More-than-Human Net Zero Futures: Disruptive Participatory Design for A Sustainable, Equitable Planet

Abstract

A rich tapestry of Design Research methods and practices are being advanced to accelerate environmentally responsible transitions across modern society. The collective aim is to push us beyond our unsustainable paradigm, the *Anthropocene*. From industry through communities to academia and policymaking, the prevailing discourse focusses on transitioning to a so-called 'Net Zero future'. Central to this vision is mitigation of human-driven climate change through the decarbonisation of industrial society, principally via increased innovation and adoption of emergent technologies. This paper argues that while mainstream visions for Net Zero futures can serve as useful socio-technical imaginaries to create stakeholder awareness regards the critical need to reduce emissions, their technocentric ideals also perpetuate the hegemonic, carbonised design-innovation practices that dominate today. To positively shift away from these reductive, solutionist narratives, Design Research must pivot and develop a disruptive yet inclusive approach towards designing for Net Zero. Climate change is a complex, dynamic system rooted upon multi-scale and multifarious interrelations and dependencies between human, ecological (e.g., flora, fauna, climate) and technological (e.g., data, AI, devices) actants. In response to this complexity, this paper proposes a novel conceptual frame that helps designer-practitioners to challenge the unsustainable technocentric status quo. Built upon a confluence of *Speculative*, *Participatory* and *More-than-Human-Centred* methods, the paper outlines how this approach can stimulate close collaboration between designers and stakeholder networks. The paper asserts that, through this scaffold, designer-practitioners can reimagine Net Zero futures which are inherently *More-than-Human*, that is, sustainable and equitable for our planet's human and non-human stakeholders alike.

Keywords

Disruptive Sustainability; More-Than-Human-Centred Design; Net Zero Infrastructures, Artificial Intelligence; Participatory Futuring

1. Introduction

It is a fertile and dynamic time for sustainable design-oriented research. A rich tapestry of inter-related methods and practices are being advanced to accelerate environmentally responsible transitions across modern society. The collective aim is to push us beyond our unsustainable paradigm, the *Anthropocene* (Galloway, 2017). From industry through communities to academia and policymaking, the prevailing discourse currently focusses on transitioning to a so-called 'Net Zero future' (UN., 2015; European Climate Law., 2021; IEA., 2021). Central to this vision is the mitigation of human-driven climate change through the decarbonisation of our industrial society, principally through the increased innovation and adoption of emergent technologies (EU., 2020). The advancement of design practice alongside new technologies has long been a symbiotic process (Thackara., 2005). Greater adoption of the latter will likely help us to decarbonise aspects of our society. However, it is imperative that we also think critically about how and why we embrace technological innovation as part of a systemic, sustainable transition. This is because untampered and irresponsible implementation of new technologies can also lead to unforeseen environmental and social rebound effects (Sharma et al., 2023).

This paper argues that while the mainstream visions for Net Zero futures can serve as useful *socio-technical imaginaries* (Jasanoff., 2015) to create awareness amongst stakeholders of the critical need to reduce emissions, their technocentric ideals can also help to perpetuate the hegemonic, carbonised design-innovation practice that dominates today. To positively shift away from the reductive, solutionist narratives, Design Research must pivot and develop a disruptive yet inclusive approach towards designing for Net Zero. Climate change is a complex, dynamic system rooted upon multi-scale and multifarious interrelations and dependencies between human, ecological (e.g., flora, fauna, climate) and technological (e.g., data, AI, devices) actants (Stead & Coulton., 2022). This paper proposes a novel conceptual frame that responds to this complexity and aims to enable designer-practitioners to begin to challenge today's techno-entric status quo. The paper outlines how a confluence of *Speculative Design* (Auger., 2013), *Participatory Design* (Schuler & Namioka., 1993) and *More-than-Human-Centred Design* (Nicenbolm et al., 2023) methods underpin this approach and stimulate close collaboration between designers and stakeholder networks. Using *Artificial Intelligence* (AI) as an exemplar of rapid unsustainable and unjust technocentric expansion, the paper asserts that through the presented methodological scaffold, designer-practitioners can start to reimagine Net Zero futures which are inherently *More-than-Human*, that is, more sustainable and equitable for the planet's human and non-human stakeholders alike.

2. Challenging Technocentric Net Zero Monofuturism

Emerging technologies like AI and 'smart' *Internet of Things* devices can help us to make better sense of the world and their adoption across many spheres of society like healthcare, transport and manufacturing have provided numerous important breakthroughs (UKRI., 2023). However, given the climate emergency, the growing environmental challenges that come with increased adoption of digital technologies are rightly beginning to be put under greater scrutiny. Bratton. (2019) asserts that due to humankind's deplorable track record, a sustainable future built upon technological intervention is a *'venture that is full of risk [and, as such,] the future becomes something to be prevented as much as achieved.'*

The rhetoric of Net zero 2050 with its keen focus on emissions and efficiency metrics feeds what Vinsel & Russell. (2020) have termed the *innovation delusion*. This solutionist narrative has the potential to engender a *monofuture* (Candy., 2010), that is, a narrow, reductive and predominantly technocentric Net Zero transition. For example, Widdicks et al. (2023) have shown how digital technologies in particular are regularly promoted as critical to *enablement* i.e., they help to increase decarbonisation by reducing greenhouse gas emissions across our global industrialised economy through improved consumption of resources such as electricity and material use. However, the deployment of these same technological developments can often fail to adequately account for their possible *rebound effects* and *unintended consequences* – whereby the introduction of a new technology, or its redesign, can offset the emissions savings it creates, and in the worst-case, increase carbon emissions.

