Cyborg Landscapes: Realizing Climate Change Reversal and Self-Sufficiency Through Technologically Enhanced Landscapes

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Abstract: Climate change is well understood as an existential threat to the world. However, the problem is often considered so big that it presents a 'wicked problem' that is intractable, especially in the context of conventional landscape architecture practice of today. This paper aims to explore the potential of digital tools and new technologies to reframe the landscape as the organizational medium of climate change reversal. Specifically, it aims to show the combination of a set of design tools and climate change reversal technologies that combine with ecological strategies to facilitate the analysis, design, creation, and monitoring of a negative carbon emissions project. This has been tested through the delivery of a landscape strategy for a large net-zero project in Arabia. The design process led to a fragmentation of project teams into disciplinary and project silos, resulting in a situation where cross-cutting tasks such as carbon monitoring and accounting fall into project 'no man's land'. The project is divided into an urban area with a small footprint and a 'nature preservation' area that covers most of the land. Through the lens of a landscape strategy and guidelines, the project explores the means, tools and platforms for the creation and monitoring of negative emissions enabled through the medium of landscape. Utilizing the notion of high-performing, 'infrastructuralised' (cyborg) landscapes the landscape is cast as critical infrastructure, enabled by a multi-tool design platform including GIS, parametric design methodologies, remote sensing, and natural capital accounting. In the project, this system was described as a closed loop 'virtuous cycles' concept enabled through parametric model developed to track the performance of the landscape.

Keywords: Cyborg landscapes, climate change reversal, negative carbon emissions, natural capital account, digital design methodologies

1 Introduction

1.1 The Hybridised Context of the Cyborg Landscape

Following the conclusion of the COP 26 Summit, climate change is widely understood as an existential threat to the world. However, the problem is often considered so big that it presents a 'wicked problem' that is intractable, especially in the context of conventional landscape architecture practice of today.

This paper aims to explore the potential of digital tools and new technologies to reframe the landscape as the organizational medium of cities and climate change reversal. Specifically, it aims to show the combination of a set of design tools and climate change reversal technologies combined with ecological strategies to facilitate the analysis, design, creation, and monitoring of a negative carbon emissions urban development.

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In a paper presented to DLA 2020, the author previously explored the design technologies supporting what was termed 'Plus Urbanism' where urbanization is reconceived as a net-positive landscape that is ecologically, economically, and socially positive part of the earth's biosphere. Since then, the project has proceeded with a different masterplan, moved through the design stages to delivery of parts of the project. This resulted in a set of fragmented project delivery teams attempting to deliver the ambitious net-positive project.

This fragmentation into disciplinary and project silos has led to a situation where cross-cutting tasks such as carbon monitoring and accounting fall into project no man's land where no specific work stream had responsibility. The project is divided into an urban area with a small footprint and a 'nature preservation' area that covers most of the land. The current paper continues that work through the preparation of a landscape strategy and guidelines for the same project explores the means, tools and platforms for the creation and monitoring of negative emissions enabled through the medium of landscape.

The project was initially conceived of as one to describe the aesthetics of the project, however the seeming importance of climate change and the goals of the project led the team to a more ambitious approach where landscape is cast as a climate change reversal medium. Central to this applied research is the notion of high-performing, 'infrastructuralised' landscapes which treat infrastructure such as renewable energy, energy storage, water infrastructure, food growing structures and systems, carbon sequestration machinery, waste recycling systems and water harvesting treatment as a constituent part of the landscape, with equal importance as traditional biotic elements of soil, plants, and fauna. This symbiosis of infrastructure and the landscape clears the way for the landscape to play a central part as the organizing medium of climate change reversal. The cyborg landscape referred to in this paper is that purposeful symbiosis of the machinic systems within and as synthesized part of the landscape.

The latter sections of this paper describe how that approach is realized and described as a set of 'virtuous cycles' which lead to the creation of intentionally cybernetic landscapes that embrace the challenge of Anthropogenic climate change.

