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# Living in the "Age of Humans". Envisioning CAD Architecture for the Challenges of the Anthropocene—Energy, Environment, and Well-Being

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**Abstract:** The Anthropocene thesis poses new challenges to human activity on the planet. These challenges also apply to the built environment. Climate change will increase existing threats, and create new ones, for both human and natural systems. Above all, the built environment is expected to provide structural stability, access to water necessary for life, and safe production of clean energy. This research-by-design was focused on designing an adaptive built environment for Anthropocene societies and the maintenance of their well-being, and on envisioning and conceptualizing new architectural solutions based on multidisciplinary knowledge and CAD parametric design methods and tools. The conceptual designs are the result of these studies. These visions show how wind loads can be reduced, water can be stored, diverse energy sources can be integrated into one work of architecture, and thermal comfort can be provided to support local communities and the life of the environment in the belief that the coexistence of species on the planet will happen. They also illustrate how humanity will be able to use the Earth and its atmosphere as an energy producer and conductor and create a global, wireless, non-commercial energy network, accessible to all.

**Keywords:** architecture; CAD; Anthropocene; landforms; energy; environment; well-being

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## 1. Introduction

The Anthropocene epoch needs new concepts of Nature–Technology–Culture, especially in relation to the built environment. Recently, the growing evidence from a broad range of scientists is that our planet has changed to such a degree that we now live in a new historical era, named the Anthropocene. In 2000, Paul Crutzen, the Nobel Prize-winning atmospheric chemist, resurrected the concept of the Anthropocene to denote the current interval of time on earth, in which numerous key processes are dominated by human activities [1,2].

The Anthropocene has emerged as a powerful new narrative of the relationship between humans and nature. The concept of the Anthropocene was introduced to capture and name this quantitative shift in the relationship between humans and the global environment. However, we can see how the Anthropocene thesis can be roundly criticized for its assorted failings—terminological, philosophical, ecological, and political. Nonetheless, the term remains relevant for one reason: It registers the geological impact of colonial and industrial activities on the earth-system development [3–5]. As such, it offers an important wedge-one that unites climate science and environmental studies with the environmental arts and humanities [6,7]. The Anthropocene thesis has recently received significant attention in both the news media and academic research programmes. The thesis offers contemporary architects, engineers, and scientists from different disciplines the chance to face up to the urgency of the modes of these enquiries and allow their consequences to unfold, alongside an effort to conceptualize the built environment and social justice [8]. Although these risks are reducing, this has not been evenly distributed over the globe, and climate change is affecting not only species of nature, but also disadvantaged people and groups in society the most. "Low income, socially and economically marginalised communities, individuals suffering from chronic diseases or social isolation, older and young people, and vulnerable populations will be disproportionately affected by climate change due to their limited ability to adapt" [8] (p. 414). Another issue is that it is not easy to find a satisfactory solution to these problems, given the heterogeneity of countries in terms of their levels of development, size, population, and natural resources, etc. Climate justice is needed [9]. Envisioning and conceptualizing the built environment for the challenges of climate change and for those architectural concepts that have been created has opened up new fields of research for the theory of contemporary architecture. These challenges have been addressed by the authors in an academic research program entitled Climate Change Adapted Architecture and Structures.

The seminal book entitled *Architecture in the Anthropocene*, edited by Etienne Turpin (2014), was the inspiration for this research [10]. It is an extraordinary and provocative collection of essays, design projects, and conversations, plotting out the planetary conditions of the Anthropocene, which were initiated in the first decade of the 21st century. Since then, various other authors have considered what the Anthropocene might mean for architecture, architectural theory, and design practice. The book "Landform Building: Architecture's New Terrain" (2011) presents and analyzes various manifestations and aspects of landscape and ecology important in contemporary architectural practice. It is not focused on an interdisciplinary phenomenon considered by landscape designers but on new design techniques and new formal strategies and technical problems in land-oriented architecture [11]. However, we have to take into account the ecosystem supply of all green areas, green masses called green infrastructure (GI) today. These areas play a crucial role in the decarbonization of the planet, and vegetation is still an essential part of landscapes and their characteristics [12]. Since 2001, the strategy of the EU Working Group on Green Infrastructures (GI) has promoted integrated spatial planning by identifying multi-functional green zones and incorporating habitat restoration measures [13]. This program is in line with the EU Green Deal program announced in December 2020.Will these programs be able to benefit the EU citizens and contribute to a more sustainable economy based on healthy ecosystems?

The most promising and innovative strategies for shaping environmentally friendly architecture are based on digital instrumentation of the evolution, morphogenesis, or emergence processes. These are strategies such as the morphogenetic design strategy and material ecology [14]. Notwithstanding, these methods and techniques (mimicking the natural processes from which the form emerges) are already usable in experimental architectural and structural design. These design methods require computational design tools that are not yet fully coupled to a digital CAD system and are not commonly used by designers.

Emerging advanced material and digital morphogenetic design techniques and technologies require a higher level of methodological integration, which poses a serious challenge to multidisciplinary research and architectural design.

By applying morphogenetics design tools and enhanced materials to embrace a morphogenetic design strategy, architecture could react rapidly, through multiple permutations, to multiple performance criteria. These novel morphogenetic designs could provide a superior architectural response to programmatic, technical, structural, environmental, and spatial requirements that conventional architectural forms are too inflexible to fully address. According to Menges "this shift from knowledge-based to behavior-based computational design and the related development of biomimetic computational design processes not only entails a change in the conceptualization of architectural performance but also architectural aesthetics" [15] (p. 4).

### 1.1. The Climatic Action of Anthropocene

Scientists across disciplines have been investigating the significance of the anthropogenic transformation of the Earth's systems (physical, chemical, and biological processes)-the changes are observed on the Earth's surface, in water reservoirs, the natural environment, and the climate—to come to a conclusion of an emergence of a new, geo-era—a human one.

The models of climatic shifts bring a glimpse into the future. Critical and increasing numbers of greenhouse gases (GHGs)—37–49% of total global GHG emissions—are emitted by cities into the atmosphere [16–19]. It is suspected that the greenhouse gases accumulating in the atmosphere will presumably heighten temperatures over nearly all Earth's surfaces, despite regional differences of exact changes. The IPCC Special Report accentuates the characteristic features of hydrometeorological and oceanographic events, a subgroup of a more extensive range of events, which may develop the characteristics of a threat if conditions of vulnerability and exposure transform them into a hazard [19].

The Munich Reinsurance Company states that there is a high probability of steadily increasing risk stemming from natural, weather-related threats, even if the global community were to pursue the goal of worldwide decarbonization (relinquishing of fossil fuels) [20]. The main reason for this prognosis is research showing approximately 100 years as the estimated time of residence of $CO_2$ in the atmosphere and its continuous influence on global warming in this period. Over the past few decades, many regions have already suffered from an increased number of heatwaves and rainfall-frequent and intense weather events exhibiting severe damage [21].

The crux priority nowadays is a movement addressing the interwoven challenge of sustainable development, disaster risk, and climate change, in face of the fact that 90% of documented major disasters provoked by natural threats, from 1995 to 2015, were associated with weather and climate-droughts, heatwaves, storms, and floods. The five countries suffering from the highest number of disasters were the United States (472), China (441), India (288), the Philippines (274), and Indonesia, (163) [21].

According to world researchers, preventive actions should be undertaken to establish a less than non-extendible 2 °C temperature rise compared to its level before the industrialization era. The temperature's exceedance of more than 2 °C might induce a risk of developing irreversible climatic challenges, which could lead to disturbing results for human daily life and for all life on Earth.

A Special Report on Global Warming states that a figure of 1.5 °C was detected by the IPCC on 8 October 2018 in Incheon in the Republic of Korea. It was essential scientific data of the Katowice Climate Change Conference in Poland in December, which gathered the representatives of governments reviewing the Paris Agreement for a countermeasure of climate change [22]. The report found that reducing global warming to 1.5 °C would require a "rapid and far-reaching" transition in the overall use of industry, land, buildings, energy, transport, and cities. Global net human-caused emissions of carbon ($CO_2$) would need to fall by about 45% from 2010 levels by 2030, reaching 'net zero' around 2050. This means that any remaining emissions would need to be counteracted by $CO_2$ removal from the air [22–24].

Climate change is also expected to modify the hydrological cycle resulting in impacts on water availability on a large scale. However, future climate change impact assessments are highly uncertain. For the first time, eleven global climate and hydrological models were used to systematically assess the hydrological response to climate change and forecast the future state of global resources of water [25–28].

The results show some regions exhibiting a large spread in projected changes in water resources within the climate-hydrology modelling chain [26]. Today, the intriguing question remains as to how humanity should adapt to such difficult living conditions.

Recently, strategies have been established to predict external environmental variations along with internal interactions between occupants, as an answer to the various weather phenomena of the global climate change era [26,28]. The new architecture and urbanism require a new way of thinking and visions of the built environment.

### *1.2. Energy Sources and Energy Security in the Antropocene*

The replacement of energy production based on fossil fuels (coal, oil, and gas) by using natural energy sources is socially perceived as an important antidote to the progressive effects of anthropogenic global climate change [8–10,29,30]. At the same time, the demand for energy and related services is also increasing to meet the conditions of social and economic development, prosperity, and health [8,9,31–33].

