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Article

Towards Sustainable Island Futures: Design for Ocean Wave Energy

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Abstract

This article explores the role of the future in contemporary technology design, and elaborates how imagination can influence the present through the mechanism of speculation. Three applications of futures are introduced: extrapolation examines present data and trends to predict possible futures, reflecting on the present imagines possible futures for insights on current practices, while backcasting visualizes a preferred future and plots a trajectory from the present to achieve it. Design speculations for Ocean Wave Energy capture systems are presented that illustrate the shaping of the future with conceptual prototypes, and a future narrative when humanity has averted a climate catastrophe.

Keywords

Design, Speculation, Design Futures, Sustainability, Renewable Energy

Introduction

Design is uniquely capable as a discipline for investigating the future; through its prefiguring, prototyping, and constant search for new permutations of form and function, design is almost entirely devoted to the future (Damian White, 2015). Simultaneously designers are constrained by the past, restricted in imagination and ability to conceptualize the future by our lineages and legacies (Hanna, Auger, & Encinas, 2017). Here we examine the role that the future plays in the present, and how imaginaries, scenarios, and speculations manifested by designers today can influence the world of tomorrow (Wakkary, Odom, Hauser, Hertz, & Lin, 2015). We situate our work as design for Sustainable Island Futures, to suggest what kind of future we are designing for. Yet even the very near future is full of uncertainty, as recent events concerning the global coronavirus pandemic have so painfully and clearly illustrated. This compounds the task of figuring out what needs to change in the present in order to bring about any preferred future. Very often our hopes for change are intrinsically linked with the fields of technology and design (Verschraegen, Vandermoere, Braeckmans, & Segaert, 2017), outcomes of which have often proved beyond our control.

To illuminate this conundrum, we first elaborate how the future is believed to influence the present, describing several conceptions of speculation as a functional mechanism. We then introduce three distinct applications of the future to design, acknowledging that more exist and may even become apparent during the course of this reading. The first application is *extrapolation;* using data and trends from the present, we make forecasts and imagine the future that will likely unfold. Envisioning the world that will potentially come into being due to contemporary circumstances is at the heart of sustainability thinking, and serves as an ethical and practical guide for our design. In the second approach we are *reflecting on the present* by imagining a potential future, adjusting our practices towards preferred, alternative presents. The third approach is *backcasting*: imagining a preferred future, we work backwards, using design tools to query what changes (e.g., political, technological, social or infrastructural) are required in the present to achieve it. These three futures applications demonstrate the bi-directional links between

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imagination and future reality, links that are then materialized through sketching, prototyping, performance and various design activities (Halse, Brandt, Clark, & Binder, 2010).

Following their introduction, we elaborate the three applications of the future through a series of design speculations from our ongoing research on the island of Madeira, Portugal, in the project REDEMA, Redesigning Madeira: Using Speculative Design to Rethink Energy Policy and Consumer Behavior. Three speculative designs for Ocean Wave Energy capture devices are described which explore the discourses of climate change and its future impact not only on our small island, but many other threatened coastal territories worldwide (Yarina, 2019). First the design concept, PowerBreaker illustrates a re-configuration of breakwater coastal erosion defences for ocean wave energy capture. This is followed by a portable energy collection device, the Blue Beast, which uses biomimicry to meld with its environment, and finally PowerCrab, a semi-autonomous energy collector unit that collaborates with others of its kind as a local networked micro-grid. We conclude with a commentary on linking futures and imaginaries with actions in the present, and the possibility to manipulate future timelines that is a unique capability of design.

Background

Design influences the future first by expanding potentiality, bringing into contemporary existence new ideas and possibilities. Then it begins to construct the future by extending actuality, giving shape to those new ideas through prototyping and making (Buwert, 2017). Technology design in particular anticipates the future (Dunne & Raby, 2013; Fry, 2009; Reeves, 2012; Verschraegen et al., 2017) for when we design new technologies, these in turn afford new ways of being and communicating (Light, 2015). Thus our intentions as design practitioners, and the agendas of our research institutions have the potential to exert a powerful influence on life in the future. This can happen explicitly in terms of incorporating social and environmental activist themes into design (Markussen, 2013), or implicitly, as legacy thinking constrains a designer's imagination, locking them into present trajectories and limiting the imagination of and the possibilities within the future (Auger, Hanna, & Encinas, 2017).