1.2 Landscape Architecture's Wicked Problem of Climate Change

Climate change presents an intractable 'wicked' problem for the design sciences, and particularly for landscape architecture which has treated the climate crisis as an industrial accident to clean up after the fact. In reality, landscape architecture is the only design discipline suited to the delivery of solutions to problems which respect no borders in the biosphere. 'Wicked' problems in urban planning were originally described by RITTEL & WEBBER (1973) where their "search for scientific bases for confronting problems of social policy is bound to fail, because of the nature of these problems. They are 'wicked' problems, whereas science has developed to deal with 'tame' problems." Landscape architecture of the 20th century could be described as having been limited to 'tame' problems on the scale of the garden.

CAMILUS (2008) describes wicked problems as "different because traditional processes can't resolve them". This necessarily complicates challenges with no precedent, such as the global climate crisis. COP 26 and its precedents have struggled with the very nature of this problem, along with its numerous stakeholders with their different views and priorities.

The landscape has a critical role to play in this crisis as the substrate that physically links all the component parts that contribute to the cause (and solutions) of the climate crisis. In contrast cities have always been conceived of in terms of their opposition to 'landscape' or 'nature' and this has served to simply obscure the potential solutions.

In 2015, Richard Weller, Claire Hoch and Chief Huang authored 'The Atlas for the End of the World' which, through a series of essays, maps and datascapes highlighted the conflict emerging between urbanism and the broader biosphere. It highlighted both worrying levels of biodiversity loss that has occurred and the clear and present risk that urban development poses to the remaining biodiversity on earth. Equally, 'The 2100 Project: An Atlas for the New Green Deal' addresses that particular challenge with a practical exploration of how we might reconcile urbanism and biodiversity.

While much has been made of the existential threat posed by the Anthropocene and the consequent effects of climate change, we must reframe the landscape architectural discourse with an optimistic approach that embraces the increasing urbanity of the world. Rather than arguing for the abandonment of urbanity and a 'rewilding' of the world the profession will need to focus on how we will continue to reshape a landscape that is now universally 'Anthropocene'.

If humanity as a species is to thrive, we will need to be bold enough to geoengineer new, enhanced natures for the Anthropocene ecosystems. But rather than dominion of the earth, the continuation of this epoch necessitates that we see ourselves as a part of the biotic and abiotic web that realistically represents our current world. Whilst this may seem to represent an intractable 'wicked problem' this could, indeed be the greatest opportunity for landscape architecture in the 21st century.

2 Conceptions of Nature & its Integration with Technology

2.1 The Cyborg Landscape – The New Nature of 'Nature'

A considerable amount of philosophical literature has established the changing approach to nature within landscape architectural and ecological practice. This is a critical issue that must be addressed for landscape architecture to remove the blinkers that curtailed its work during the 20th century. By freeing itself of the constraints of conventional ecology that prizes a 'return' to 'pristine' landscapes, we can create a new and hybridised reality for landscape architecture. BOVIN et al. (2016) clearly establish a position that truly pristine landscapes unaffected by human intervention have not existing for more than 10,000 years. Embracing that position gives philosophical permission to landscape architects to honestly represent man as a part of nature and "explore how we can design, build and live in the nature caused by people" VAN MENSWOORT (2012).

Similarly, HARAWAY'S (2016) argues that nature and culture "*can no longer be the resource for appropriation or incorporation by the other"* pointing out that it is no longer possible to distinguish between 'nature' and 'culture'. Culture and cities have therefore become an indistinguishable part of nature in the Anthropocene.

Traditionally, however, cities have always been conceived of in terms of their opposition to 'landscape' or 'nature'. The challenge of climate change compels that *"the city is no longer* *something we can understand as architecture, as a mass of formed material that we can distinguish from a non-material void which can be characterized as countryside or periphery"* (READ 2007).

Thus, it is not nature that needs saving but rather humanity's place within nature. To ensure our survival as a species, we must ensure that we actively address the entire biosphere towards a planet of 10 billion humans. This may necessitate planetary scale geoengineering but we as landscape architects can start by ensuring that each instance of urbanism must commit to the idea of restorative urbanism. We as a profession must intentionally seek to change the host ecosystems that we are part of.