Since the 1990s, research and scientific experiments have been carried out, on the one hand, on the development of technologies and devices, and on the other hand, on application methods and the availability of obtained renewable energy. Today, it is a separate field of research, although related to other scientific disciplines, including structural and environmental engineering. The results of these studies are well-known and widely published in scientific journals and available in the public media. However, these studies do not often address the problem of renewable energy production in the face of weather hazards caused by anthropogenic climate changes [34–39].

The models of climatic action mentioned above warn of natural hazards associated with weather. Anthropogenic weather phenomena are already destabilizing energy forecasts, and soon they will become a destructive force for some devices and installations producing so-called green energy.

Wind (whirlwinds, swirls, cyclones, hurricanes) is already seen as an unpredictable force that destroys buildings, ground transmission networks, wind farms, and solar farms, both onshore and offshore. Not only can floating offshore wind plants, floating solar plants, and electricity generation from tidal streams be endangered by cyclones and hurricanes formed in the oceans, but also by tsunamis caused by tectonic movements under the seabed. Drought and seasonally high temperatures require increased energy and water consumption to sustain life, which causes water levels to decline in rivers and reservoirs, which reduces the energy efficiency of small and large hydroelectric plants. Floods and local inundations threaten primarily small home power plants. Nevertheless, companies have been preparing wind, water, and solar projects for Central and Eastern Europe with a total capacity of over 200 megawatts since 2009, namely installations that can power over 4300 companies and offset over 8,100,000 tonnes of carbon dioxide emissions. However, these projects do not consider the risks of the weather and the resulting energy insecurity, in the hope that this can be prevented or in the belief that climate change is political fiction.

The European Green Deal launched in December 2019 mainly focuses on the energy performance of architectural objects by more extensive use of renewable sources and prioritizing energy efficiency. Within this strategy, a boost of eco-design in building materials and products, increased digitalization, and climate-proofing of buildings is needed to promote the decarbonization process of Europe. This program is a new strategy for transforming the European economy for a sustainable future and the well-being of EU citizens [40]. However, insufficient emphasis has been placed on energy security in the pursuit of well-being. Nevertheless, the need for such security is already one of the basic needs of humans, dependent on energy supplies in terms of civilization. However, the European Green Deal opens up new possibilities of obtaining funds for research on such technology for producing "green energy" that will be resistant to anthropogenic changes in the weather, ensuring energy security.

Unfortunately, by human domination of the key systems that maintain the planet's conditions, many ecosystems have already been unnaturally destroyed. Their recovery will require increased investment and operational risk-taking. Nevertheless, to quote Fuller's words: "The environment always consists of energy-energy as matter, energy as radiation, energy as gravity, and energy as events" [41] (p. 26). All that needs to be done is to reach for it.

Over a hundred years ago, Nikola Tesla envisioned a source of inexhaustible, clean energy that would be free for everyone. He was convinced that the Earth had "liquid electric charges" running beneath its surface, which, when interrupted by a series of electrical discharges at repeated fixed intervals, would generate an unlimited source of energy, generating enormous low-frequency electric waves. The method developed by him to use the energy of the Earth and its atmosphere as a producer and conductor of electricity has been confirmed experimentally. Electricity was sent over the ground thirty kilometers without the use of transmission networks [42].

This idea was inspiring in the conceptualization of new architectural forms, with the belief that modern science and technology would meet this challenge.

## 2. Materials and Methods

The objectives of this research were achieved by means of the academic research design program Climate Change Adapted Architecture and Structure, led by the authors. This program was focused on the design of the adaptive built environment for Anthropocene societies and the envisioning and conceptualization of new architectural solutions, based on advanced digital technology.

This research used several recent studies: The Anthropocene Working Group (AWG) and the Stockholm Resilience Centre (SRC) were found to be especially noteworthy [3–7,19,24,27,28,30,31,35–37,39]. The AWG is an interdisciplinary research group dedicated to the study of the Anthropocene as a geological time unit, whilst the SRC is an international research center looking into resilience and sustainability science. The other main sources of information [18,21,22] on climate change were the annual IPCC (Intergovernmental Panel on Climate Change) reports. The IPCC prepares comprehensive Assessment Reports about knowledge of climate change, its causes, potential impacts, and response options.

In order to achieve architectural goals, two complementary research methods were used, namely pre-design research and research-by-design methods [43,44]. The pre-design phase provides insight into potential responses and future design directions. In research-by-design, the process of architectural design is a path through which new insights, knowledge, practices, or products are created [43]. In this case, an architectural form can already be presented in a drawing or model as a vision/concept, initiating the development of the design in the real sphere. The Research-by-Design method adopted here is often undertaken in architectural design, especially when dealing with a multi-threaded design task, the solution of which is difficult to predict. It is a kind of investigation through which design is explored as a method of inquiry, by the development of a project and also by exploring the different materials by which a design can be carried out—handmade sketches, digital modelling, mapping, structural, and environmental analysis, amongst others.

### *Research for Envisioning Architectural Forms for the Anthropocene*

Various climate scenarios (global and national projections) relating to the future climate and potential consequences due to anthropogenic factors were analyzed. These scenarios predict future conditions that will account for both man-made climate change and natural climate variability. They usually concern selected countries or regions [16–20]. For instance, the most up-to-date assessment of how the UK climate may change in the future provides the UK Climate Projections (UKCP) [19]. The climate scenario differs from the climate projection, which is the description of how the climate system will respond to a greenhouse gas and aerosol emission scenario simulated by a climate model. The development of climate models such as climate projections requires that the outputs are manipulated and combined with observed climate data in order to be used as inputs to impact models. For this reason, these models rarely deliver sufficient information to estimate the future impacts of climate change [45]. However, the assessment of the adequacy of individual climate datasets can only be done in the context of each method of constructing climate scenarios, as different methods have different baseline climate data requirements.

The first part of the research provided an answer as to how human activities have altered different landscapes at a variety of spatial and temporal scales i.e., plastic alluvial sediments from waste are an integral and environmentally sensitive component of geological data in the Age of Humans [4,7,9,28–30,39,46–49]. Landscape evolution models (LEMs) have the ability to characterize key aspects of geomorphological and hydrological processes. Nevertheless, their usefulness is hampered, inter alia, by the scarcity of available calibration data [45]. In 2010, Johan Rockström introduced the Planetary Boundaries diagram [49] on behalf of the Stockholm Resilience Centre (SRC)—a collaboration between Stockholm University and the Beijer Institute of Ecological Economics at the Royal Swedish Academy of Sciences. This ongoing research tool represents a framework of quantitative borders within which humanity can continue to develop and thrive for generations to come. The diagram collects data from 1950 to the present and is continuously updated. The current status of variables is alarming due to the fact that five indicators—climate change, phosphorus and nitrogen flow to the biosphere and oceans, species extinction, and land system change—have already crossed the safe boundary field. Within this group, biochemical flows and biodiversity levels have skyrocketed since the end of the Second World War and are now considered to be beyond the zone of uncertainty (high-risk indicators). A similar process is currently being observed in terms of the consumption of primary resources, such as biosphere degradation, population growth, energy use, and economic activity [3–9,29–32,46–49].

Energy and climate change are the basic sources of knowledge not only for geologists, climatologists, and scientists dealing with environmental protection, but also for architects, engineers, and urban planners focused on climate-change-oriented design. The shift from fossil fuels to renewable energies will have numerous consequences. Studies that examine the political, social, and ecological dimensions of this shift have proven useful. Research into the role that energy regimes and the search for energy security have played in shaping humans and their societies and their effects was also significant [29–39]. The impact of anthropogenic alternations of the global ecosystem leading to environmental crises also affects individual and social well-being. A holistic and multidisciplinary approach was adopted, which facilitates understanding this issue from a socio-ecological perspective [31].

In the pre-design phase, four data groups were prepared, namely landscape characteristics with green infrastructures, socio-economic factors, hydrological systems, and climate change policies and risk assessment.

The study research was conducted in view of diagrammatic analyses of challenges in the following decades and impacts on multiple social and biophysical systems, regarding, among others, coastal development, urban infrastructure energy demand, population health, water supplies, and current geological and geotechnical matter. The main negative and positive factors of the Anthropocene affecting the production of renewable energy and the efficiency of sources were especially considered.

The comparative analyses of these materials allowed the challenges of the Anthropocene, to which architecture can respond to by sensitive design conceptualization, to be identified. Those challenges that are most common and are a global result of both climate action and human activity were selected for study through design. The most significant issues for architecture and the built environment were described. If architecture is able to respond to these listed challenges (Table 1), humans will experience the Anthropocene with better well-being.

The research-through-design phase was focused on the attempt to apply derivatives of natural phenomena, behaviors, and processes that may affect the formation of spatial forms in architectural design that is able to integrate energy production from various renewable sources in a safe way. These emerging processes require the recognition of architectural structures, not as singular and fixed bodies, but as connected with complex energy production devices and material systems that have a lifespan and exist as part of the environment of other active structures, being, at the same time, an iteration of a series that has proceeded by means of evolutionary development. Different technologies e.g., heat pumps, solar panels, waste-to-energy, and even free cooling combined with renewable fuels, were considered. The models used to represent the intentions of a desired piece of architecture visually are in the form of diagrams, drawings, digital abstracts or physical models, and computer-generated images, prepared using CAD design tools. The CAD system uses the computer as a helpful extension to establish design processes based on geometric information. The designed object is represented as a metric construct of points, lines, surfaces, and solids in three or two dimensions.