Smart device e-waste, unrelenting AI data generation and an overreliance on globally dispersed, energy intensive *Cloud Computing* server farms also bolster digital technology's unsustainable impacts (Author et al., 2020). These rebound effects can also lead to what is known as *Jevons' Paradox* (Alcott., 2005). This is where resource efficiency is increased through technological improvements that in turn results ultimately leads to more resources being consumed due to increasing demand. Previous examples of the paradox include the sharp increases in coal-use as new technologies were adopted during the *Industrial Revolution*. Crucially, it is not our devices nor systems that have led us into this era of digital unsustainability. It is due to the way we have continued to design them to deplete precious natural resources, generate copious amounts of carbon emissions and create mountains of obsolete technology (Becker., 2023). These harmful impacts are, for the most part, a symptom of the problematic design patterns and rhetoric persistently put forward by technology firms predicated on commercial gain and market growth (Author et al., 2022). It is just to argue that responsibility for this growing *digital paradox* (Hazas & Nathan., 2017) also rests with the design researcher-practitioners who proactively service technology producers and providers. Indeed, whilst the practice of *design futures* can help to highlight potential benefits of designing emerging technologies with greater consideration for sustainability, it also operates in tandem with what Tony Fry. (2009) terms design *defuturing*:

> "Fundamentally, [designers] act to defuture because we do not understand how the values, knowledge, worlds and things we create go on designing after we have designed and made them."

Our current technology design, research and innovation paradigm actively contributes to these problems. Even if researcher-practitioners seek to design a digital device, service and/or system that they intend to be 'sustainable', their design will likely have unintended consequences and give rise to environmental and societal trade-offs – on a *glocal* scale given increasingly pervasive nature of these interventions. The environmental scholar Elizabeth Kolbert. (2021) similarly notes this *defuturing* potential when describing that efforts to implement sustainable technologies and practices often result in "people trying to solve problems created by people trying to solve problems."

3. Artificial Sustainability

As digitalisation proliferates across society, autonomous AI systems are increasingly being implemented to mediate today's unfettered dataflows. Vallor & Vierkant. (2024) describe such systems as a confluence of "software applications, machines, and people, that is able to take [action] with little or no human supervision". Importantly, due to their perceived immateriality, AI systems are regularly considered to be a resource efficient technology which helps to mitigate the unsustainable impacts of our data-driven ecosystem (Author et al., 2022). For example, in seeking to develop a 'smarter', more dynamic generation, storage and supply network which can better optimise and direct the socio-technical transition to Net Zero, many decision-makers in the energy sector are embracing AI and *Machine Learning* (Rozite et al., 2023, Maher et al., 2022).

Despite their Net Zero advantages, the scale and ubiquity of AI technologies means that such *algorithmic governanc*e (Johnston., 2022) is also resulting in exponential environmental impacts. AI systems are themselves extremely energy hungry and create huge amounts of CO_2

emissions (Heikkilä., 2022; Crawford., 2021) that contribute to digital technology's growing global footprint – currently 4% of worldwide emissions (Freitag et al., 2021). The rapid emergence of Generative AI tools over the past three years or so, is only exacerbating these problems. Dodge et al. (2022) highlight how the creating one image via a common Generative AI tool consumes almost the same amount of energy (approximately 0.012kWh) required to fully charge a mobile phone. Their analysis reveals that there is much variation between such tools however, as well as differences resulting from the size of image produced. They state that the least efficient Generative AI image software can consume as much energy as 950 smartphone charges (11.49 kWh). Crawford. (2024) similarly notes how a Generative AI search uses 4-5 times the amount of energy of a conventional web search. Alarmingly, they also stress how said systems "need enormous amounts of fresh water to cool their processors and generate electricity [and current estimates suggest that] globally, the demand for water for AI could be half that of the UK by 2027."

The environmentally extractive impacts of AI technologies are compounded by their socially unsustainable implications. Whilst AI can help provide consumers with more value and choice, the growing complexity of energy markets means that 'high frequency' automated decision-making based on user and system data, forecasts and models is deemed to be necessary for the operation of energy infrastructures in their entirety (Johnston., 2022). Consequently, AI technologies are essentially becoming 'moral agents' (Wallach & Allen., 2008) as they are 'learning' to make decisions regards customers' energy supply and consumption with limited human oversight. This autonomy raises important ethical considerations for Net Zero transitions - particularly if, as outlined, the harmful impacts of the technologies themselves is starting to outweigh their environmental and social benefits. Increasing AI autonomy could also open gateways to distortion or manipulation of energy markets and discrimination against particular individuals or groups. There is a growing body of research on racial and gender bias in AI systems that supports this hypothesis, for example, Van Niekerk et al., (2024).