In this sense, technology is not simply a tool to be applied in the design of cities or the management of cities but rather is also a fundamental part of cyborg landscapes. Conceiving of the landscape as a cyborg requires us to consider technological elements as part of the arsenal available to landscape architects, whether that is a direct air capture carbon capture machine or a constructed wetland. To respond to the enormity of the climate crisis a higher-order integration of all aspects of technology and culture must be embraced.

3 The Practice of Climate Change Reversal

3.1 Questions Posed for Landscape Architecture

The preceding sections outline both a philosophical imperative to address the problems created by human occupation but also to do so through an intentionally hybridized and 'infrastructuralised' form of landscape. This raises a critical question of what this means for the practice of landscape architecture and urbanism today? How do we rationalize the significant challenges of climate change reversal into the creation of places? How can we frame that challenge for today? Can this complement the drive to liveability in today's cities? Can we embrace environmental technologies as a critical part of the landscape?

In the author's paper presented at DLA 2020 these questions drove the development of an ideal of 'Plus Urbanism' where urban landscapes were cast as a net producer of resources, rather than a net consumer. Explored through the lens of an urban masterplan for a new urban region of 26,000 square kilometers of land, the project embraced the optimistic potential of landscape as a performance-based system of biosphere adaptation. Whilst optimistic and aimed at reliably delivering a net-positive urban landscape in terms of energy, carbon, water, food, materials and waste it failed to prove that the intent was achievable. To take the example of energy self-sufficiency specifically, it did not complete tasks such as mapping how much renewable energy was required, what type of energy source should it come from, where should those different sources be harvested from on the site and how might energy requirements be affected by built form efficiency. The scheme was not selected as the winner of the design competition and thus was not progressed beyond the stage of the competition, reducing the potential to enhance its veracity.

Fortuitously, the project proceeded to a next stage where the design team was tasked to prepare a landscape strategy and guidelines for the territory. Whilst originally tasked to provide an aesthetic vision, the design team instead sought to synthesize the urgency of climate change, the sustainable design goals outlined in the project and the intent to preserve most of the landscape as a nature reserve. In doing so the team was forced to create new tools and systems that enabled both a digital design process and a design vision of a cyborg landscape that is a seamless marriage of technology and the landscape.

This paper intends to explore the development of and codification of this philosophy into a cogent strategy for transformation of the biosphere to positively adapt the climate crisis. It does so through the continued work on a case study of a large-scale urbanism project by the author (and a large multi-disciplinary team). That has led to the development of a platform that recast landscape as the medium of climate change reversal. That process is described in the following sections.

3.2 First Principles: A Clear Statement of Purpose

The questions in the preceding section were both intimidating and wicked. To grapple with the enormity of the projects scope, the first task undertaken was the preparation of a landscape manifesto for the project that included a range of general statements that were coupled with specific and measurable outcomes as summarized below:

- *The coming development of the project and its supporting developments will affect the site considerably. While 4% is 'developed' 44.8% of the site is 'infrastructuralized' to support that development.*
- *We must see the infrastructuralization of the landscape as our opportunity and our responsibility to go beyond restoration of ecologies to the creation of 'enhanced' human ecologies that address the causes and impacts of Climate Change.*
- *The development of the project can show the world how to reframe human ecologies as the solution to climate change and a means to provide prosperity that is reciprocal with nature.*
- *Through the application of 'virtuous cycles' in the landscape project we aim to do no less than meet the entirety of the governments Paris Agreement Nationally Determined Contribution aim to annually abate up to 130 MtCO2e by 2030.*
- *At the same time, we aim to provide a net-positive landscape that delivers more water, food, energy, biodiversity and economic prosperity than is required by the occupants.*
- *In doing so we seek to reframe that Landscapes of the site as a symbol of hope and beacon to the world, a global blueprint for a better future.*

(Extract from Project Landscape Manifesto by Aecom / MSP)

The aim is to assess the land and prepare a landscape strategy and guidelines for the whole territory that would unify and plan for all of the land, especially for the undeveloped land that comprised 95% of the territory. This land was envisaged as something of a nature reserve where the rewilding of the land would compensate for the development of a new city on a portion of the land. Our intent was to instead, synthesize both the conservation goals of the client and the stated goals of the urban development within the project, specifically:

- Net-zero operational carbon emissions
- 100% self-sufficiency in energy production
- 100% self-sufficiency in food production
- 100% self-sufficiency in water production and wastewater treatment
- 100% self-sufficiency in waste treatment and recycling

In addition to the stated development goals, the project team sought to extend the objectives to create a completely closed loop system that was called the 'virtuous cycles' that included:

- Negative emissions of carbon (sequestering significantly more carbon than is embodied & operational)
- More than 100% self-sufficiency in energy production
- More than 100% self-sufficiency in food production
- 100% self-sufficiency in water production and wastewater treatment on site
- 100% self-sufficiency in waste processing and recycling on site
- 100% creation of building materials from the site with 100% renewable energy

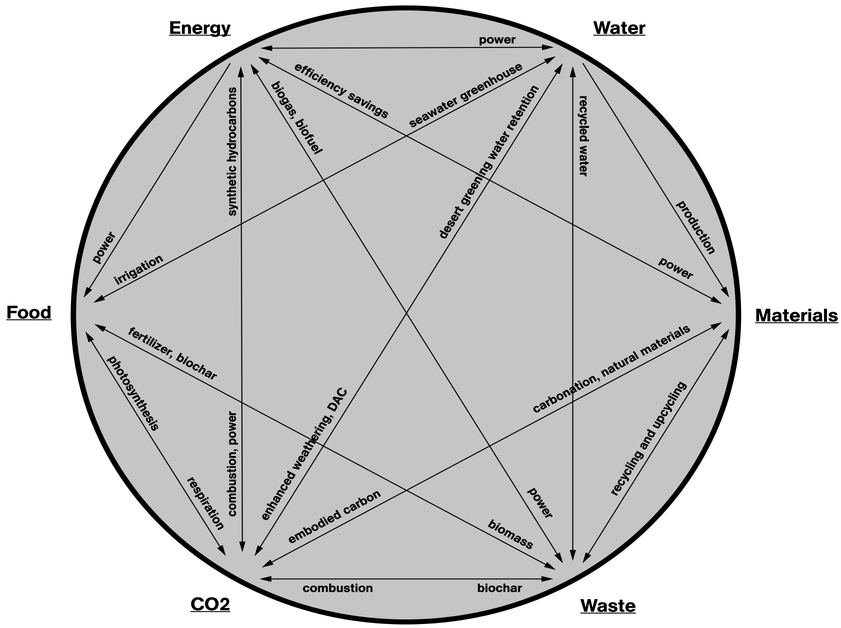

Fig. 1: Virtuous cycles diagram that maps closed loop nature of the systems (Aecom / MSP)

A quantification of the ecosystem services was deemed to be required was generated to create measurable spatial targets for performing infrastructural ecosystem services.

3.3 Creating a Register of Performance

To definitively demonstrate that the goals had been achieved, the first task of the project was to classify and assess the existing quality of all habitats on the 26,000 square kilometer site to form a baseline. To put this in context, the site is roughly equivalent to the size of the country of Belgium and the entire project (of which this survey was but one part) was completed over a 6-month duration.

This task was delivered with an ecology team that used a high-resolution aerial photography mosaic merged with a digital elevation model and some site survey information to create a habitat database in QGIS. That habitat database included boundaries of each ecosystem, an assessment of existing quality of the habitat and an analysis of key species within each habitat. Whilst some information creation was automated using algorithmic approaches, this was largely an exercise of manually tracing habitat boundaries and in many instances recording every single tree in key areas.