**Table 1.** Challenges in the design of architecture in the Anthropocene and conditions that should be met.

| Challenge | Condition |
|---|---|
| Structural stability | Resistance to wind load and flood waves, aeolian processes, erosion and deposition |
| Water self-sufficiency | Rainwater collecting capacity |
| Energy self-sufficiency | Obtaining clean energy and diversification of energy sources |
| Sharing water with the natural surroundings | Possibility of rainwater supplies |
| Sharing energy with the built environment | Accumulation of energy reserves-energy storage |
| Thermal comfort | Possibility of using the land as<br>a natural heat insulator and as<br>a means of control of the solar exposure of covered spaces at ground level |
| Environmental neutrality | Use of technologies limiting a negative impact on the environment |
| Independence of raw materials | Acquiring environmentally neutral and eco-friendly building materials |
| Energy security | Diversification of energy sources<br>Securing energy production:<br>opportunity of using the landform space to secure devices for the production of renewable energy<br>possibility of using the land as a natural energy conductor |
| Integrating local community | Sports and leisure |
| | source: own elaboration |

Through comparison with earlier approaches to human habitation in the past and present, our aim has been to deepen the knowledge and interpretation of new emerging approaches to architectural and urban design in relation to the challenges of the Anthropocene epoch. This analysis has confirmed that new architectural objects will be dependent primarily on the achievement of a multiplicity of stable states that link changeable environmental conditions and spatial requirements to a corresponding formal and structural articulation. Table 1 is a summary of the study and presents the main challenges and problem issues that an architect must overcome in order to design an architectural object for the Anthropocene.

The architectural design concepts presented below are an attempt to answer the challenges presented above (Table 1). Particular emphasis has been placed on providing structural stability and access to water necessary for life and obtaining clean energy and diversification of energy sources. Physical activity is an important element in maintaining both the mental and physical health of people of all ages—the older generation and children as well [50]. By offering a local community freely accessible facilities for leisure and water sports, where families and other persons can spend time, the aim was to achieve social integration and well-being during anthropogenic changes in the natural environment. "Human beings achieve happiness–psychological well-being–through living with and for other people" (Helliwell, 2014, ([8], (p. 81, [51]))). These visions are an attempt to answer the question of how to conceptualize architectural forms using terrain/land features to support green infrastructures and the coexistence of species and their well-being in the "Age of Humans".

## 3. Results: Designing Landform Architecture Using CAD Tools

Landform architecture is the result of engaging the land in an architectural form, or its representation. It allows one to explore multi-dimensional architectural meaning through the manipulation of space, material, and structure.

In geology, a landform is understood as a component of the Earth's surface that is part of the terrain. There are four major types of landforms: Mountains, hills, plateaus, and plains. Numerous factors have influenced the formation of the terrain, ranging from plate tectonics to erosion and deposition, which can generate and affect landforms. This creates nonlinear systems that can exhibit complex behaviors that are impossible in linear systems [47,48].

Our attention was focused on designing architectural forms that refer to typically non-linear geomorphic systems. For the research-through-design approach, sets of design variables affecting climatic comfort and energy diversity and its production security were selected, based on a simplified system, which supported the very early stage of the design process.

The task was to envision a public-use architectural object in a municipality within an attractive landscape or in a recreation resort. This would be a place of leisure for the residents of big cities, especially on days free from work. At the same time, it would meet the needs of the local community. The utility function of the object would include a swimming pool with raised seating, an Aqua Park, catering services with a restaurant and cafeteria, and other services to ensure the year-round attractiveness and profitability of the object. This facility could become self-sufficient as a type of communal shelter against weather threats accessible for all.

### *3.1. Challenge: Wind Erosion and Wind Deflation*

Winds can shape landforms via a variety of aeolian processes, such as the formation of fertile soils, such as loess, and by erosion. We can learn from nature how to shape architectural forms in order to reduce wind load on their structure. We can also learn from nature about the efficient management of energy and materials, by finding effective engineering solutions and structural designs. Architects often mimic the forms of nature and successful mixing of nature's shapes at all scales. They believe that natural formations should be crucial in any design, and the basics of self-organization processes should be used in built environment development.

Wind erosion is a natural process that moves soil from one location to another by wind power [48]. It can cause significant environmental and economic damage or be an inspiration for architectural design (Figure 1).

In this concept (Figures 1 and 2), the envelopes of the building and the land with vegetation are the physical separators between the unfriendly and friendly environment, which minimize destructive wind actions and loads and include resistance to air, water, heat, light, and noise transfer. These are the key components of the landform, which determine the quality of the indoor conditions and control them, irrespective of transient outdoor conditions, while also providing thermal comfort.