These underexplored rebound effects call into question the environmental and social sustainable trustworthiness of autonomous AI systems. Consequently, there is an urgent need to innovate more sustainable and equitable futures that accommodate AI – particularly for energy stakeholders keen to deliver on governmental Net Zero promises such as the UK's strategy (BEIS., 2021).

4. Fifty Shades of Green (Design)

AI technology's capacity for help to *future* and *defuture* society's transition to Net Zero is evidently real and sobering. How then can we begin to collectively shift to *sustainable* and *equitable* technological futures that are more resilient to potential rebound effects? With its unique ability to bring arts and humanities and scientific disciplines together, Design can help us shape a sustainable world that flourishes beyond *Net Zero 2050*. Design researcher-practitioners have long been key change agents for vital, global transformations. In his book, *The Sciences of the Artificial*, Herbert Simon. (1969) famously asserted:

> "Everyone designs who devise courses of action aimed at changing existing situations into preferred ones. The intellectual activity that produces material artifacts is no different fundamentally from the one that prescribes remedies for a sick patient or the one that devises a new sales plan for a company or a social welfare policy for a state."

Whether it be a product, service or system, from this positionality, the success of a particular designed future can be said to correlate with how well it meets the preferences of the people that use it, and/or are impacted by it. Unfortunately, this adherence to a *Human-Centred Design* (Norman., 1998) approach – and the strong focus on profit and growth that has accompanied it – has helped our current unsustainable paradigm, the *Anthropocene*, to thrive. Resultantly, most of our designed outputs fail to acknowledge the wider damaging environmental and social consequences that accompany their creation, adoption and end of life (Author et al., 2021). This is in spite of early sustainable design pioneers like Packard. (1960), Papanek. (1971) and Schumacher. (1973) all stressing the need to design futures that are intrinsically environmentally sustainable and socially equitable. Further, Schumacher. (1973) also called for the adoption of what he termed *appropriate technologies*, that is, ones which primarily serve citizens and communities on a local level by being decentralised, affordable and small-scale. *Appropriate technologies* thus sit in deep contrast to the widespread, proprietary technological entities like AI that currently have dominion across much of society.

Massive in scale and continually evolving, global unsustainability is a 'wicked problem' (Rittel & Webber., 1973) which is becoming increasingly difficult to solve outright. It can be what Timothy Morton. (2013) terms a *hyperobject*, who contends that "the more data we have about hyperobjects the less we know about them – the more we realise we can never truly know them." Building upon Packard. (1960), Papanek. (1971) and Schumacher's. (1973) revolutionary ideals, many successive Design scholars have sought to redress the 'wicked' issue of sustainability. Demonstrating this trajectory, Ceschin & Gaziulusoy. (2016) developed a *Design for Sustainability Evolutionary Framework* – a timeline which maps the core pragmatic scholarship undertaken across the field over the latter half of the 20th century. From *Green Design* through *Product-Service-System Design* to *Design for Systemic Transitions*, the framework is a valuable schema which clearly illustrates how sustainable design has evolved from "a technical and product-centric focus towards large scale system level changes in which sustainability is understood as a socio-technical challenge."

A gamut of additional interrelated systemic, sustainable design methods (Sweeting & Sutherland., 2022) has also emerged since the millennium. Domains including *Circular Design* (Ellen MacArthur Foundation., n.d.), *Cradle to Cradle* (Braungart & McDonough., 2008), *Regenerative Design* (Wahl., 2016), *Emotionally Durable Design* (Chapman., 2005) and *Biodesign* (Antonelli., 2022) share much of the same DNA as those fields outlined by Ceschin & Gaziulusoy. (2016). The Design Research community (and beyond) has also taken what can be termed a "speculative turn' over the past decade or so. Here a collection of inter-related methods including *Critical Design* (Bardzell & Bardzell., 2013), *Adversarial Design* (DiSalvo., 2015) and *Design Fiction* (Coulton et al., 2017) are being applied under the umbrella term of *Speculative Design* (Wong & Khovanskaya., 2018) to create novel, creative visions for preferable futures that run counter today's unsustainable and inequitable status quo. As Alex Steffen. (2016) argues "we can't build what we can't imagine… the fact that we haven't compellingly imagined a thriving, dynamic, sustainable world is a major reason we don't already live in one." To this end, the primary aim of *Speculative Design* practice is to raise awareness, provoke debate and perhaps even begin to shift perceptions regards the adoption of emerging technologies including AI, and the possibilities presented by these so-called advances for enabling *and/or* defuturing *sustainable futures*.

Despite this progress, the planet and its people continue to live in the shadow of a deepening climate emergency. Increasing sea levels, carbon emissions, extreme weather, biodiversity loss, social inequity, and technological waste – climate change is no longer a future prospect but a reality of the here and now. In order to engender responsible and resilient Net Zero futures, design researcher-practitioners also need to open up their sustainable design practice. They must begin to embrace a confluence of methods, namely *Speculative Design*, *Participatory Design* and *More-than-Human-Centred Design.* Importantly, it is the latter method which binds this methodological union and helps stimulate closer, more equitable collaboration between designers and key Net Zero transition stakeholders – humans, natural ecologies and systemic technologies.