New practices and schools of thought are gathering around the idea that imagination and speculation are tools for shaping the future (speculativeedu, 2019), yet details remain vague concerning how imagination can actually change the world. There are various design practices that attempt to leverage fiction and speculation to initiate discussions (see e.g., (Auger, 2013; Lindley & Coulton, 2015)) but do so without attempting to explain how imagination can in fact manifest a different reality. Without real-world examples, evidence as it were, the transformative power of speculation is itself speculative. Anecdotal examples of science fiction's influence on the unfolding future abound, such as the submarine, cyberspace and the video phone. These have emerged in our lived experience decades after their birth in literature and a rich debate has developed concerning science fiction's actual influence (see e.g., (Idier, 2000; Zaidi, 2019)). In such cases science fiction can be seen as a form of techno-social commentary that potentially influences the shape of things to come (Dourish & Bell, 2014), yet there are equally numerous examples, such as Artificial Intelligence and Virtual Reality, that have arguably not yet lived up to their predicted socio-technical influence (Murray, 1997). This intermingling of science fiction with forecasting and prediction, common in design fictions, is beset by uncertainty (Reeves, 2012).

Speculative practices in design have often exhibited a similar predictive imagination, for example, Dunne and Raby's search for "other worlds and alternatives" (Dunne & Raby, 2013) or James Auger's initial take on imagining potential futures (Auger, 2013). This can be expanded beyond science fiction storytelling to articulate futures concepts through engineering prototypes; first expanding potentiality with fictional prototypes (Lindley & Coulton, 2015), and then more concretely by creating objects and systems, material speculations (Wakkary et al., 2015) that either allude to, or with some functionality, enact the visions and narratives of possible futures.

Our interpretation of design speculation is grounded in this proposal, that the processes of making constitute a language that can transmute current states of affairs into new materialities (Watts, Auger, & Hanna, 2018). However, to ensure that potentiality has a route to become actuality (Buwert, 2017), our imaginaries, the utterances of this language, must be constrained to plausible inventions and remain connected to actual and familiar world-views (Auger, 2010). This basic design consideration runs parallel to the speculative philosophy of Whitehead (Whitehead, 1978), who frames imaginative speculations as a basis for understanding reality (including our own experiences), which are grounded by evidence and observations. Speculation is used to fill in the gaps in one's knowledge left by what cannot be observed and explained, yet that speculation must be *adequate* and *applicable* to the reality

(Whitehead, 1978) and as such, inspired by reality. At the same time, speculation is constrained by reality and the experiences we seek to understand (Debaise & Stengers, 2016; Whitehead, 1978).

Using speculation to explain experienced reality means also being open to different possibilities and other multiplicities without being trapped in pre-built visions of the world, as outlined by Debaise and Stengers (Debaise & Stengers, 2016). Broaching conceptual alternatives facilitates the development of a broader, multi-faceted explanatory system of one's experiences and opens the discussion of what would be, might be, must be and so on, considering past events, present conditions, as well as future scenarios and narratives (Booth, Rowlinson, Clark, Delahaye, & Procter, 2009). Speculations create a "discomfort", a breaking point that challenges the actual reality from which emergent tension between familiar and unfamiliar stimulates the imagination to question the status quo (Auger, 2013; Dunne & Raby, 2013), opening it up to alternative possibilities. Indeed speculation, whether it be spontaneous, encountered in fictional literature, initiated by an object or imprinted through a design intervention, interrupts one's established worldview. Bell, disentangling Stengers, suggests that just such a disruption is the catalyst that sets the transformative power of speculation into action (Bell, 2017). Something new is inserted that clashes or causes confusion and in this fleeting moment, before the confines of one's status quo are re-established, there exists the possibility of departure, of *difference*, an opportunity and encouragement for the individual to accept another, alternative possibility (Bell, 2017). In this way speculation creates or clears the mental space for a fresh ideation to occur, and exerts direct influence on the range of possibilities. The impetus for change attributed to such breakpoint events aligns with the concept of estrangement, the introduction of deviations to convention, or surprises that disrupt the flow of action, interaction and engagement. Estrangement can facilitate moments of creativity and intuition (Schön, 1983) and is an important aspect of design intervention to facilitate change (Markussen, 2013).

From this explicit engagement with the *future* a complex and somewhat confused terminology has emerged between competing brands of futures research and technology design, e.g., Design Futures, Futuring, Speculative Design, Speculative Fabulation, Alternative Presents, Design Fictions and Envisioning, among others (Auger, 2010; Dunne & Raby, 2013; Fry, 2009; Lindley & Coulton, 2015; Reeves, 2012; Salazar, 2017; Verschraegen et al., 2017). In order to avoid both semantic and political arguments, we simply embrace this investigation of the future as central to *design*, in particular when we focus on sustainability (Fauré, Arushanyan, Ekener, Miliutenko, & Finnveden, 2017). We observe a current state of affairs, imagine how it could be different, and take informed action towards construction to bring a new state into being. Our speculation engenders imaginaries, our prototyping seeks to manifest these as aspects of the world, and these practices are intrinsically linked with our conceptualization of the future. As we approach the existential threat of climate change, our design is at first informed by conventional methods of prediction and forecasting. Yet, we need to actually begin shaping the world of tomorrow from the present, for example using backcasting and other methods (Fry, 2009; Halse et al., 2010), and we want our speculations to have a real-world impact, beyond merely provoking reactions or stimulating debate. The next section illustrates three such approaches to the future within our design practice, as we explore Ocean Wave Energy as one aspect of a Sustainable Island Future.