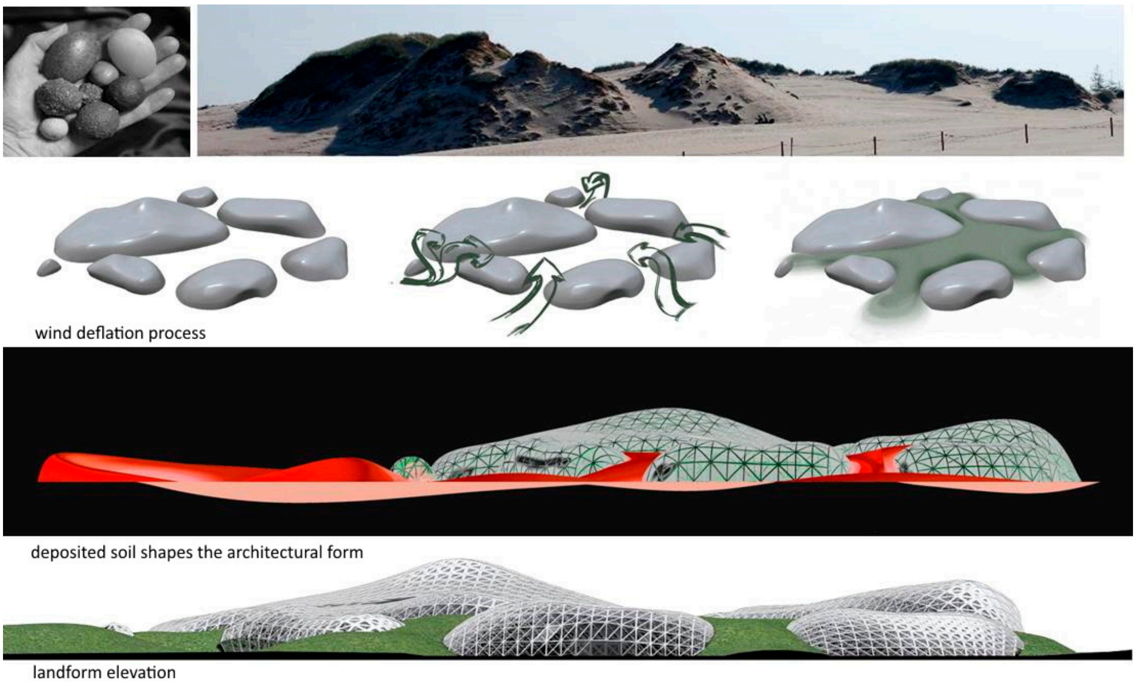



**Figure 1.** Wind deflation and recreation: Wind deflation analysis—design concept development (Michał Czapiewski).

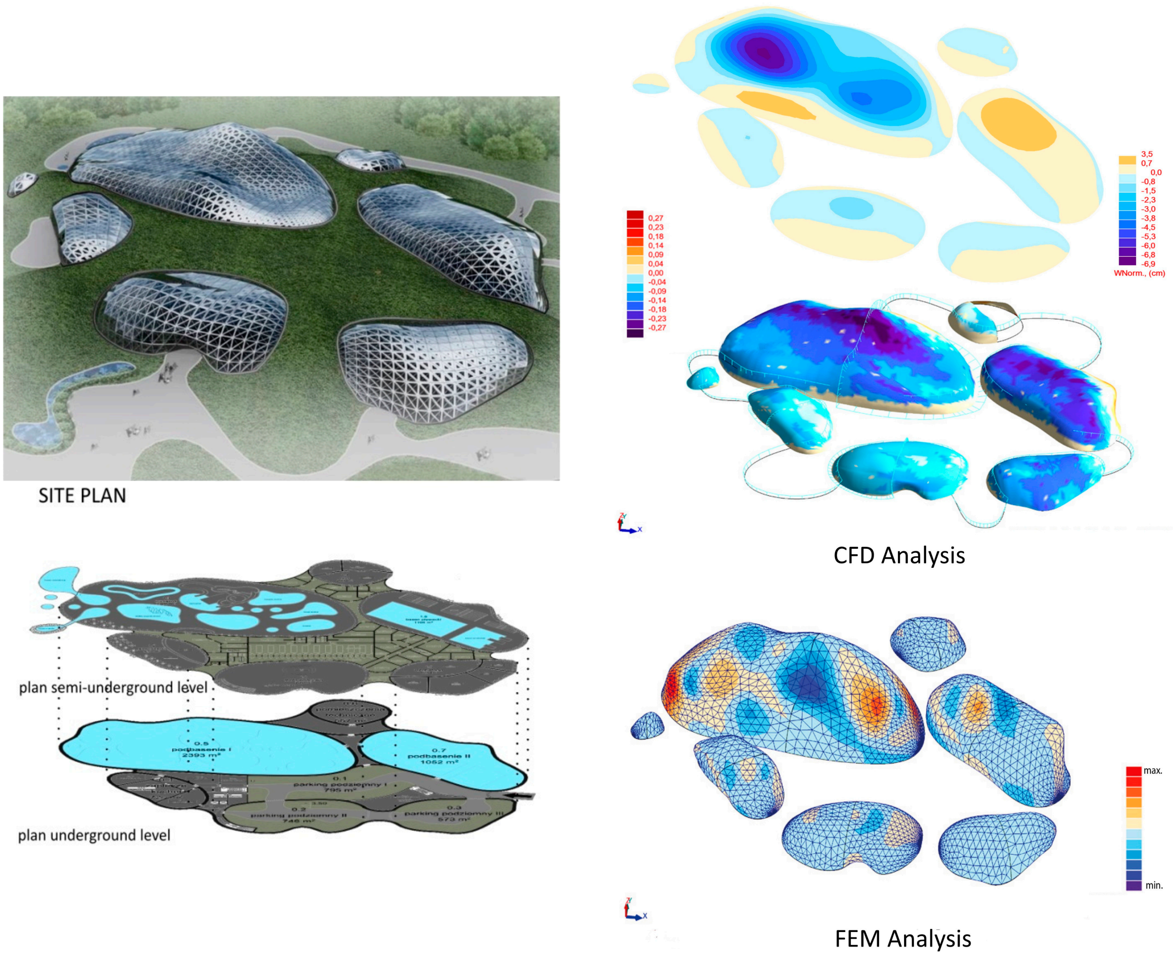



**Figure 2.** Wind deflation and recreation: CFD analysis and FEM analysis—design concept development (Michał Czapiewski).

An envelope can be defined "as a system's ability to adapt itself to deliver an intended functionality under varying conditions, through design variables changing their physical values" ([52] (p. 516, [53]). The overall shape of the envelope was determined by CFD and FEM analyses. The results of these analyses defined the final surface geometry, which was used as the basis for the geometry of its supporting structure. In this case, cladding modularization should take into account the structural tessellation of the surface and vice versa. The geometry of the supporting structure is affected by the overall shape of the envelope but acts as a support for the panel system of its cladding (Figure 3). However, other aspects also need to be considered during the design process, such as the cladding configuration and optimization, fabrication, and construction processes. For these reasons, the geometry of the structure needs to be designed and evaluated together with the other envelope layers (in the case of a structural skin) [54,55]. CAD 3D software offers a variety of tools for geometric surface modelling. Working with NURBS, one can model free surfaces and explore their geometric alternatives. Turrin suggests applying a parametric approach to studying the aspects of climate and structural performance, in which the free surface is treated as a set of points where each point is assigned its own parameter. Then the surface will follow these points. NURBS tools allow for modelling the surface that is to be transferred to the point distribution. Thus, the set of points is a key element for the parametric description of the reference geometry of the designed surface [53]. This approach can be recommended in modelling large complex geometric surfaces, especially during the exploratory phase of the conceptual design.

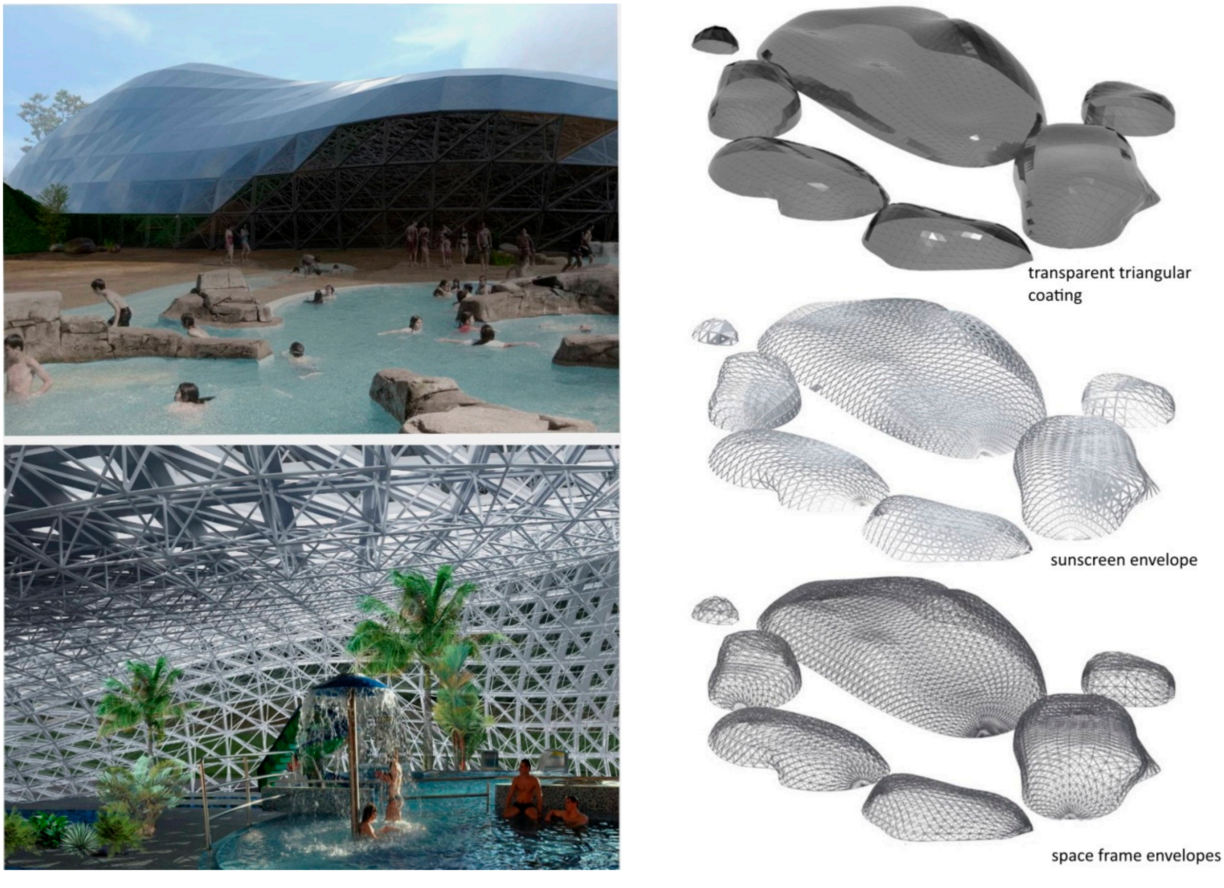



**Figure 3.** Wind deflation and recreation, modelling space frame structure of envelopes (Michał Czapiewski).

Geometrical analysis is of central importance to form-finding processes in a digital environment. 3D-modelling, using software packages, offers a variety of tools for geo- metric surface analysis. Zebra analysis in Rhino, for instance, uses NURBS surface evaluation to aid the visual analysis of surface smoothness, continuity between surfaces, and so on (Figure 2). The analysis of surface continuity helps to assess the structural consequences of how surfaces meet. These kinds of analytical parametric models, developed along with the computation, can provide auto methodologies, which use static data to analyze an immobile geometric model. These are new parametric tools that adjust geometric models in response to real-time data. In contrast to solid-based digital design, these tools also synthesize dynamic data in real time to generate a flexible geometric model [56]. In addition, it is also important to use a digital simulation of airflow in the early design process as a design assistance tool. Computer simulations, such as CFD, while not a full replacement for aerodynamic labs, have been introduced that can be manipulated and observed to help solve architectural and urban issues. The analysis by FEM of complexed free-form structures encourages simplified assumptions to be made. In this kind of modelling, various elements are used—in this case, a bar element. The mutual compatibility of the elements is often a difficult problem for the modelling of free-form structures. This compatibility is necessary to ensure their convergence. In order to solve it, a finite number of elements with a rotational degree of freedom should be applied.

Many abstract geometric shapes can be produced in virtual space. However, as Januszkiewicz notes, only "When the geometry of the architectural form is the result of performative analyses, it ceases to be an abstract form, and is considered as a material formation. Therefore, the essence of such design lies in the rules governing relationships and the model illustrating structural and material relations. Digital models obtained by this way are structural models, in which the relationship between material parts and the whole form can be modulated parametrically" [57] (p. 8 np).

The envelope of the building can be considered as a skin—as a complex membrane, capable of energy, material, and information exchanges. By combining automated shades with conventional thermostatic controls, it can control itself homeostatically, so as to maintain the stable internal temperature cell that we require to survive. It can be designed to operate "as part of a holistic building metabolism and morphology, and will often be connected to other parts of the building, including sensors, actuators and command wires from the building management system" [58] (p. 3).

In 1960, Fuller and Sadao imagined an extensive architectural envelope that would regulate the city's ecosystem. They proposed to the city of New York a two-mile geodesic dome spanning Midtown Manhattan. This project also included surprise sets of calculations: Buildings under this envelope could be built lighter and cheaper without the need for weather proofing [59]. This concept could be applied during the Anthropocene era to protect people and living nature or recover ecosystems, e.g., the well-known Eden Project in Devon (2001) by Grimshaw Architects.

