Nature-Based solutions and Circular economy: structuring a long-term project for a climate resilient design

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ABSTRACT: The growing systemic fragility outline the necessity to rethink the design action for a renewed relationship within societies and the environment. Climate change is shaping a new paradigm that urges human action to reduce the carbon footprint. At the same time, urban areas are showing an increasing need to gain more resistance to disruptive climate events. Thus, the purpose of the research is to present Nature-Based Solution and Circular Economy as a unitary resilient design approach, displaying both adaptation and mitigation actions to adapt our cities and mitigate further climate alterations. The contribution portrays the necessity to implement the two approaches to structure a long-term project, so going through the current scientific debate and displaying some regeneration design projects. These are selected based on: regeneration projects at the neighborhood scale; the Circular Economy is applied to the material flows of built environment regeneration, reducing the CO_2 building impacts; Nature-Based Design addresses the reclamation of polluted lands and re-naturalizes the common ground to prevent climate risks. The configured design method opens to new practices that could foster the preparedness to climate change events and design a more resilient built environment. Consequentially, resilience is defined by applying adaptation and mitigation action to prevent climate risks, adapt the urban space, and improve the usage of resources. Finally, the research will question the morpho-typological modification that resilience can bring in the contemporary design panorama, claiming further research on the relationship between climate change and architecture.

KEYWORDS: Climate Change, Nature-based solution, Circular economy, Urban regeneration, Resilience
PAPER SESSION TRACK: Global Sustainability: Mitigation and Adaptation

A GLOBAL FRAMEWORK: CLIMATE CHANGE AND DESIGN

The theme of environmental risk and spatial responsiveness has been widely present within the design culture since the previous century. We could even argue that some of the contemporary practices that we spot as new design strategies are, instead, millenary operations that, with various names, have characterized the history of the project. For example, experience such as the circular economy, looking at it as a design strategy, directly recalls the buildings reuse practice during the roman/medieval periods, in which components of ruins or other constructions were removed and integrated into new artefacts. Other themes, such as the one relating to nature and urban life, have repeatedly risen to the forefront of design ideas only to drop in the face of developmental pressures, economic constraints and shifts in stylistic taste (Vidler 2010).

Nevertheless, the 20th century was central in structuring the basis for a growing sensibility toward the issue of sustainability and ecological responsibility (*Bruntland Report, Limits to Growth, Silent Spring* etc.). Indeed, these two themes have, in different ways, defined a structured path that nowadays is strengthened not only by the threat to the conservation of the environment but also by the evidence that risks such as climate change bring to the space we inhabit and live every day. Thus, concerns about the planet's survival have acquired importance, and the climate emergency has undoubtedly emerged as a crucial issue since the beginning of the 21st century. According to the International Panel for Climate Change (IPCC 2021) forecasts, the phenomena linked to climate variability will intensify in the coming decades, and extreme events related to the climate will increasingly constitute a social and ecological risk.

It is already clear how climate change cannot be considered an occurrence of the modern world or a temporary emergency; rather, it is a proper discontinuity of the previous global climate system. Because of this reason, we could argue that climate change is a *macro-catastrophe* (Bertin Maragno & Musco 2019) that is affecting the whole world, and it is amplified by human action (IPCC 2021). Furthermore, the consequences deriving from this environmental and climatic crisis is changing the balance of life on the planet (Crutzen 2000), producing a growing onset of risks, accentuating pre-existing fragility and dangerous conditions.

This perspective clarifies how climate change is an unstoppable event and that it should also influence the design practice in defining the perspective in which we will structure the space within this different system.

Indeed, climate relapses are affecting the built environment and the space among buildings, producing an increasing onset of hazards: heat island effect, floods, hurricanes, and droughts, together with social injustices, economic crisis, and pandemics are shaping the current era, affecting people and spaces, defining an unbalanced framework.

The effects of this change seem to worsen within urban areas (Kabisch et al. 2017), where it is possible to find a stratification of complications due to climate fragilities, generally overlapped on previously unstable socio-spatial contexts such as peripheral or abandoned areas. Indeed, the climate risk could be considered as an

> Anthropocentric concept, as it addresses damage to people and to assets that are at the same time located in a dangerous area, exposed to a given natural or man-made threat and vulnerable to the latter. (Menoni 2020, 27)

Therefore, it is urgent to study methods to face and counteract the effect of the changes, and urban areas can play a key role in this rethinking. Indeed, these are the main place of CO_2 emissions, of which 36% are attributable to the construction sector, as well as the most densely populated contexts: in Europe, urban areas host about 72% of the population (United Nations, Department of Economic and Social Affairs 2014), with estimates potentially in growth.
An important path to tackle the issue of climate change is to increase the resilience of our urban systems, decreasing the carbon footprint of buildings and, on a broader level, rethinking the design action to adapt our city, increasing the natural carbon sequestration and reducing the threads derived from climate hazards. From these statements, in 2015, the Paris Agreement set three objectives: limit the global temperature to increase more than 1.5 °C, promote climate resilience and low carbon development through the adaptation to the various climate impacts, and invest in resilient low carbon development.
Moreover, the United Nations, with the 17 sustainable Developments Goals (2015), defined a series of challenges to restructure our society and symbolize an urgent call to action to improve a transversal development, in which one of the goals (the 13th) specifically address the urgent action to combat the climate emergency, as an act of preservation of planet's and human's future.
This framework is heavily impacting the construction of the city of the future, implying a rethinking of the design activities for the new areas of urban expansion and the regeneration actions. During the last decades, various solutions have begun to spread in this direction, interacting with different types of fragility, deepening the consciousness of the relationship between ecology and design, trying to interact with the issue of climate resilience from a different perspective.
Specifically, in recent years, two main strategies have acquired centrality: the so-called nature-based solutions and the circular economy. Therefore, it is relevant to understand how these two tools can be framed as instruments to face a broad set of fragility, climatic as first. As a result of this, nature-based solutions and circular economy are not presented as punctual technical solutions but considered in their ability to produce ecosystemic effects. Because of this reason, the contribution aims to show the possibility generated by the complementarity of nature-based solutions and circular economy. This complex condition defines the research framework, which considers the neglected urban areas that are facing or have concluded regeneration processes. Specifically, the contribution will highlight how the complementarity of nature-based solutions and circular economy can increase the resilience of a site, affecting the reduction of carbon emission and raising the capacity of the project to adapt to the urban environment.