Applying the Future to Design

In our work three distinct applications/engagements with the future are employed: 1) *extrapolation*, 2) *reflecting on the present*, and 3) *backcasting*. These three techniques provide different lenses through which design can envision, analyze and understand the future.

Extrapolation

The first approach is *extrapolation*, in which the future is forecasted from present states and trends. Through extrapolation it is possible to envision a future that will likely unfold, to inform the changes we might make today in design practice, the same technique as is widely used in decision and policy-making (Hyndman & Athanasopoulos, 2018; Robinson, 2003). This approach can involve short-, medium- and/or long-term projections based on *quantitative* assessments of accumulated data, leveraging available knowledge to develop models and patterns to predict the future. Extrapolation can also be subjective and therefore *qualitative*, and lead to radically different future possibilities. Such "judgmental" extrapolations are often used when data are lacking, insufficient, or when a decision must be taken for ethical or normative reasons (Hyndman & Athanasopoulos, 2018).

Extrapolation based on data, augmented with intuitions of probable futures, serves as the basis for the global forecasting industry (Verschraegen et al., 2017).

> An extrapolation that guides our design practice, for example, views models of rising sea levels (IPCC, 2019) with a critical, rather pessimistic observation that humanity (so far) has shown little real interest in changing behaviors to reduce global warming, and therefore a future in which sea levels have risen significantly, the higher end of predictions, is inevitable.

Reflecting on the present

Our second approach to the future is *reflecting on the present*, making sense of current states of affairs by imagining the future, which is typically ascribed to Speculative Design and Design Fiction (Dunne & Raby, 2013). This approach differs from extrapolation in that it focuses attention on the present; its critical perspective examines contemporary practices and behaviors to inform designs that represent desirable alternatives. By creating imaginaries, building worlds within which cultures, societies, technologies and nature have formed bonds and entered relationships beyond those of the present, we examine how design and technology have been embraced, and how this has affected the denizens of that imaginary world. This offers insights into our own present and the potential outcomes of the socio-technical life that we are enacting through design today. In contrast to the imaginary prototypes commonly attributed to design fiction, which exist within a story world (Lindley & Coulton, 2015), our design speculations lay plans for prototypes that should exist within our world, as embodiments of the processes and actions we attribute to the future. The reflecting on the present approach encapsulates "what-if" questions within physical objects which become a medium for discussion, texts in a broader discourse on the present as well as potential futures (Auger, 2013). These design speculations must be functional, but they can also push the boundaries of what is possible and real just enough to allow for spectators, and those engaging with the prototypes themselves, to embrace potentiality as plausibility. Such making-of is akin to a material speculation (Wakkary et al., 2015), which unlike fictions that embed discourses on the future in narrative texts, are actual material representations of the future possibilities we aim to explore.

> Building on the previous example, but this time reflecting on the present, our vision of the future is filled with uncertainty: sea level rise may be negligible or it may overwhelm the coastline as we know it, and this range of possibility affects how, and what we design today. What if we build things that are simply inundated by much higher storm surges than anticipated, or we build on higher ground, and the sea level does not rise as much as expected?

Backcasting

Our third application of the future to design is *backcasting* (Robinson, 2003), when we imagine a preferred future and work backwards, using design tools to query what needs to be accomplished and what changes must be made for our present state to arrive at that future. This process has also been articulated as envisioning (Reeves, 2012) and requires a broadly interdisciplinary approach that addresses fundamental conflicts concerning whose vision of the world should move forward (Manzini & Rizzo, 2011), if and how dissenting perspectives on the preferred future shapes of things should be adjudicated (Keshavarz & Maze, 2013). While backcasting may seem simplistic and subjective, it is arguably the most complex of future design operations. Compiling a vision of the future is not only about deciding how we want it to be, but identifying those aspects we do not want to be, and plotting their eventual de-futuring (Fry, 2009). Overthrowing these aspects of the present, gradually or radically, necessarily entails a dismantling of certain behaviors, cultural practices, modes of consumption and ways of being that have become established around them (Light, 2015). This in particular makes visible the entangled complexity of our hybrid social, technical and natural worlds (White & Wilbert, 2009) as we pick them apart in the process of becoming something new.