### *3.2. Challenge: Wind Load Reduction and Rainwater Collection*

Increasing wind loads and drought or heavy rainwater are factors that define the global climate change era. An oasis is the combination of a human settlement and a cultivated area in a desert or semi-desert environment. Oases also provide habitats for animals and the spontaneous growth of plants. Rain showers provide subterranean water to sustain natural oases.

In the architectural concept design above (see Figure 4), the form emerges under the influence of contextual conditions (wind and rain) and should be flexible, able to change in shape, like the sand dunes of a desert area. The concept of emergence through adaptive natural processes has relevance for the evolutionary, structural modelling of the tectonic relationships between structure and material [60]. This vision appeals to natural formation processes that can be mimicked and modelled using morphogenetic tools coupled to a CAD system, for example, Genr8 software.

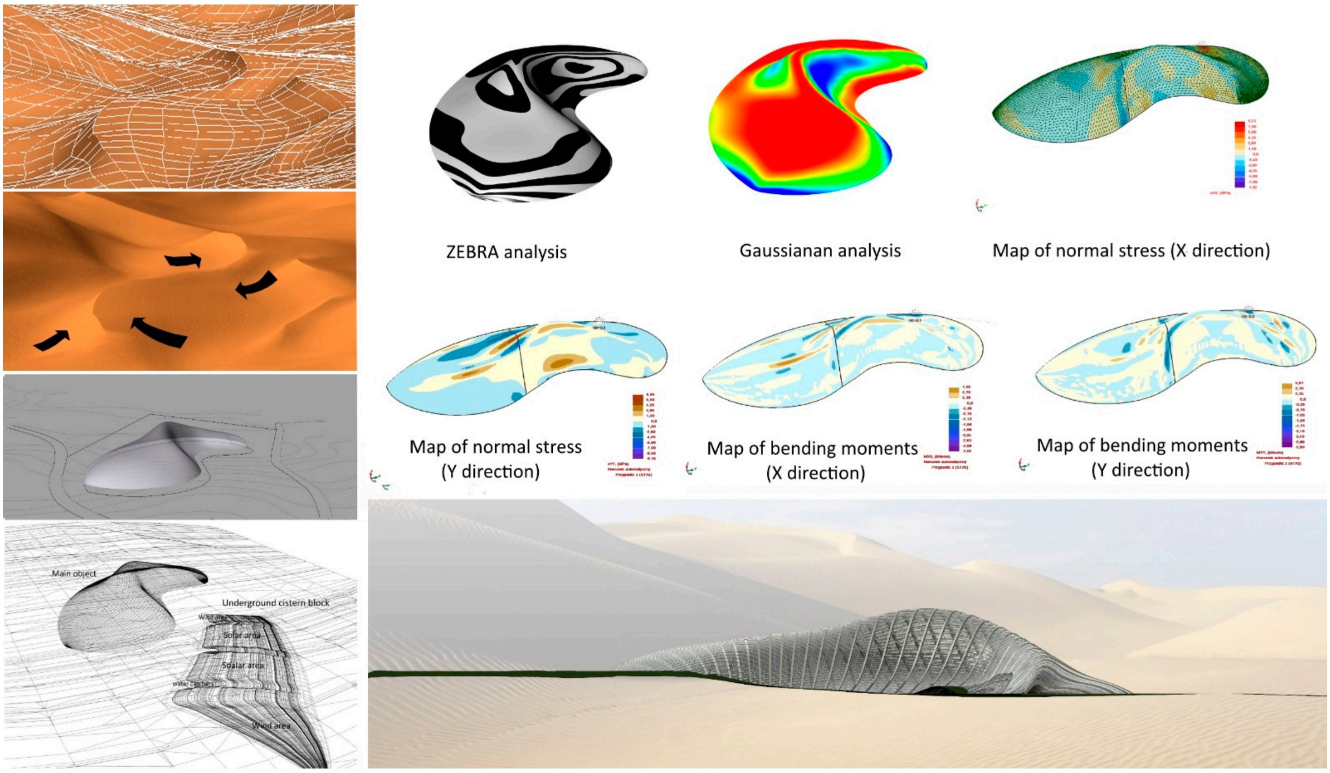



**Figure 4.** Anthropogenic oasis and Aqua Park with underground cisterns and a solar farm—design concept development and analytical stage: Geometric analysis and FEM analysis (Agnieszka Polińska).

In this case, self-organization enables form-finding as a response to force (wind), in relation to the physical context. The question is whether the structures could become lighter if they reacted actively to these effects from the environment in an adaptive manner. Then, such structures have the potential to become self-optimizing systems, based on smart strategies and intelligent computing models. Is it possible that a free-form building envelope could consist, as in the project presented here (Figures 4 and 5), of rods and strings that would bend in response to the wind, distributing the load in a relatively similar way to sand moving in a desert? Nowadays, new technologies, smart materials, and systems based on biological models have contributed to understanding the behavior of building systems, their design, and controls.

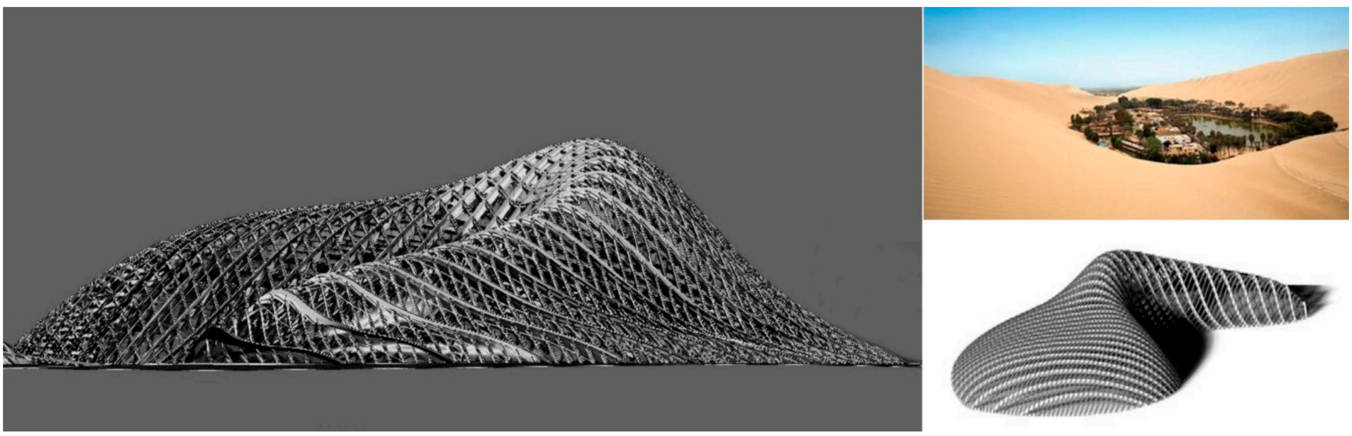


**Figure 5.** Anthropogenic Oasis Aqua Park, digital tectonic models.

A new generation of high-performance envelopes has resulted in the emergence of sophisticated assemblies combining real-time environmental response, dynamic automation with embedded microprocessors, advanced materials, wireless sensors and actuators, and design-for-manufacture techniques [61]. This kind of envelope could provide a home for endangered natural species or cover a desert oasis with the possibility of a synergic relationship with them, allowing humans to interact with the natural world.

For further development of adaptive, flexible envelope structures, it is necessary, for example, to solve the shape control problem based on inverse dynamic analysis of a multi-body flexible system, which should be integrated into an intelligent architectural envelope. Is it possible to invent adaptive architectural structures that sense and react to changes in their surroundings? Such structures would achieve a better performance e.g., to changing external climatic factors, such as wind, rain, sun, etc., and provide users with better thermal comfort and well-being. Current trends in architecture have been characterized by growing use of active building envelopes, which reconfigure themselves to respond to external and internal changes in the climate and user behavior.

### *3.3. Challenge: Rainwater Collection Flood Prevention and Leisure*

Floods are caused by many factors or a combination of them. These are mainly long-lasting, intense rainfall (concentrated locally or in the catchment area) or strongly accelerated snow melting. Floods occur when ponds, lakes, riverbeds, soil, and vegetation cannot absorb all the water [62]. The changing climate might cause rainfall to fluctuate, which might be from human activities, such as draining wetlands, deforestation, and building paved surfaces, preventing soil from proper/effortless water absorption [63]. The use of rainwater collection techniques has been traced back to the Neolithic Age [64,65]. In the civilizations of the Middle East, rainwater-harvesting cisterns were common on a home-by-home basis. These cisterns would range from approximately 2000 $m^3$ to 9500 $m^3$ and would often be stored underground. Communal cisterns were common and accessible to everyone. Technologies were used such as sediment traps prior to entering the large cistern, which could hold as much as approximately 200,000 $m^3$ of water [64]. The techniques of rainwater harvesting developed in historical times can be updated and used in the Anthropocene.

The main design task was to find a solution for a free-surface Aqua Park vision fitting into the natural landscape with the ability to collect rainwater in large underground cisterns. The cisterns should be built of local materials (stone), according to proven historical patterns [64–66], to allow integration with the architectural object. All aspects of rainwater harvesting have been outlined, including passive and active system setup, storage (separate for rainwater, spring water, drainage water, stormwater catchment) stormwater reuse, distribution, purification analysis, and filtration. There is also a section on rainwater harvesting for wildlife to support the surrounding green infrastructure. This concept design is in line with the network of natural and semi-natural areas, or green spaces in rural and urban areas.