5. More-than-Human Net Zero Futures

As noted, climate change is a *hyperobject* (Morton., 2013) – a vast, evolving, ecosystem rooted upon multi-scale and multifarious interrelations and dependencies between human, ecological and technological actants. We must thus develop a conceptual frame that aids researcher-practitioners to effectively design for this complexity, as well as challenge the technocentric Net Zero status quo which is currently reinforcing it. The emergent field of *More-than-Human-Centred Design* (Forlano, 2017., Giaccardi, & Redström., 2020) provides a useful lens for retaining human perspectives but decentering their hegemony. *More-than-Human-Centred Design* helps designers to better foreground the vital exigencies of ecological, bio-diverse stakeholders – including flora, fauna, micro-organisms, and landscapes. At the same time, it also allows us to consider the role ubiquitous technologies like AI, *Internet of Things* devices, data and algorithms play throughout today's deeply entangled design ecology (Stead & Coulton., 2022).

More-than-Human-Centred Design has been shown to be impactful if combined with *Speculative Design* techniques (Nicenbolm et al., 2020; Stead & Coulton., 2022). Whereas much 20th century Design was predicated on unfettered, extractive materialism (Taylor, Peralta & Kermik., 2013), speculative approaches afford designer-researchers a way to emancipate their practice from the capitalistic ideologies of modernity (Author., 2020). To this end, Speculative Design has, for the most part, pivoted around Dunne & Raby's. (2013) assertion that Design must shift from the commercial, problem-solving normative of 'designing applications' to the exploratory, meta-physical inquiry of 'designing implications.' Knowles et al. (2018) assert that this type of design-led research can increase environmental consciousness of technological impacts amongst a broad range of audiences – from academia, through industry, to wider publics. Such speculations aim to facilitate discussions about the potential societal implications of technologies to be considered *within the present* before said possible implications come to pass. This discursive capability also points to another dimension of *Speculative Design* practice – *Participatory Futuring*.

When design researcher-practitioners envision future technological products, services and infrastructures, they do not intend for these interventions to operate in isolation. Peach & Smith. (2022) describe how application of a *Participatory Futuring* approach facilitates important critical and creative engagement with a broader range of stakeholder positionalities. Moreover, by applying this method in unison with *More-than-Human-Centred* and *Speculative Design* expertise, researcher-practitioners can begin to meaningfully concretise the systemic environmental, social and technological intricacies of transitioning to Net Zero. Working with citizen-communities, industry, policymakers, third sector organisations and other social actants generates opportunities to explore a more expansive array of alternate futures than a designer and/or design team has the knowledge nor capacity to do so alone. This collaborative process is essential for shaping more responsible and resilient Net Zero prototypes, tools and pathways. Further, it helps to mitigate potential for continued, injurious *defuturing* as opposed to positive *futurin*g practice. Figure 1 illustrates this explorative and pluralistic Net Zero design ontology.

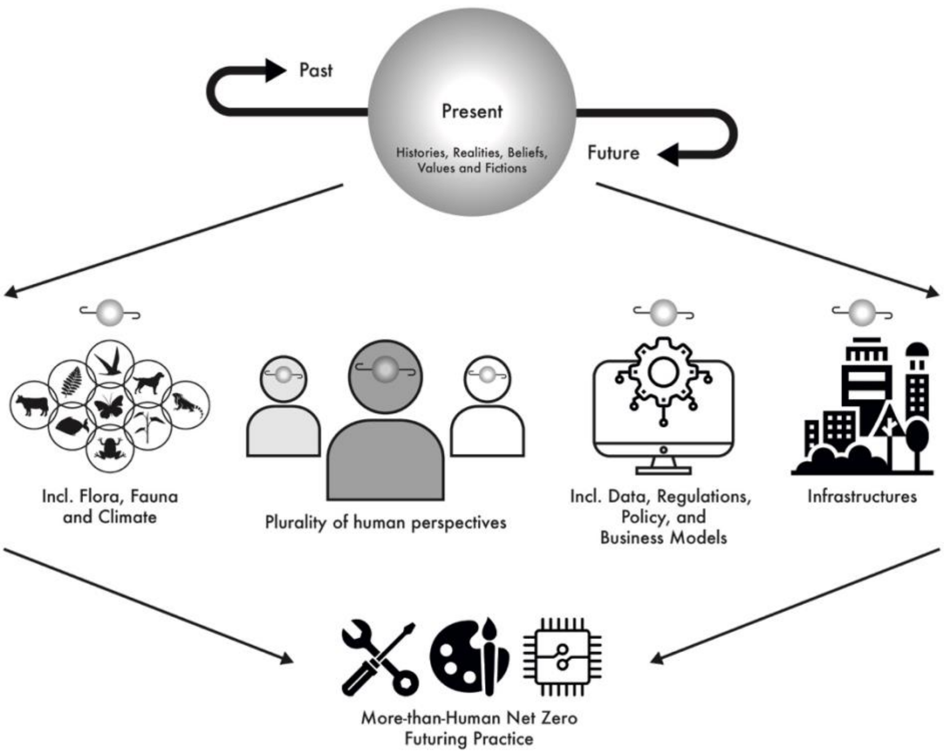

Figure 1. *More-than-Human Net Zero Futuring Practice (After Gonzatto, van Amstel, Merkle, & Hartmann., 2013, and Author., 2024).*