> Continuing with the example, but now backcasting, we imagine a future without the upheaval and destruction of massive sea level increases. Humanity has taken responsibility and implemented the extensive and necessary changes to stabilize the climate and sea levels have risen only slightly. This can

only have happened in the future if today we take concrete steps to balance development and the long-term health of the natural environment.

A Future with Ocean Wave Energy

That our future will be shaped by climate change is no longer speculation (UNEP, 2019) as all indicators suggest that the responsible industry and regulatory authorities are missing every opportunity to arrest the impending climate disaster (Jackson et al., 2018). This statement foregrounds two, near-future scenarios that guide the REDEMA research project and its investigation of community-scale ocean wave energy systems. Both scenarios stem from the current knowledge of legacy power generation and carbon emissions that are driving climate change (IEA, 2019), resultant global sea level rise (IPCC, 2019), and increasing intensity of storms which can accelerate coastal erosion (Basto & Centemeri, 2014; Masselink & Russell, 2013). One scenario, “continuing the status-quo”, tells us that due to the inaction of institutions and inability of individuals and societies to enact meaningful changes, the future is threatened by an inevitable climate cataclysm. The other “embracing change” scenario, imagines that social and technological practices of the future will be transformed to avert an outright catastrophe, or at least lessen its effects on humanity, the environment, and our co-inhabitants on the planet. Where these futures diverge is in their factoring of human agency and whether, or not, the future narrative includes sufficient actions taken to combat climate change and the rethinking of global energy production and consumer behavior that would be necessary to achieve a climate balance.

Design concept

The current climate predictions link rising sea levels (IPCC, 2019) with carbon emissions from energy production (IEA, 2019) and the potential for accelerated coastal erosion. Our design speculations are inspired from the coastal environment and the breakwaters that we (perhaps vainly) hope will keep the tempestuous ocean at bay and protect our coastal infrastructures. Breakwaters are complex, if static mechanisms, that typically consist of an undersea rubble mound topped with concrete tetrapod armour units; when ocean waves interact with the breakwater, wave energy is dissipated among the tetrapods, whose interlocking bodies redirect the force of the water. Our design reconfiguration approaches the tetrapod as a design object that symbolizes humanity’s existential struggle with the natural environment.

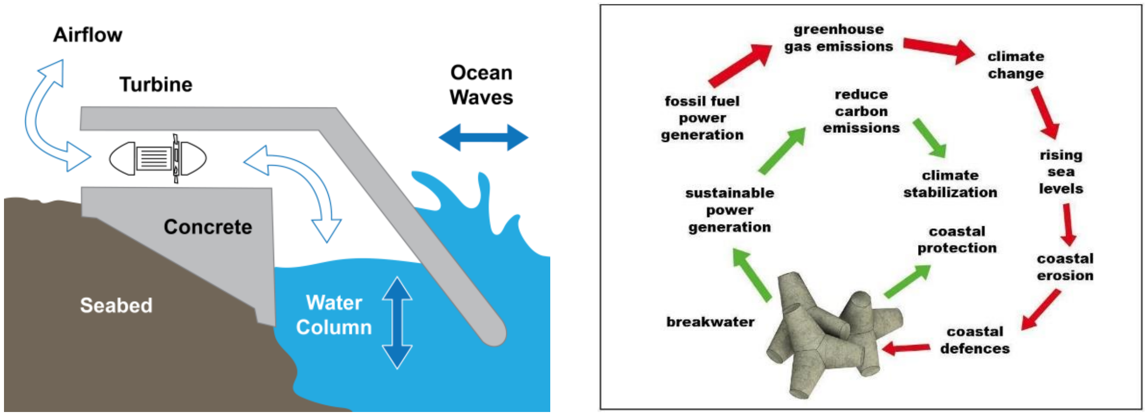

Fig. 1: (a) Oscillating Water Column diagram, (b) Design Reconfiguration

This design concept is grounded on existing precedents found in various projects attempting to integrate energy collectors into breakwaters (e.g., (Mustapa et al., 2017; Vicinanza et al., 2019) and in particular the European Wave Power Plant on our sister island Pico, located in the Azores (Falcão, 2000) which uses an Oscillating Water Column (OWC) (Heath, 2012) design that translates the surge of the sea into wind to drive a turbine generator (Fig. 1, a).

We re-imagine breakwater armors as new objects imbued with these capabilities, artifacts that are not only defending against a consequence of climate change, but producing low carbon-emissions electricity and thus participating in the fight against climate change itself (Fig. 1, b).

In the following we describe three speculative artefacts and their relationships to the approaches to the future in design presented in Section 3. Each of these confronts the status quo of the present and builds towards our preferred narrative of the future, the one that includes action taken to avert climate catastrophe.