The spatial idea of the Rolex Learning Center served as the main architectural concept of the design but was adapted to a new public use. The fluid interior space provides a seamless network of public services for leisure with freely located smaller open watercourts that are resourced from the underground rain- or thaw-water tanks (Figures 6 and 7). Part of that water undergoes a filtration process and supplies the swimming pools, while the other part remains in greywater circulation, and the rest is stored for the dry season, to supply the surrounding landscape.

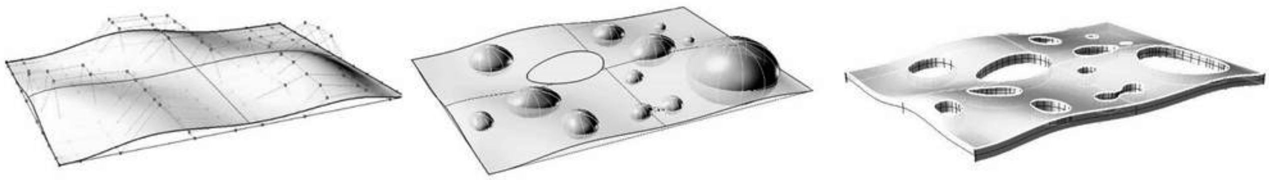


**Figure 6.** Modelling (step by step) the geometry of the free surfaces with Rhinoceros CAD software-initial concept design.

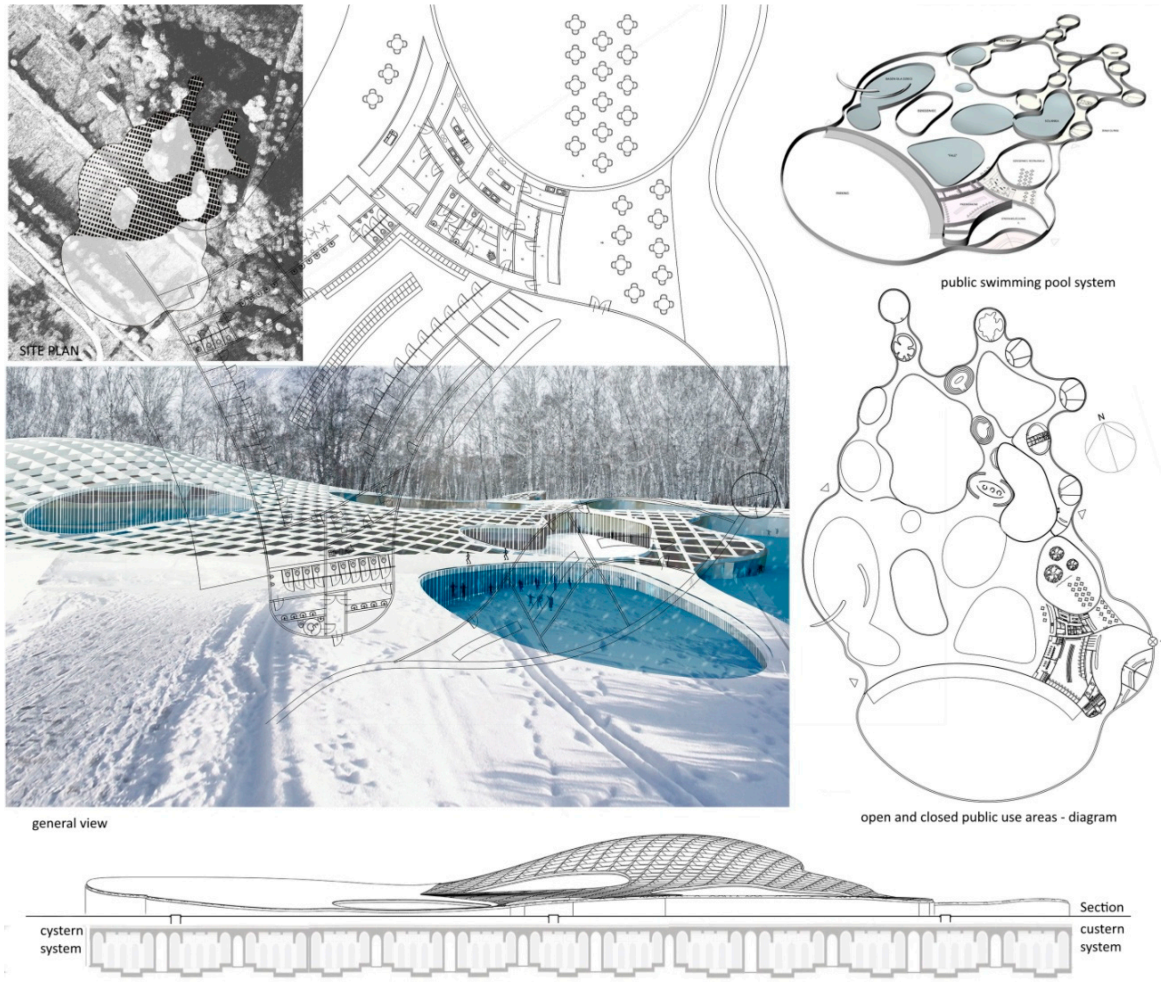



**Figure 7.** Flood prevention and leisure—concept design development (Katarzyna Dobrowolska).

The Aqua Park consists of two geometrically complex and undulating slabs with openings (Figure 6). Under-stressed arches should be between the two slabs. Thus, a wide range of design criteria can be integrated into each level, far beyond just structural aspects. Thanks to this assumption, the building can function as a partially open or fully closed facility. The geometry of form in the concept design has been achieved by contouring and traced using the Rhinoceros freeform modeler. Mutsuro Sasaki, who developed the concept of "Morphogenesis Flux Structure" [67], whilst working with SANAA, Bollinger + Grohman, and Arup, implemented this new shape-analysis approach for waving slabs, which he called Extended ESO (EESO) [68,69]. The Evolutionary Structural Optimization (ESO) can also be understood as an evolutionary design tool, one that is not limited by the availability of calculation and methods of analysis. This technique, as a kind of form-finding method, enables this design to be a completely unique structure. The pioneer of this method was Heinz Izler, who studied the shape of a hanging piece of fabric. The shape was then the starting point for the design of concrete shell canopies. With the development of IT, classic form-finding has been replaced by processes of tracing performative capacities in a specific morphology. As load-bearing characteristics usually vary across the shaped form in terms of articulation, no region represents a pure structural typology.

In engineering and architectural design, form-finding is commonly used to shape structural form in response to gravity. Form-finding is also a design method, which deploys and operationalizes the self-organization of material systems under the influence of extrinsic forces. Such an understanding demands shifting the focus of the architectural design goal from producing static objects to generating systems of motile and active materials that respond to their environment. The question is then: How can we approach form-finding, if a material form continuously transmutes in response to an equally dynamic force-context? According to Hensel, an approach to this design problem must engage with three generative feedback processes. The first piece of feedback concerns the context-specific forces that act upon the material form, which are in turn influenced by the material form through levels of resistance to change. The second feedback process comprises the dynamic relation between the material arrangement and the human subject. The third feedback process involves the interactions between the human subject and the environment that assert an indirect influence on the material arrangements [70].

The form-finding processes driven only by structural optimization never constitute the optimum shape of an architectural form, but rather embody and integrate a multitude of parameters. It might be assumed that there is a similarity between formative processes occurring in nature and the design methods with the use of design tools imitating these processes. In CAD processes, each individual architectural form or structure needs to be fully defined and modelled (especially when it is a free form), in order to be evaluated in terms of its tectonics (building abilities), its aesthetic quality and space, and changing the existing axioms of design. The full integration of structural engineering into the design process of architecture does not guarantee higher aesthetic values of architecture or revolutionary structure and space but enables their potential to exist. In the past, engineers such as Heinz Isler, Pier L. Nervi, Frei Otto, and Santiago Calatrava studied the works of nature in order to abstract solutions, which they later translated into the language of building structures. Now, more than ever, engineers are entering the natural world to learn its logic of energy and material conservation, structure efficiency, and its ability to adapt to changing environmental conditions.

### *3.4. Challenge: Water Retention and Leisure*

Drought conditions negatively affect agriculture, water supplies, energy production, and many other aspects of society. As climate change continues, droughts will, according to the available models, become more regular, last longer, and cover a larger area. Retention is the answer to both the problem of drought and flooding. It involves using a set of simple ways to collect water from the local area, which allows the flow of water to be stopped or slowed down, whilst taking care of the development of the natural environment.

The concept design entitled "Retention and Leisure" illustrates how the metaphors of nonlinear geomorphic systems and CAD free-form building envelopes can be engaged, enabling them to be conceptualized into a human-friendly survival environment (Figures 8 and 9). During drought, the natural environment is supplied with water from retention reservoirs. The green infrastructures are an integral part of this concept design.