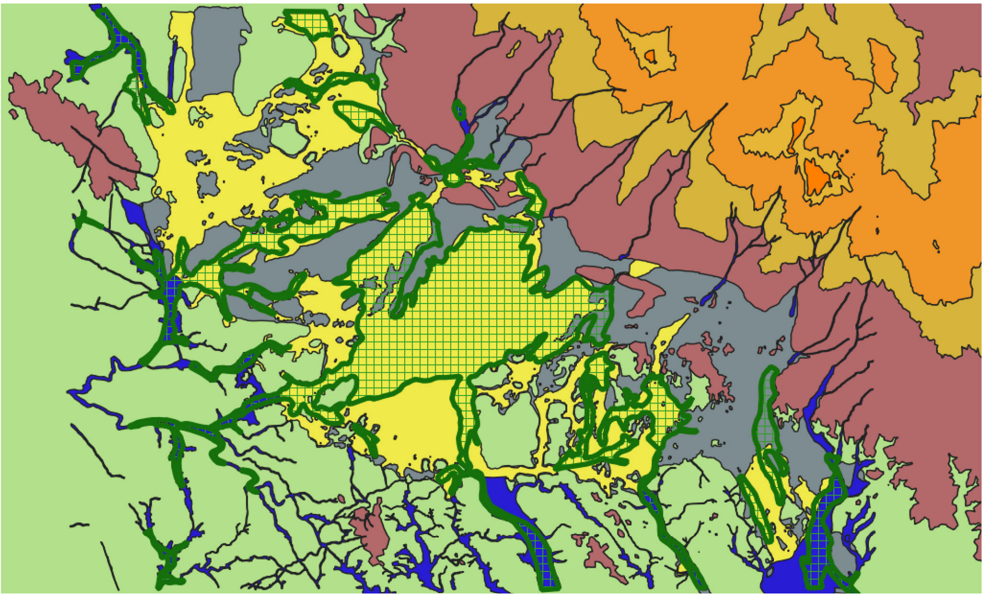

Fig. 2: Sample of QGIS habitat maps, described in detail in habitat descriptions (Aecom / Dr Gary Brown)

This allowed the entire site to be assessed to fit into several IUCN conservation categories that permit varying levels of use. These IUCN categories formed the basis of four key land use 'transects' – inhabited areas, potential productive use areas and lower value wilderness areas and high-value wilderness areas. Critically, the land classified inhabited and productive needed to carry most of the infrastructural systems required to achieve the stated goals of the project, and indirectly indicate its carrying capacity.

3.4 Creating a Measure of Success – Natural Capital

As mentioned in the introduction to this paper, the project had run a natural course of progressing from a visionary masterplan to several constituent development projects, infrastructure projects and sector goals (food, water, energy, sports, etc.). This natural subdivision of the projects meant that all projects and sectors began measuring achievement of development objectives independently (or not at all). Some cross-cutting measures such as carbon were not effectively dealt with at all and ran the risk of being lost all together.

It became clear to the project team that that a unified system of measurement was critical in quantifying success across the entire project. The system of measurement selected by the design team was natural capital accounting (NCA). Natural capital is defined as the world's stocks of natural assets which include habitats, geology, soil, air, water and all living things (World Forum on Natural Capital 2022). NCA originated as a system of environmental-economic accounting in the early 1990s. In September 1992, the Commission on the Environment of the Organization of American States (OAS) Permanent Council held a seminar on Natural Resource and Environmental Accounts for Development Policy. A proposal was made at that time to create a program to coordinate and strengthen the efforts of countries and institutions undertaking such initiatives resulting in the 1993 SEEA system. This has evolved into the natural capital accounting systems of measurement for ecosystem services.

The ecosystem services are often closely interlinked, so that over-exploitation or poor stewardship in one area can have detrimental effects in another. From an economic perspective, the profitability and long-term viability of some sectors depends on well-functioning ecosystems, notably agriculture, fisheries water and wastewater services, as well as pharmaceuticals. The future of our natural environment, economies and health therefore requires an understanding of impacts and dependencies on natural capital and the ecosystem services it provides, and to integrate these considerations into long-term development strategies, risk management approaches and other economic activities and planning. For this reason, the system was chosen as a means to measure, track and report progress against the development goals. Using the basis of the habitat maps and land use transects described previously this was developed as a managed GIS database through ArcGIS Storymaps as a dynamic searchable, hyperlinked site that tracked targets and achievements based on geo-referenced evidence over time.