Extrapolation: PowerBreaker

Extending the current state of affairs into the future, the question is not if, but how much global sea levels will rise. In response, we re-imagine the aforementioned tetrapod into an energy harvester, a *PowerBreaker* (Fig. 2, a and Fig. 2, b) that has been reshaped as an Oscillating Water Column with internal Wells turbine (Raghunathan, Tan, & Wells, 1982). The original inert, concrete tetrapod can be considered a *technological* artifact, as it is a physical object, created by one or more agents following a *make-plan* associated to a description. It is created in order to enable a particular *use-plan* (Borgo et al., 2014; Houkes & Vermaas, 2014; Verbeek & Vermaas, 2009), to be installed among the breakwaters for deflecting wave energy. PowerBreaker has a new configuration, achieved through a new make-plan, and a new relationship to the waves because of its new use-plan, the harvesting of wave energy. The new object embodies and mediates ethical issues concerning "how to act" which are central to design in the service of creating sustainable futures (Verbeek, 2006). Rather than the breakwater representing human agency in reaction to, or preparation for rising sea levels, PowerBreaker suggests that same breakwater can pro-actively reduce carbon emissions and combat temperature and sea level rise.

Inspired by the world in which we live, the design re-appropriates the form and placement of tetrapods among the breakwaters with a future object. It is simultaneously of this world, a modification of the current state of things, and an imaginary object derived from our scenario of a sustainable island future. Outwardly the object is much the same, and it can continue to fulfil its purpose of deflecting ocean waves and protecting the infrastructures that lie behind it. Inwardly the object is redefined, and the addition of the technological component, a turbine generator, affects a radical social and conceptual transformation. The PowerBreaker is given a new purpose and a redefined relationship to the ocean waves. The original engineering artifact on its own is a relatively ineffectual thing, as a single tetrapod can do little to hold back a storm surge; when placed together with many others of its kind, however, a tetrapod can contribute to the breakwater. When the tetrapod also becomes an energy harvester, each individual unit gains in importance, and again they work together, this time as a micro-grid to produce electricity, adding new value and potential to the breakwater.

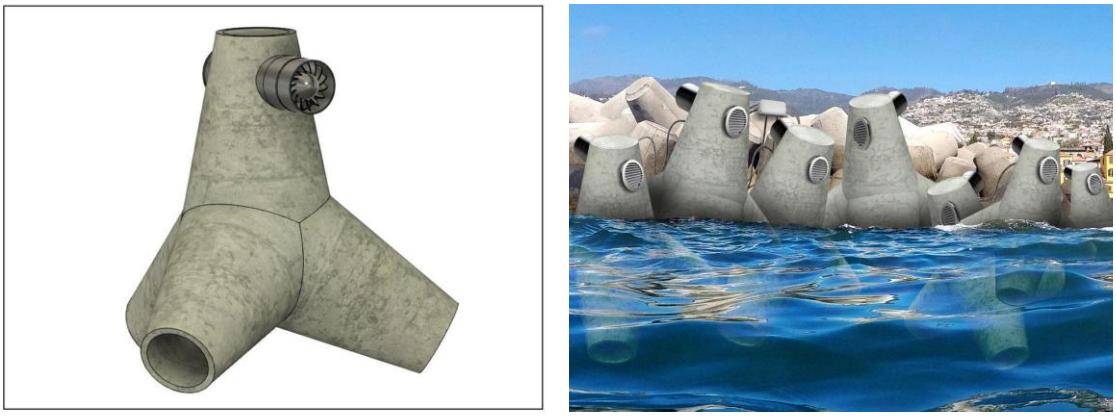

Fig. 2: (a) PowerBreaker Speculative Design Concept, (b) PowerBreaker Future Installation

Through a techno-material re-configuration, the PowerBreaker becomes a socially charged object that reworks the future narrative. Before it represented humankind's attempt to shield ourselves from the sea, to protect some vital infrastructure on its leeward side; it fit into a vision of humanity as always hiding behind a wall of concrete, shielded from the effects of climate change. The new form, in contrast, embraces the energy of the sea, turning its destructive potential into part of the solution, confronting climate change by producing low-carbon emissions electricity. However small the contribution of each may be, together they (will) act to reduce the driving force behind climate change. The narrative of this new object, the PowerBreaker, is not only a testament to the transformative nature of design, but also an ode to the collective human potential and our ingenuity in facing adversity.

Reflecting on the present: the Blue Beast

Our first method is to examine the current state of affairs for clues to its potential unfolding, and while this does serve as a source of design ideas, it is largely a passive imagining of future conditions. A more active engagement with the future is a process in which we reflect on the present through the act of imagining that future. We began this speculation starting from a state of the near-future world in which artifacts such as PowerBreaker might actually exist, the result of continuing our present trajectory into concrete prototyping, mass-production and widespread deployment.

