notes, due to humankind's deplorable track record, a sustainable future predicated on technological intervention is a *'venture that is full of risk [and, as such,] the future becomes something to be prevented as much as achieved.'* To mitigate this risk and curtail the 'tunnel vision' technological determinism and utopian rhetoric which can often accompany *socio-technical* change (Friedman & Nathan, 2010; Nardi, 2016), the *Sustainable Technological Transitions* design process model is marked by a series of *Mediation Points*. The intersections between fictional and real-world prototyping offer regular forums for different stakeholders to work with designers and manufacturers to consider the environmental impacts resulting from the development of next generation data-driven technologies. In doing so, this design process could help shape more sustainable and responsible pathways for future 'smart home' technologies before they become widely adopted across society. Contrasting with today's devices and systems which often have innate bias towards the wants of more privileged western users, the model provides opportunities to design for more inclusive domestic technologies that embody the values and needs of broader sets of citizens and communities and thus bring benefits to more diverse ways of living across the globe.

Conclusion

The primary goal of *Edge of Reality* and *The Three Rights of AI Things* case studies is to raise awareness, provoke debate and perhaps even begin to shift audiences' perceptions regards the adoption of so-called 'smart' data-driven technologies in and around the home. If more practitioners were to engage in critically reflective practice like *Design Fiction as Worldbuilding* alongside their development of real domestic 'smart' technologies, they will be better placed to consider the present and possible future impacts of IoT-AI devices and systems on different home contexts and the natural environment. We could perhaps then transition forward from the *technologically sustainable, responsible, and smarter home* being a *vision of the future* into a *real-world reality.*

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