6. Developing Disruptive Participatory Design Practice for A Sustainable and Equitable Planet

Global North citizens are beginning to experience the types of effects of climate change that have unfortunately been the reality for many in Global South communities for decades (Mitrović., 2018). Thus, to *e*ngend*e*r Net Zero Futures which are equitable as well as sustainable in scope, a shift away is needed from the what (Kozubaev., 2018) sees as the privileged and hegemonic 'Western-centric incarnation' of futuring. Arturo Escobar. (2018) similarly urges design to "transition from the hegemony of modernity's one-world ontology to a pluriverse of socio-natural configurations" where no single accepted present reality persists but a plethora of "history, beliefs, values, and fiction are all implicated in the cultural construction of past, present, and future realities" (Stead & Coulton., 2022b). To galvanise this change, researcher-practitioners require a disruptive yet inclusive design strategy which can account for the deepening physical and metaphysical entanglements between "place, the environment, experience, politics, and the role of digital technologies in transforming design contexts" (Escobar., 2018).

The combined application of forward-looking methods *Speculative, Participatory* and *More-than-Human-Centred Design* provides the substrate to build this disruptive and inclusive design agenda. Figure 2 illustrates a *Participatory Design research workshop process*. The following sections describe the series of novel research tools and activities designed to maximise inclusive participant engagement as part of this process. These interventions combine to create a *generative discursive space* (Bleecker., 2009) in which participants can collectively work together to critically consider the independent and interdependent relations between actants, the systemic trade-offs, and the possible unintended consequences of increased technological design, implementation and adoption upon Net Zero futures.

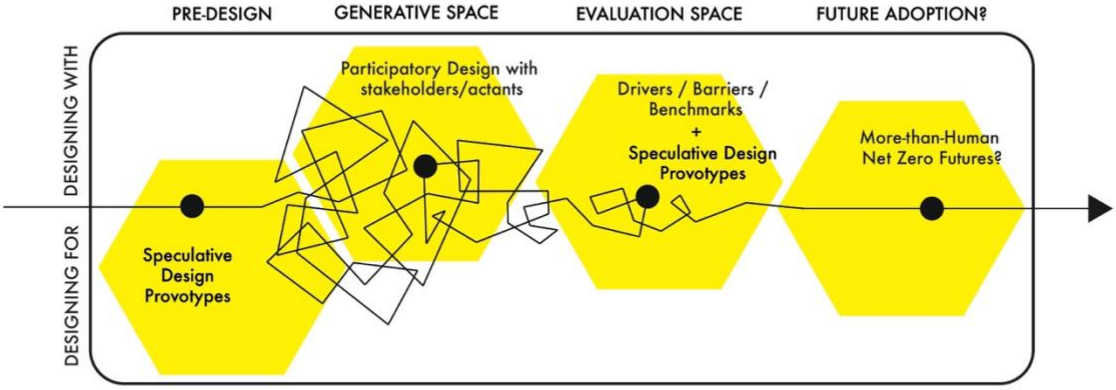

Figure 2. *Disruptive Participatory Design workshop process (After Sanders & Stappers, 2014., and Author et al., 2023).*

6.1 Speculative Provotypes As Discursive Artefacts

Figure 3 depicts a *speculative provotype* (Welier & McKenzie., 2017) – *InterNET ZERO* – an interactive *More-than-Human* game world. The term *provotype* is a combination of *provocation* and *prototype*. The game has been developed through the application of a specific strand of *Speculative Design* called *Experiential Futures* (Candy and Dunagan., 2017). Via this immersive, provocative and ludic game experience, participants can better understand how AI technologies are becoming 'moral agents' as they are 'learning' to make decisions regards people's energy supply and consumption with limited human oversight. As has been outlined in *Section 3: Artificial* Sustainability, this autonomy raises important ethical considerations for sustainable energy transitions, particularly if the environmental and societal impacts of the technologies themselves are starting to outweigh the benefits. To this end, *InterNET ZERO* serves to engage participants in alternative sustainable and equitable *More-than-Human-Centred* dialogues regards Net Zero futures.

In doing so, the game operates as a *discursive artefact* (Tharp & Tharp., 2018), challenging normative technocentric narratives by opening up space for participants to critique the extractive and inequitable material impacts of 'immaterial' AI systems.

Figure 3. *InterNET ZERO* is a *speculative provotype* – an interactive *More-than-Human* game world which allows participants to consider environmental and social impacts of AI systems.