This future vision prompted quite some introspection and self-reflection on our intentions, our design practices, the financial considerations, as well as the environmental impact of our designed things. We embarked on an investigation into the potential ecological implications (Frid et al., 2012) of our proposed designs that directly questioned the value of putting more concrete into the ocean and its potential implications for hydrodynamics, sedimentation, imposition on coastal habitats and effect on marine biodiversity (Aguilera, Broitman, & Thiel, 2016; Burt, Feary, Cavalcante, Bauman, & Usseglio, 2013; Ido & Shimrit, 2015; Oricchio et al., 2016; Scyphers, Powers, & Heck, 2015). More imminent reflections on the great dimensions and massive weight of a concrete tetrapod revealed the PowerBreaker as impractical for design prototyping in our labs: our future object could simply not be created with our current capabilities and resources. This demonstrates how the imagination of our future object inspired the reflection on our possible present, the world in which we invest more time and energy creating the PowerBreaker. Furthermore, the aforementioned uncertainty as to the extent of sea level increase incited further reflection on our design: placed too low in the future coastal zone, the generators would be submerged and destroyed, yet placed too high and not met by the rising sea level, PowerBreakers would produce no energy. As moving these multi-ton concrete energy devices would also be of great expense and effort, our reflections on the present suggested a change of direction is needed.

Hence our imaginations turned to more simple, portable wave energy collectors that could be integrated with existing breakwaters. Financial constraints, as well as a project principle of building from recycled materials wherever possible, led to a new design concept which utilizes the blue PVC barrels we keep in the lab for metal scraps. Observations of marine organisms at local breakwaters further transformed the design concept through biomimicry (Blok & Gremmen, 2016). The local coasts are inhabited by Arrow Crabs (*Stenorhynchus lanceolatus*), and we observed how well they cling to the rocks even as the surge jostles their forms about. They exhibit a tension, all their legs working in unison, and they position themselves always just right. They look to be scavenging bits of food from the water and combing through the algae even as they dodge the current. This dynamism inspired our design of a tensioned arm-and-claw rig to secure generator units among the tetrapods. Moreover, attention to the living crabs has infused our prototype design with a particular communication value, as biomimicry brings the design to life. The blue crablike object will be a striking spectacle - we reason that it will catch the attention of islanders and visitors when we install it at the local pier. It will be a reflection of nature as much as a DIY welded steel frame, a piece of public art that reminds everyone who encounters it of our existential relation to the sea. It will also produce electricity, allowing us to charge participants' phones, play MP3s and have a wave power beach party, with a low power disco ball at night, demonstrating our concept of community scale wave energy collection. These ideas all come together in the *Blue Beast* (Fig. 3, a).

Fig. 3: (a) Blue Beast Prototype Visualisation, (b) In-House Wells Turbine Design

The Blue Beast is a work-in-progress (unfortunately put on hold due to Covid-19 restrictions). It incorporates the Wells turbine, a particular shape of turbine developed specially for OWC plants, which spins in the same rotation regardless of the direction of airflow (Raghunathan et al., 1982). Our project engineer pieced together a design for the generator unit (Fig. 3, b) that includes the Wells turbine, a generator (possibly a motorcycle alternator) and on either side a directional wind vane. With some attention to the shape of air ducting (Shaaban & Hafiz, 2012), our ø 40cm Wells turbine could comfortably generate 1-2Kw of electricity. Taking this into consideration, we reviewed surveys that suppose only moderate wave energy potential around the island of Madeira (Alvaro Garcia & Peter Meisen, 2008; Rusu & Soares, 2012). A critical take on such appraisals suggests they are typically made from the perspective of a commercial investment-return mindset, and valued on potential contribution to the national grid (Moriarty & Honnery, 2016) rather than to communities or individuals. In contrast our Blue Beast speaks to community-scale installations, micro-grids that are built, maintained and produce energy for small local populations, often disconnected from national grids (Gray, Findlay, & Johanning, 2016; Soudan, 2019; Wiseman & Bronin, 2012). We raise the possibility that community-scale power generation can make contributions in ways that decision-makers may overlook, for example as a micro-grid cluster of Blue Beasts that powers a hotel and beach bar or a small port's harbour lights. This is a broad speculation, of course, as actual power output will be dependent on unpredictable sea conditions and real data will only begin to emerge once the prototype is completed and installed to begin its life by the sea.