The land was shaped so that two retention reservoirs related to the function of the Aqua Park could be created. The process of Digital Terrain Modelling involves the creation of a data structure that the software can instantly "touch", in order to retrieve elevations or slopes, representing either existing or proposed conditions. The basic concept behind Digital Terrain Modelling is not new in the Civil Engineering and Surveying industry. There are several methods of terrain modelling using CAD tools. The simplest method is to import CAD drawing formats directly into Rhino, in order to isolate contour lines. With Rhino tools such as "Extract points" (for modelling contour lines) and Pach, surfaces with the desired topography can be obtained.

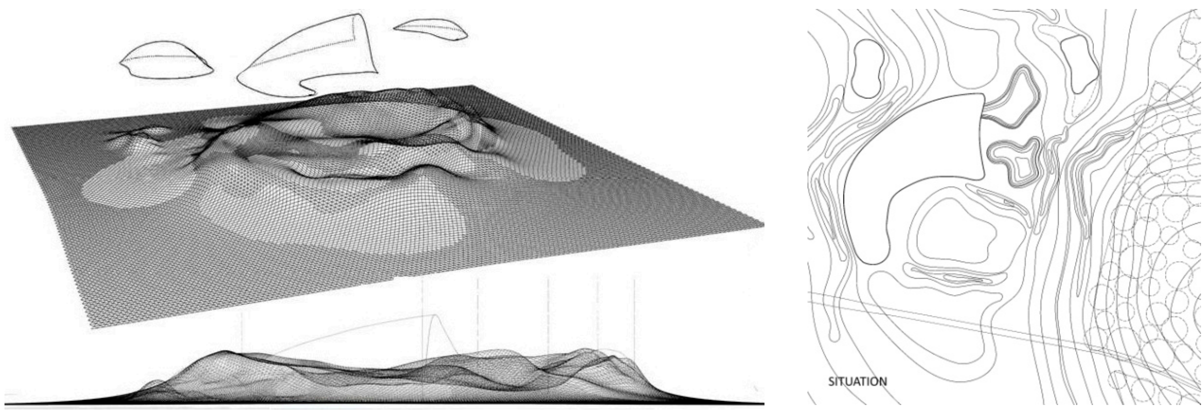



**Figure 8.** Retention and Recreation: Terrain model by AutoCAD—concept design development (Magdalena Zalewska and Iga Prüffer.


**Figure 9.** Retention and Recreation: Terrain model using Rhinoceros (on the **left**); visualization of Aqua-park section (in the **middle**); site plan (on the **right**) (Magdalena Zalewska, and Iga Prüffer).

Working with site survey data is a critical component of any landform design. The information is presented as anything from 2D markers to points in 3D space or contours. For instance, GlobalCAD Terrain offers the tools to produce "intelligent" surveys, either by converting an existing drawing or starting from scratch. If any intelligent survey point marker is moved, then its associated XYZ value is automatically updated to suit the new location. These tools should encourage architects to design architectural forms in which the terrain plays a key role.

### *3.5. Landform Architecture—Energy Diversity and Production Security*

The concept designs presented above are a vision of architectural forms for public-use objects in response to some of the most common challenges of the Anthropocene. Four different concept designs were selected and are presented here. These are concept designs for a municipal facility, free-standing objects not integrated directly with the urban fabric, but integrated with the natural landscape. They illustrate how the land can evolve into an architectural representation of the built environment, to reconnect a physical construction with social realities, human perception, and environmental considerations.

We were searching for architectural forms that could respond to phenomena such as wind erosion and wind deflation, and we were also looking for a way to create a green oasis in drought-affected areas with desert features, or how to combine recreation with the need for flood prevention or water retention.

These concepts of landform architecture also allow for the integration and management of various renewable energy sources in one facility. Table 2 shows that achieving the expected energy self-sufficiency of landform architecture is possible with the synergy between efficient and targeted different renewable energy sources. Thus, the landform facility is energy self-sufficient and can even be treated as an independent, small power plant. Combining renewable energies into heating and cooling systems is not new in Europe. There are already many practices integrating "green energies" such as solar, wind, and geothermal into one system [38]. On the other hand, the combination of renewable energy production with an architectural object of public use is a new concept. This approach to architectural design and this way of thinking can be extended to other components of the built environment such as housing estates, office complexes, commercial facilities, etc. Housing areas are especially in the spotlight in the EU program "renovation wave". Concepts for how to make these estates self-sufficient in energy and operate as independent units (small power plants) will emerge.

**Table 2.** Integration of various renewable energy sources into envisioned facilities and approximate energy demands.

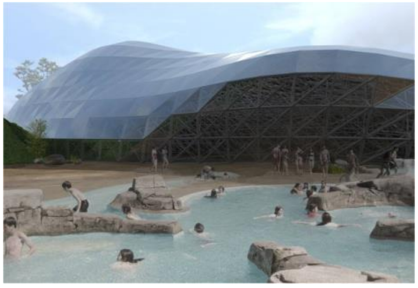
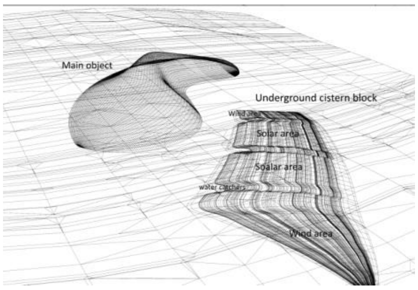
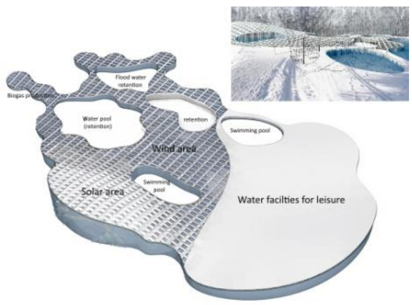
<table>
<tr><th>Sports and Leisure Facility</th><th>Energy Sources Capacity</th><th>Type of Devices</th></tr>
<tr><td>Wind deflation and recreation<br>
<br>
Landform footprint area: 7246.7 m$^2$<br>Basement area: 7164 m$^2$<br>Ground floor: 7521 m$^2$</td>
<td>Solar 60–150%<br>Wind 40–75%<br>Water 52–64%<br>Biogas 100%<br>(ignition of the heat pumps)<br>Approximate energy demand:<br>506,400 kWh per year<br>Energy storage: 30–50%</td>
<td>PV coating of envelopes<br>(elastic PV panels)<br>Movable, vertical axis wind turbines<br>hidden in the silo<br>Tidal turbine (underwater)<br>Bio-tanks and installations mounted into the<br>inner space of landform<br>(biodegradable waste from users)<br>Cogeneration modules, heat pumps<br>ventilation: windshields (ancient refrigeration<br>systems) + air-condition</td></tr>
<tr><td>Anthropogenic Oasis and Aqua Park<br>

<br>
Landform footprint area 3500 + 4250 m$^2$<br>(cistern)<br>Basement area: 3309 m$^2$ (main object)<br>Ground floor: 1350 m$^2$ (main object)</td>
<td>Solar 70–100%<br>Wind 40–60%<br>Water 40–70%<br>Biogas 100%<br>(ignition of the heat pumps)<br>Approximate energy demand:<br>200,120 kWh per year<br>Energy storage: 120%</td>
<td>Cistern block<br>Movable PV flat panel sets<br>Movable, vertical axis wind turbines<br>hidden in the silo<br>Tidal turbine (underwater)<br>Bio-tanks in the inner space of the block Main<br>building<br>Rainwater harvesting (envelope) for<br>living nature's irrigation of the object<br>Underground water tanks</td></tr>
<tr><td>Flood prevention and leisure<br>

<br>
Landform footprint area: 8158.5 m$^2$<br>Basement area:8010.7 m$^2$ + cisterns area<br>Ground area: 3050.7 m$^2$ (covered)</td>
<td>Solar 60–150%<br>Wind 40–75%<br>Water 52–64%<br>Biogas 100%<br>(ignition of the heat pump)<br>Approximate energy demand:<br>190,120 kWh per year<br>Energy storage: 120%</td>
<td>Movable PV flat panel sets in a solar<br>area—hidden in the grid-shell structure<br>Movable, vertical axis wind turbines<br>hidden under the grid-shell structure<br>Tidal turbine integrated with the water<br>catchers and distribution system<br>Bio-tanks and installations mounted under the<br>grid-shell structure<br>(biodegradable waste from users)</td></tr>
</table>

**Table 2.** *Cont.*

| Sports and Leisure Facility | Energy Sources Capacity | Type of Devices |
|---|---|---|
| Retention and recreation<br><br>Landform footprint area: 91,547 m$^2$<br>Basement area: 4309.4 m$^2$<br>Ground floor: 3152.3 m$^2$ (covered) | Solar<br>Wind<br>Water<br>Biogas %<br>Approximate energy demand: 206,130 kWh per year<br>Energy storage: 70–90% | PV coating of envelopes<br>(elastic PV panels)<br>Movable, vertical axis wind turbines hidden in the basement silo<br>Tidal turbine (underwater)<br>Bio-tanks and installations mounted in the inner space of landform<br>(biodegradable waste from users)<br>Cogeneration modules, heat pumps<br>ventilation: windshields (ancient Middle East pattern) + air-condition |
| | | source: Own elaboration |

The abundance of space in the ground part of the form (under the vegetation or the green layer), which can be provided by the structure of the landform, allows for the protection of energy devices against the effects of weather hazards. For instance, vertical-axis wind turbines located in a silo would slide out above the surface when the weather conditions are proper. Biogas production should also be hidden beneath the surface of the landform.