6.2 Systemic Giga-Mapping

Noel et al., (2023) argue, like Escobar. (2018; 2024), for critical *pluriversal, positional* and *relational* thinking to become fundamental tenets of next generation design praxis. However, it is important to recognise that one community's vision of a sustainable and equitable future might present unsustainable and unjust challenges for others. "The earth may be one, but the world is not" opined the famous Brundtland Report (World Commission on Environment and Development., 1987), acknowledging the inherent difficulties of energizing diverse stakeholders to the then nascent concept of *sustainable development.* Sevaldson. (2011) developed the technique *giga-mapping* as a means to identify the heterogenous actants that exist across complex systems and to define the trade-offs and tensions that flow between said entities. With the context the design of an autonomous AI product-service-system, Figure 4 shows how the technique can engage participants in *More-than-Human* discourse and navigate associated *pluriversal, positional* and *relational* thinking. To facilitate this exploratory process, four themes support participants through their collaborative *giga-mapping* activity –

- **Entanglements** – *Who are the actants that facilitate, benefit, and/or are disadvantaged by current and future technological interventions? Humans, nature, data, industry, business models, policy etc.*
- **Positionality –** *Where do partners/workshop participants and wider stakeholders fit within the system? How are they independent/interdependent?*
- **Trustworthiness –** *What is the current state of sustainable trust between actants?*
- **Power relations –** *Which actants currently have most dominion and how can other actants counter these entities to engender a more sustainable, equitable Net Zero future?*

Empowering participants with the agency to work together to make the structural hierarchy of a *More-than-Human* system more visible, can help them to define new opportunities for design pathways for next generation sustainable and equitable Net Zero innovation.

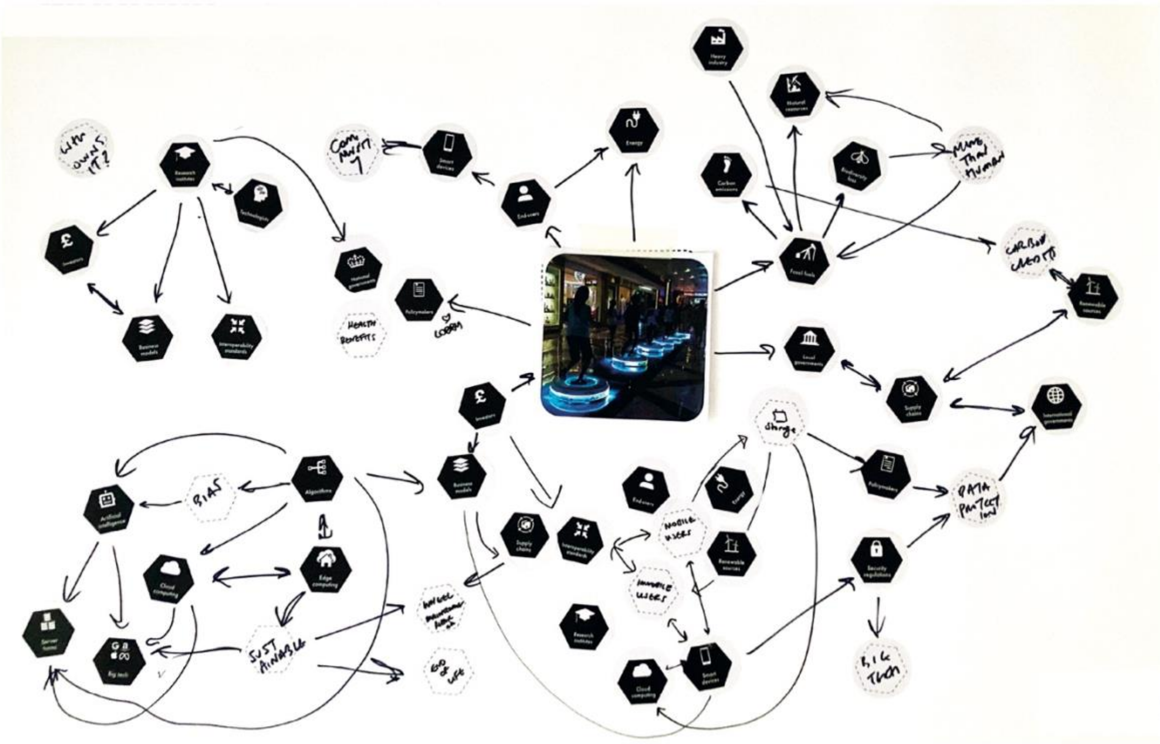

Figure 4. *A Giga-Map for an autonomous AI product-service-system (After Sevaldson., 2011).*

6.3 Pace Layering

Brand's. (2018) concept of *pace layering* provides another novel tool to facilitate participants' *divergent thinking* regards the interdependences and independences of complex systems like Climate Change. Figure 5 illustrates how, across a stratum of six fundamental layers, the method allows participants to explicate the pace of change required for enacting sustainable and equitable Net Zero transitions. Like the *giga-mapping* process, key themes stimulate participant engagement –

- **Mobility vs Resistance** – *What is stopping sustainable/equitable change from happening across the system? How can actors become agile across the layers?*
- **Temporality** – *How long will it take to change?*

Importantly, Brand. (2018) stresses how each layer is functionally different and operates independently. Yet, the layers are not disconnected and proactively inform one another. Moreover, “the fast layers innovate, [while] the slow layers stabilise.’ Participants must negotiate these properties as they contemplate the layers’ individual and shared implications for cultivating More-than-Human Net Zero Futures.