Backcasting with the PowerCrab

Biomimicry imbues a life of its own. As we re-imagined our wave energy collectors as portable installations with the Blue Beast, we further conceived of them as semi-autonomous, moving about by themselves, just as Atlantic Rock Crabs (Grapsus adscensionis) scurry about the tetrapods in the local harbour. This brought forward a progressively speculative but no less realistic design, the *PowerCrab* which mimics not only the forms of the marine organism (Fig. 4, a), but also their individual and communal behaviors (Fig. 4, b). PowerCrabs are generator units that climb up and down the breakwaters, situating themselves to best catch energy from the waves to feed a micro-grid. Their mechanical, robotic bodies will follow the rise and fall of the tides, orienting to the angle and attack of incoming waves for the most efficient energy collection. Over time they will learn, developing plans and collaborative actions based on their "lived" experience of weather and sea conditions, gathering in formations as energy collection clusters, even removing themselves from the sea and huddling together when unsafe storm conditions arise (as they frequently do).

Fig. 4: (a) Biomimic Rock Crab Legs, (b) PowerCrabs in a Future Deployment

PowerCrab appears last in our timeline, the most “futuristic”, longer-term design, and the one that seems farthest from the real world. PowerCrab represents our future, as researchers and community members, in which the world’s energy production will be greener and cleaner. Based on past and present human activity this seems an increasingly tenuous expectation (Guterres, 2019), yet from a technological perspective PowerCrabs are not implausible. Despite the myriad challenges that advances in machine learning, environmental sensing, robotics, and autonomous systems research present (Wang & Siau, 2019), we can imagine such objects participating in the sustainable islands of the future. For now PowerCrab remains an imaginary technological artifact from a potential but distant future that our current engineering explorations could help make possible. In the course of this project, we can create these forms, but we can offer them only limited mechanical ability and sensing, perhaps enough to lower and raise their bodies to keep level with the rising and falling tides; there will be no full autonomy. However the possibilities raised through such a sensational design communicate a preferred version of the future, one in which ingenuity and dramatic innovation are capable of possibly even reversing climate change. The design becomes a bold representation in the present of what our future might hold, opening up possibilities and other ways to be, if only we choose a better narrative to guide us.

Discussion

What does facilitating meaningful change really look like using speculations such as these? In the previous descriptions of our design speculations, we offered some suggestions. By generating PowerBreaker, a concept that reacts to the doom and gloom forecast of global warming caused by human (in)action, we have encapsulated our discourse in a familiar form. We subsequently reinterpreted the concept as the Blue Beast, a more practical, realistic and affordable prototype that is inspired by a real-world entity (the Arrow Crab), a biomimic whose form and function reflects its role and the space it occupies. Finally, we engaged in speculation anew with PowerCrab, examining a preferred reality and backcasting this semi-autonomous device; it is from that future in which humans have taken control and are actively combating climate change and it is a thing we can begin working towards now. In the following discussion, we examine what is in fact one unified speculative design, and further illuminate *extrapolation*, *reflecting on the present*, and *backcasting* as applications of futures to contemporary design.

PowerBreaker utilizes *extrapolation* to draw out a future scenario from the present and embody that in the re-configured tetrapod. The trajectory of continued fossil fuel overuse and rising global temperatures has melted enough pack ice and expanded the volume of seawater such that global sea levels have risen significantly. More frequent storms, longer in duration and of greater intensity exacerbate coastal erosion, as higher, more powerful storm surges threaten island futures globally. Our only recourse is to hide behind the seawall barricades, and hope our breakwaters will protect us. This vision of the future is based on data projections (IPCC, 2019), and even if we are optimistic, and believe that humanity will somehow rise to the challenge and effect meaningful change (Guterres, 2019) only the extent of the catastrophe is still margnially within our control. PowerBreaker represents this narrative, and developing, building, and installing it in the sea to power street lamps along the promenade would be a design intervention to broadcast the urgency of countering this narrative to everyone out for an evening stroll. Yet even the concept suffices to drive this discussion, interjecting the question, "Can human ingenuity really take control of this scenario and turn it into something less extreme?"

The Blue Beast is *reflecting on the present* through a vision of the future, and we re-evaluate our design and resource capabilities as a small team in the present. In contrast to the PowerBreaker, which is design centered on the future, Blue Beast is a reaction to a near future scenario in which we have developed and built the PowerBreakers. We are confronted not only by possible impacts of placing them in coastal environments, but by the scale of such development that is more than we can realistically handle, and the uncertainties that might anyway render them ineffective. The Blue Beast shifts attention away from the present fascination with human intervention, the giant tetrapod that can hold back the might of the sea and focuses instead on a small living organism, the Arrow Crab. This biomimicry widens the perspective of our futures discourse: we clearly must design not only for human exigencies, or out of care for the environment, but also design to account for the other living creatures in the sea (Haraway, 2016). We realize the need for a form that doesn't weigh multiple tons, require a crane to put into place, and can potentially harm or interfere with coastal habitats. Yet perhaps the most important reflection on our present is driven by that uncertainty in the future; it forces us to completely redefine our design to allow for portable, semi-permanent wave energy collectors that can accommodate various conditions, fluctuations, and continue to be useful throughout the wide range of potential sea level increases. We cannot know precisely what the future holds, so our design is much more likely to find application if we change it now into something more flexible than concrete.