The cistern block for the Anthropogenic Oasis and Aqua Park was conceived as a multi-functional underground structure that not only collects and distributes water but is also home to renewable energy equipment. PV flat panels extend horizontally and are then set to the desired angle. Alongside the extension of wind turbines, the cistern block can also contain small tidal turbines.

Nowadays, digital design tools in CAD allow one to carry out analyses and simulations of solar insulation with great precision and, moreover, determine the areas predisposed for the placement of PV panels (Ladybug, a plug-in of Grasshopper and Diva software). Computational fluid dynamics (CFD) software performs the simulations necessary to determine the shape of buildings and devices as well as their locations in order to obtain the best possible environmental performance. There is also software from the Audytor OZ series, which is used to support the calculation of the designed heat load of rooms, the determination of the seasonal demand for thermal and cooling energy in buildings, and the preparation of Energy Certificates for buildings and their parts. With the use of these tools, proposed visions are feasible from an engineering and technical point of view. However, this requires a new approach to energy policy.

The European Green Deal program encourages the implementation of innovative ideas, especially when the main aim is to achieve climate-friendly architecture and environmental neutrality, independence, and energy security of buildings and their complexes. It is a retreat from a centralized system of coal power plants towards decentralized production of "green energy". The results presented here are in line with this European program, providing an attractive alternative approach to the decarbonization process of Europe.

## 4. Discussion

Humans have made an indelible mark on the planet. We are witnessing "overwhelming global evidence that atmospheric, geological, hydrological, biospheric and other earth system processes" [7] (p. 222) have been transformed by human actions. Does this mean humans are unable to regulate social systems and scientific fields to protect the Earth's system?

This model has developed four distinct phases: Knowledge establishment, knowledge accumulation, knowledge maintenance, and knowledge exploitation, which gave rise to a multidisciplinary framework that applies equally to humans, animals, and organizations. One of the most basic resolutions in nature is the balance between the need to obtain new knowledge and the need to use that knowledge to improve performance. However, optimal performance usually requires some trade-off between exploratory and exploitative behaviors. Researchers in many disciplines are searching for a sustainable solution to this dilemma [71–73].

The contemporary understanding of ecology should be changed, as well as the way in which architects approach the built environment and green infrastructures. Important for the ecology of the Anthropocene are issues that concern the coexistence of species. The recognition that two categories of processes may jointly operate to promote species coexistence, "stabilizing mechanisms, that increase negative intraspecific interactions relative to interspecific interactions, and equalizing mechanisms, that minimize inherent differences in species growth performance" [71] (np.), has been a major advance in ecology in the past two decades [72]. The outcome of competition (coexistence vs. exclusion) is determined by equilibrating these two types of forces. For instance, when competitors have similar "ecological fitness" (the degree of their adaptation to the environment, independent of other species), coexistence is more likely, as competitive exclusion between such species should be slow. The importance of these two categories of coexistence forces has been attentively assessed in recent years [73].

Reducing greenhouse gases requires resignation from the current technology of obtaining energy and its use. This is the greatest challenge of the Anthropocene era. Fossil resources (such as coal, gas, and petroleum) are running out due to their exploitation throughout the planet. It also demands a change of lifestyle [31]. In 1940, R. Buckminster Fuller introduced the term "energy slave" to describe the energy required to power the modern lifestyle [74]. The concept refers to the technological or mechanical energy equivalent to the physical working capacity of a human adult. The energy requirements for any lifestyle can be calculated as the number of "energy slaves", equivalent to the number of human laborers that otherwise would be needed to produce the same amount of energy. In 2013, it was estimated that the average European employs the equivalent of 400–500 "energy slaves", 24 h a day [68,75,76].

The vision of energy usage of the European Climate Foundation, entitled "Roadmap 2050" identifies four 'pathways', each using different proportions of renewables. It is a plan that assumes that such drastic intervention to mitigate climatic changes will emphasize the meaning and power of the European Union [76]. Achieving energy savings with an impact on climate change will require decoupling economic growth from energy consumption and reinforced measures in all Member States and in all economic sectors (European Commission 2012). Since December 2020, the idea has been developed by the European Green Deal to diversify energy sources in one object [40].

The progressive shift towards natural solutions as a source of efficient construction, zero-waste systems, water management, energy saving, and thermal environment control is conducive to the latest technologies (especially computational software). In the past, humans, fleeing natural disasters, sought shelter underground (ancient underground cities). So why not use the land to protect modern human habitats. In the near future, will humanity be able to develop Nikola Tesla's invention of using the earth and its atmosphere as an energy producer and conductor and create a global wireless non-commercial energy network, accessible to all?

Historically, natural systems have served scientists and creative designers well. Design methods have been based on the direct perception, observation, and exploration of nature. Living organisms have given rise to new technologies, inspired by biological solutions at both the macro- and nano-scale. Nature has solved engineering problems, such as environmental exposure tolerance and resistance (e.g., redundancy issues), the ability to adapt self-assembly, hydrophobicity, self-repairing, or self-healing and material abilities, and the harnessing of earth and solar energy, and rainwater. Currently, this pattern is changing and there has been some adaptation to the new conditions, to the changing characteristics of the climate, in terms of ecology as well as geology.

The Anthropocene is causing architectural forms and building structures to be adapted, which demands new tools and a new approach to design. Such structures should contain a multiplicity of stable states, which link changing wind loads, spatial, and thermal control requirements to a corresponding formal and structural articulation, and also provide a sense of security and well-being its users.

In the construction industry, IT developments have led buildings to use mechatronics to respond in real-time to data. Often, this is for environmental purposes and the well-being of users—for instance, the opening and closing of louvres, based on internal air temperature and weather reports—but, increasingly, mechatronics is being used in energy- and water-saving strategies, and for spatial effects. In designing these responsive systems, multi-parametric modelling provides one way of visualizing the response of a building to real-time data. Will recent progress towards a higher-level design synthesis of material self-organization, digital morphogenesis, associative parametric modelling, and computer-aided manufacturing (CAM) allow for the elimination of energy-consuming devices from buildings?

The involvement of morphology and ecology in architectural design seems feasible today [77]. Ecology, which is understood as the relationship of the organism with the environment, is then the central concept of design. In this approach, the theoretical and methodological framework would relate to intense material differentiation and energy interventions that capture behavioral trends in a given environment.

The proliferation of new digital and computational sensing techniques is of importance to architectural studies in the Anthropocene. The waning confidence in modernity is today both accompanied and stimulated by an increase of new approaches: Complex big data and algorithms associated with climate change, and new techniques for mapping the complexity of ecological systems. However, there is also a particular and growing interest in 'non-modern' or 'atavistic' and 'indigenous' ways of sensing and relating to the environment. However, new complex forms and systems emerging from Anthropocene processes will also be developed incrementally, through the processes that can be visualized in morphogenetic design as subsequent versions of the genome and phenome.

## 5. Conclusions

The negative effects of human activity cannot be completely erased from the planet, but with the appropriate scientific and technological progress, much can be restored. This is essential for the life, health, and well-being of all species. One of the remedial measures is a technological change in the methods of obtaining energy. However, first, a consensus must be reached between those who believe in continuing a destructive way of life and those who believe in protecting the environment and living in harmony with nature.

The new architecture and urbanism emerging from the "Age of Humans" will require a new way of thinking and conceptions of architecture and secure energy production, both from the perspective of the designer and the individuals experiencing the built environment. Responding to the challenges for architecture listed in Table 1 requires new awareness based on a socio-ecological approach that is built on the belief that the Earth is a shared home, and we have no other. The answer to the challenges for architecture listed in Table 1 requires a new consciousness based on a socio-ecological approach in the belief that the Earth is a common home, and we have no other—our well-being depends on this answer. This needs to be geared towards new sustainability, combining ecological, energetic, and economic efficiency. Integrating the architectural form with the production of renewable energy from diverse sources requires a new approach to, and understanding of, the variable impact of environmental factors. The conducted research into envisioning CAD architecture for the challenges of the Anthropocene has allowed us to identify important demands, such as new analytical tools that are easy to use in the early design phase (solar, wind analysis, and energy efficiency balance).

Anthropocene-adapted architectural forms and building structures also demand a conscious combination of ancient and new technologies, smart materials, and new energy sources. Architects can gain this through a design strategy that connects energy with structural and material processes using digital tools. These structures will contain many stable states that combine changing spatial requirements with appropriate formal and structural articulation and will use the energy of the Earth and the Sun, accumulating water to share this good with the living nature.

The capacity for building envelope to actively support building function and energetic balance is critical to the future of building design. Climate change policy is often presented as a choice between mitigation and adaptation, where "mitigation" refers to efforts toward reducing the accumulation of greenhouse gases in the atmosphere and "adaptation" refers to adjusting to the impacts of a warming world through enhancing an ecosystem's resilience. This is a false dichotomy, and to address climate change hazards, we need to begin the process of writing both mitigation and adaptation strategies into new building codes and standards that will also include vegetation.

With the use of parametric and multi-criteria tools and computation techniques, buildings can be designed to suit a variety of requirements, the implementation of which will lead to a change in the built environment and lifestyle on the planet.

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