Fig. 3: Screenshot of Digital Natural Capital Account Beta Site (Aecom / MSP)

3.5 Capitalising on the Green Economy

In preparing the digital natural capital account, the project team saw significant opportunity to use the tool to leverage sustainable finance opportunities that the digital NCA would act as substantiation for. The team provided high-level outline of the current sustainable finance options available to highly ambitious, net-positive environmental developments, with a particular focus on climate finance and green finance. The strategy described the global sustainable financing context, and then outlined the opportunity to develop a bespoke innovative green financing strategy for the client. This included strategies ranging from payments for ecosystem services (PES) schemes to climate finance and green finance.

Providing access to funding sources that total trillions of dollars provided a potentially lucrative and financially viable means to overcome the so-called "valley of death" that acts as a challenge to the delayed project paybacks for sustainable infrastructure projects (GOODFELLOW-SMITH 2019).

As such the digital NCA was structured as a tool to avail and substantiate eligibility and ongoing payments from sustainable finance sources.

3.6 Taming the 'Wicked' with a Digital Landscape Architectural Platform

In addition to the digital natural capital account, the team also developed a digital dashboard, (initially in Excel) to quantify with a high degree of precision the total areas of land take required for each of the virtuous cycles. This gives precise land areas required for all the cycles based on a series of input variables (for example, built-up area, population, energy efficiency of BUA, embodied carbon in BUA, water efficiency, etc.). This was developed to generate key metrics which are summarised as follows:

- Energy: square kilometers of solar PV, number of wind turbines
- Water: area and power required wastewater treatment & desalination (mechanical and/or nature-based system)
- Waste: area required for waste sorting, recycling, W2E, Biochar Creation, etc.
- Food: area required to grow 100% of daily caloric requirements (2,300kcal per day, per person) in conventional and/or high-tech farming
- Carbon: area, power demand and payback period for 100% carbon sequestration within selected number of years, embodied carbon measured as a performance requirement for new buildings

These metrics were based on proven performance of available technologies rather than relying on experimental or not-yet-commercialised technologies. Once generated, these requirements were matched to available land for productive uses to ensure that the biodiversity areas, rewilding sites and ecological networks were not negatively impacted.

This net-zero dashboard approach is in the process of being developed as a live online platform that can be interlinked with Rhino and Grasshopper to feed into a parametric model that distributed the requisite infrastructure, nature-based solutions and urban development based on land suitability and natural capital value. This development stack of digital NCA, net-zero dashboard and algorithmic distribution system are a long-term development goal so that it may be used on all projects to quickly generate scenarios and clear planning parameters for sustainable development.

This system has been deployed with a constantly evolving catalogue of technologies that included nature-based solutions and technological solutions, used as the basis of deployment to prove the achievement of the stated virtuous cycle goals.

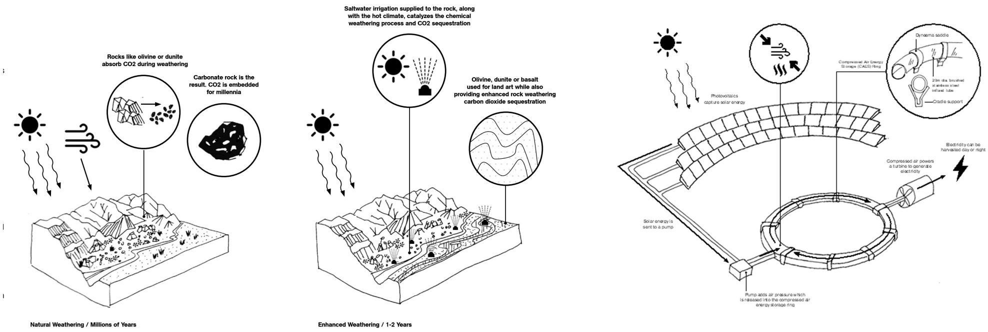

Fig. 4: Samples of virtuous cycle technology catalogue (carbon-enhanced rock weathering, energy: solar PV with compressed air storage) (Sketches by Atelier One as part of Aecom / MSP Team)

In doing so the exercise interlinked all goals for the project which were then codified into a set of development guidelines to guide the development of all landscapes and buildings. These were essential to ensuring the achievement of the natural capital goals and ultimately ensuring that the project could be delivered to the ambitious goals of the virtuous cycles.