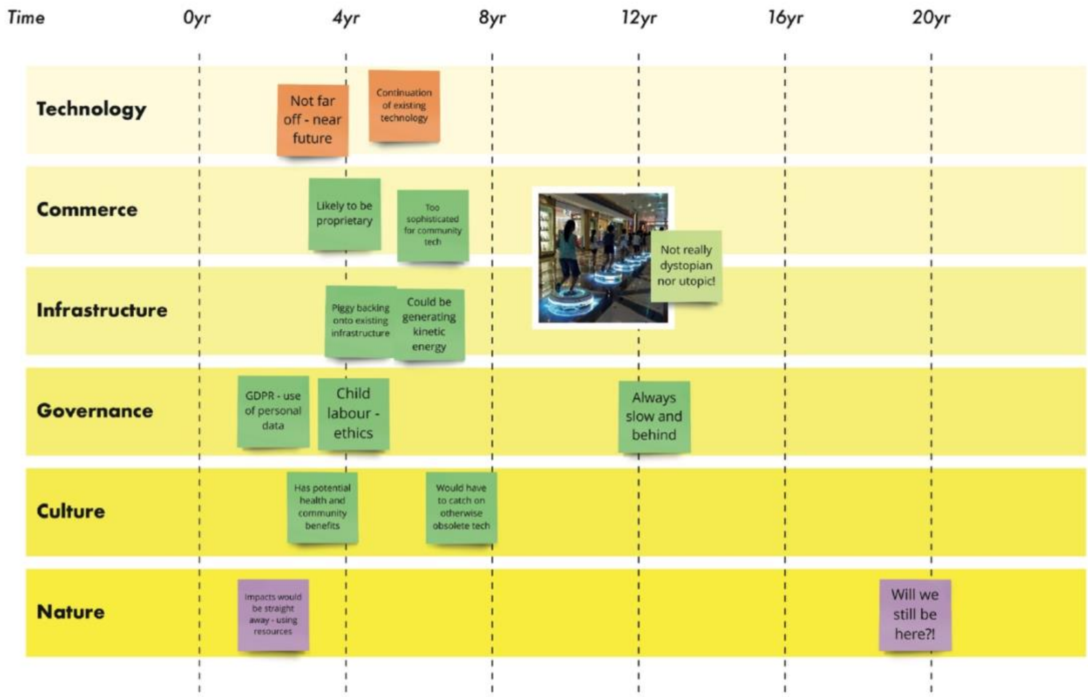

Figure 5. *Pace Layering for an autonomous AI product-service-system (After Brand, 2018).*

6.4 More-than-Human Net Zero Participatory Futuring Toolkit

Together, the *Speculative Provotyping*, *Systemic Giga-Mapping*, and *Pace Layering* form a *Participatory Futuring toolkit* for More-than-Human Net Zero innovation. Through these interactive, creative activities, participants engage in a process of ‘two-way construction’ (Tang & Nakarada., 2023) by which they become ‘co-constructors’ of the ensuing insights and meaning. To promote inclusivity and accessibility, the toolkit can be employed online or during in-person workshop contexts. The physical iteration of the tools increases the immersive nature of the activities. As Figure 6 shows, participants are able to more tangibly articulate their personal/mutual expertise, values and desires regarding Net Zero technology development. They can also work together to expose any potential near future risks and rebounds said technologies may possibly enact.

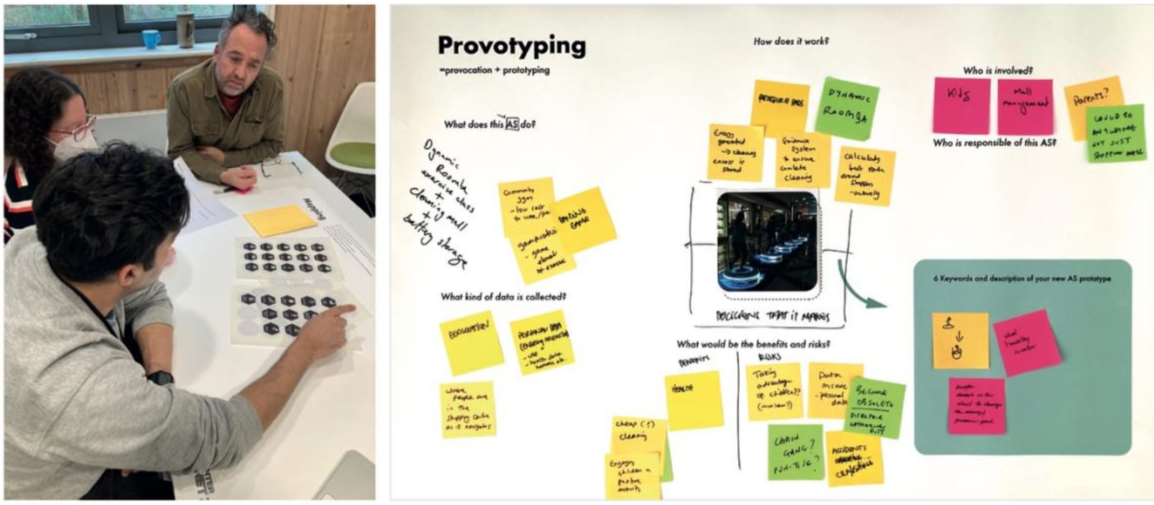

Figure 6. *The More-than-Human Net Zero Futuring activities collectively form a Participatory Design toolkit.*