At last we come to the PowerCrab, the most futuristic and seemingly far-fetched design speculation, which applies *backcasting*. This is an advanced, somewhat intelligent machine, with memory derived from a lived experience of its environment. PowerCrab's learning algorithms, collaborative planning abilities and robotic, semi-autonomous mobility represent a point in time perhaps 10 or 20 years from now. It can only have come from a world in which institutional, social, political, and financial backing have driven science and technology full speed towards solving the climate crisis. The future that it leads to is a preferred future in which humanity has embraced development, but with sustainable values, when human achievement is once again represented by innovation and problem solving. PowerCrab is backcasted from a world when, if there is still climate change, it is perhaps not the catastrophe we now anticipate. These lurking, huddled forms, collected in swarms of renewable energy collectors will be seen on coastlines around the world, their microgrids will be ubiquitous, and energy consumption will have been drastically reduced by the great changes initiated in *our* time, the present. PowerCrab is an aspirational design, one we may not achieve in the project lifetime, but one which we hope will one day signal that we have made meaningful progress on our journey towards Sustainable Island Futures. The PowerCrab's biomimic carapace in the here and now will attract attention, drawing people into the spectacle of these artificial creatures offering us free energy. Even if people begin to think about them selfishly, "If these crabs were all along the coastline, would I have to pay for my electricity?" they will have served their purpose of facilitating the imagination of renewable energy as an integral part of everyday experience.

Science fiction elaborates social and cultural groundings offered in a broader story, and through world-building creates an environment within which things are established as part of the social and technical fabric of that existence (Dourish & Bell, 2014). Such imaginings of the future offer an easy bypass of socio-technical bias that can cloud our evaluations of real-world, present-day technologies. However at the heart of our project is the unfolding near-future narrative of climate change (UNEP, 2019); it involves our present reality, our near-future actions, and the exigencies of a time when humanity will face the consequences of today's inaction. In this sense we do not need the worldbuilding that is typically necessary in science fiction (Zaidi, 2019) as we already find in our present-day narrative the stage, set and the players coached to act out a climate cataclysm. What we aim to achieve through our design speculations are the props, scripts and direction needed to promote the structural, cultural and behavioral changes that will lead us towards a brighter, not a dystopian future. Instead of an appraisal of the present that encapsulates all that is wrong with our current state, we need more positive and progressive narratives, perhaps more easily pronounced than Donna Haraway's Chthulucene, but equally pragmatic and responsible (Haraway, 2016). Anthropocene is thinking of our current state that is derived from the perceived inevitable outcome of a world marred by human intervention. We agree on the phrasing of this as an event, rather than an epoch (Haraway, 2016) and would transform it into a breakpoint, which can facilitate openness to alternatives, much as a viral outbreak that shuts down global industrial production dramatically slows consumption and reduces global emissions almost overnight, creating a breakpoint that could allow space for ideas about doing things differently rather than returning to the status quo (Guterres, 2020). In the current pandemic crisis, it is not helpful to speculate that there will never be a treatment, a cure or a vaccine. Rather, it is crucial to imagine and explore the ways in which the crisis can be overcome. Why should we not take the same approach to climate change?

Conclusion

In this article we have described three distinct applications of the future and imagination in design practice. *Extrapolation*, *reflecting on the present*, and *backcasting* have been elaborated through a series of design speculations that illustrate ways forward to Sustainable Island Futures. *PowerBreaker*, the *Blue Beast* and *PowerCrab* begin life as imaginaries, potential sustainable energy systems of the future, whose eventual actualization could author a more upbeat narrative in which humanity is taking meaningful action to fight climate change. Through recursive site investigations, engineering tinkering, academic research, interdisciplinary outreach and further speculation, initial sketches evolved into more sophisticated designs. Taking forms from the local environment, and allowing them to inspire objects of imagination and action, this is design for the future which we believe that one day help provide clean and green (or blue) electricity to coastal communities far and wide. As ideas they live, familiar to our own experience, not too far from the logic of the world. As constructs they embody a wider discourse on energy use and climate change and exert influence through cultural commentary, transforming the fatalist future scenarios in which we can only fight the rising tide, into storylines from a time not so distant that tell of our reduced dependence on fossil fuels and technological innovation that defied all predictions and did, indeed avert an outright climate catastrophe.

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