3.7 Formulating the Vision

A final step in the process was for the team to translate these spatial and systemic plans into a set of functional guidelines and prototypes for future designers to use. These were intentionally set up as performance-based approaches that strongly encouraged the employment of nature-based solutions and new technologies. This also had to find a satisfactory development identity that highlighted the futuristic and sustainable qualities of the project.

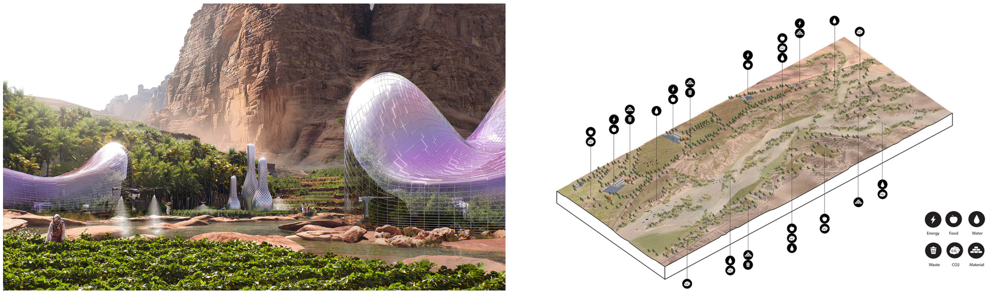

Fig. 5: Visualisations of landscape prototypes incorporating the virtuous cycles (Aecom / MSP)

4 Analysis and Further Research

4.1 Developments of the System

As with any design methodology or system, the exploration outlined in this paper is not without imperfections. Several improvements are ongoing, and we fully expect that to be a continual requirement for the functional deployment of this as a design system. The following list of improvement outline that there is still considerable work to be done

- Improvements in the interoperability of workflow and the real time connections between the dashboard, GIS database, digital NCA and Rhino/Grasshopper script to distribute the virtuous cycle components:
- The GIS interface which struggles with the size of the site and the complexity of information;
- The ability to visualize development and population scenarios in multiple platforms and in real time; and
- The ability to convincingly formulate the package into a highly usable statutory land Use planning tool based primarily on eco-infrastructural performance.

We do however feel that the conceptual delivery of the system does demonstrate a viable approach to climate change reversal through the lens of the landscape. The development of the project and its predecessors that have led to it outline the author's concept of a form of synthetic landscape that promises a resurrection of nature as cybernetic landscape of bounty that provides more than it consumes. Through a combination of tools including GIS, digital natural capital account, Rhino and Grasshopper, Excel and Power BI this case study extends the idea of plus urbanism to a real, quantified and engineered solution that proves the central thesis that the landscape can be an organizational medium that delivers climate change reversal.

5 Conclusion and Outlook

The case study presented herein hints at a definitive solution that proves the achievability of negative emissions and net positive form of future urbanism. We believe that it extends the discourse on landscape and ecological urbanism and proves the central thesis that the landscape is the medium through which we can reverse climate change. We have explored these ideas thorough a transect of projects that personify the trajectory towards net positive development. This has included a range of projects realized in practice, academia, competitions, and intellectual explorations.

Ultimately the project described in this paper illustrates a possible move towards cybernetic landscapes of the future. The development of the project and its predecessors that have led to it outline the author's concept of a form of synthetic landscape that promises a resurrection of nature as cybernetic landscape that provides more than it consumes.

Through a combination of tools including GIS, digital natural capital account, Rhino and Grasshopper, Excel and Power BI this case study extends the idea of Plus Urbanism to a real, quantified and engineered solution that proves the central thesis that the landscape can be an organizational medium that delivers climate change reversal.

Considering the desperation of the COP 26 meeting, this project demonstrates that the potential is real and realizable. Indeed, if it is achievable in the Arabian Gulf, one can contend it should be achievable in any landscape in the world.

However, the proof of the concept is yet to be delivered as a developed place and exists as a series of digital models. The greatest challenge is yet to be met – that of turning the vision of the research into built form that delivers on a negative emissions scenario. Indeed, this is the current focus of the work and perhaps the greatest challenge that faces all explorations of digital landscape architecture methodologies.

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