6.5 More-than-Human Net Zero Transition Design Model

The *More-than-Human Net Zero Transition Design model* (Figure 7) collectively embodies the exploratory process of *Speculative Design* futuring practices, *Participatory Design* activities and the critical thinking of *More-than-Human-Centred Design.* Through this temporal framework, researcher-practitioners can work to envision *fictional prototypes* for more sustainable, equitable futures of technological products-services-systems. Crucially, this activity evolves in tandem alongside the development of their more immediate, real-world counterparts (Author et al., 2021). To help curtail technocentric solutionism and mitigate the risk of rebounds and *Jevon's Paradox*, the *Transition Design* model incorporates regular *Stakeholder Evaluation and Re-envisioning Points.* These intersections between fictional and real-world prototyping offer regular forums for researcher-practitioners to collaborate with key stakeholders (humans, natural ecologies and technologies) to consider the environmental impacts resulting from the development of Net Zero innovations. As Meadows. (1999) asserts, intersections like these become *leverage points* to 'intervene in the system' – particularly for environmental benefit. In doing so, this design process could help to shape more sustainable, equitable and responsible pathways for Net Zero technologies – before they become widely adopted across society. In contrast with today's unsustainable devices and systems which often also have innate bias towards the wants of more privileged western users, the model seeks to provide opportunities to design for more inclusive, *appropriate* technologies that embody the values and needs of broader sets of citizens and communities as well as respond to the climate crisis, now and into the future.

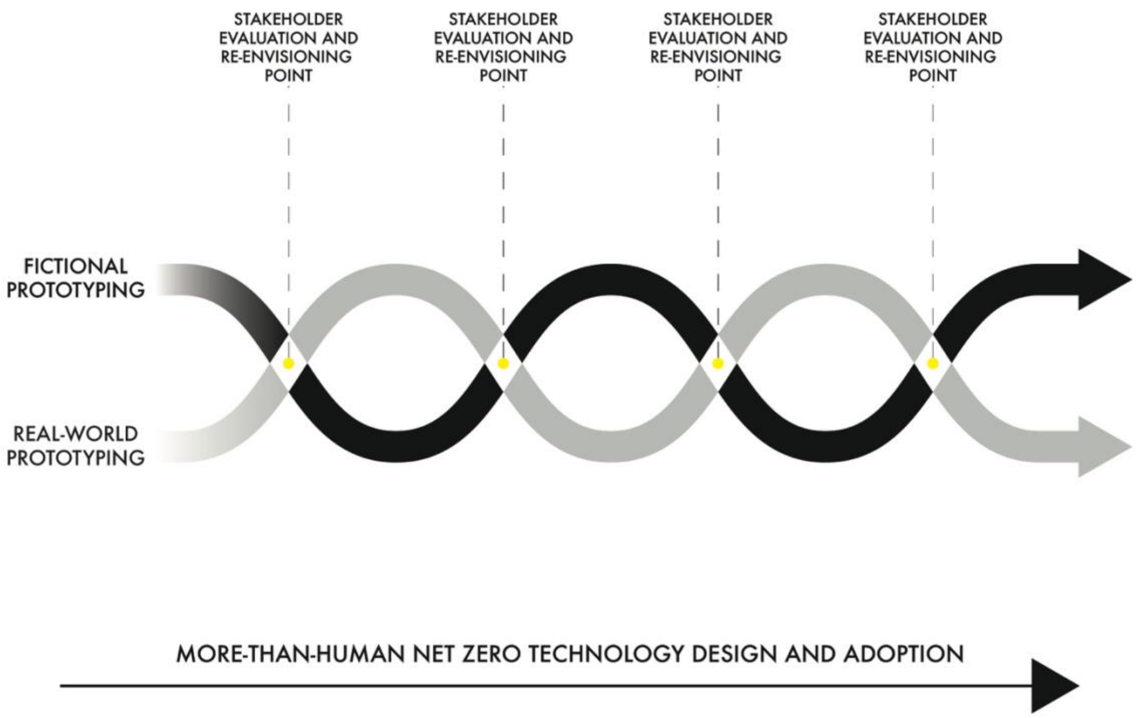

Figure 7. *More-than-Human Net Zero Transition Design model.*

7. Conclusion

When designing for Net Zero futures, architect, designer and critic Cedric Price's. (1966) observation is nevermore pertinent – "technology is the answer, but what was the question?" Considering their propensity to defuture sustainability as much as future its potentiality, it is imperative that designer researcher-practitioners think much more critically about how and why citizens and society adopt emerging technologies such as AI as part of the Net Zero transition. This paper underlines how a confluence of *Speculative Design, Participatory Design* and *More-than-Human-Centred Design* can facilitate researcher-practitioners to begin to design for this entangled problem space. In outlining creative, disruptive design-led thinking and praxis that enables inclusive collaboration, this paper provides a fertile foundation for further important work. The key objective for design is to responsibly align appropriate and resilient technological innovation with urgent, 'glocal' environmental and societal concerns. By collectively adopting the presented research frame, researcher-practitioners can create opportunities to envision and potentially build a sustainable, equitable Net Zero future for our planet.

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