1.0 METHOD

Starting with the threads of climate change, the necessity to increase the resiliency of the urban system is a direct consequence. The present research starts from this to state the different scope that nature-based solutions and circular economy can play across the design process and the main effects on the urban environment. Thanks to a broad literature review and supported by a series of case studies, this analysis has been conducted to emphasize the design practice relapses that long-term resilience and specific design strategies could have. The article will display three of these case studies, highlighting the complementarity of the two strategies. Specifically, to present the design perspective, the contribution considers regeneration projects settled in European urban neglected areas that addressed the regeneration applying, as complementary design tools, nature-based solutions, and circular economy. These two strategies are recognized as emblematic not only for their increasing presence among several projects but also considering the centrality they have in the European Agenda1, thus modelling the financial and spatial future of Europe.
The case studies are analyzed highlighting their design approach, in which it is visible the use of nature-based solutions to restore grounds and the circularity as a renewed design mindset to approach the contemporary project, where also the regeneration of polluted soils and neglected areas can configure an action of urban reuse toward a circular city perspective. In detail, the projects reflect on the role of nature within the urban project, whether it is applied to the soil reclamation (De Ceuvel) or as a punctual solution as a green roof (Luchtpark Hofbogen). Circularity, instead, is studied in his conception of rethinking the material flows (Ilot de l'Arc de Triomphe), whether the study is applied at the singular constructing element or at the whole architecture as reuse action.
The main scope of this contribution is to highlight design processes where adaptation and mitigation are conceived as complemental results to achieve a long-term resilience to cope with the climate change hazards. To do this, the two design tools are analyzed through a case studies analysis and then synthesized in a conceptual scheme that reflects the general strategies that we can find at the urban and architectural scale. The description of the projects is not aimed to deeply survey their feature, rather show some practices of regeneration in which the tool of nature-based solution and circularity are implemented not only as a technical solution but considering their impact in defining the spatial features of architecture in perspective able to increase the resilience of the urban space.
Finally, an open question will be raised regarding the morpho-typological issue when nature-based solutions and circular economy are displayed in a project, opening with some theoretical issues highlighted through the case studies presented. Indeed, the transition of the project, reflecting the necessity of increased urban resilience, is still lacking a reflection upon the form construction of architecture.

2.0 PRACTICES OF REGENERATION

As already stated, concepts like resilience, mitigation, and adaptation, have gained a central role in the architectural debate, encouraging the construction of renewed narratives and practices, making interacting an ecological attitude with architecture and urban design (Bulkeley 2013).

Indeed, a growing number of sustainable projects is rising, trying to cope with climate change threads (Hawken 2017). In this framework, nature-based solutions and circular economy can be studied as main climate strategies, affecting the design practice.

At first, it is crucial to understand how these two strategies can make projects more resilient to climate emergency. These strategies, indeed, are based on the concept of making urban systems more resilient through adaptation and mitigation, so defining space adaptable to future known and unknown shocks.

Although the application of circular logic can increase the adaptive capacity of communities (Amenta & Qu 2020) by acting on the local metabolism and establishing best practices with socio-economic implications, nature-based solutions show a high predisposition to structure spaces with high resilient capacity, in a perspective of urban adaptation of grounds. Mainly when applied to open space, they show positive effects concerning the reduction of effects such as the heat island, improving the urban microclimate (Musco & Fregolent 2014), increasing urban biodiversity (Kabisch 2017) and contributing to increasing the draining soils. Furthermore, these solutions play a significant role in constructing spaces that resist risks such as floods or rainstorms, which are increasingly affecting urbanized areas due to climate change. Concerning this theme, it is possible to find numerous projects that have introduced nature-based solutions as tools of urban resilience in a preventive or subsequent manner to a cataclysmic event. The role of nature within the contemporary project that aims to reclaim the urban grounds is not – or at least not only – related to the issue of *nature in the city* that shows a simplification of the theme, rather a proper adaptive process, where nature is an instrument of “adaptation rather than domination, ‘living with’ rather than ‘living over’.” (Hagan 2015).

Next to the adaptation, we can frame the second typology of the output of these resilient tools: mitigation. This is mainly focused on the reduction of greenhouse gas emissions to reduce the pressure of climate change. As the counterpart of adaptation, nature-based solutions play a minor role. In fact, despite acting in the subtraction of CO_2 from the air, it would seem that the main contribution in the reduction of climate-altering gases is found in the application of circular logic within the building processes. Considering the urban and architectural scale, the application of circular processes allows a reduction in CO_2 emissions (Cheshire 2016), acting through specific design solutions such as the maximization of dry construction (that allows future reuse of the building components), the reuse and recycling of materials, as well as greater control of flows of resources (energy and materials).

Talking about architecture, the concept of reuse, also in the direction of retrofitting abandoned built assets, is central when dealing with circularity; indeed, the reduction of carbon emission is also connected with better use of what is already built in our cities and in the ability to give to new projects the capability of being reused in future. In fact, only in Europe:

> The construction and operation of buildings occupy almost 40% of the depletion of natural resources and 25% of global waste. Construction and demolition waste has become a major source of urban waste and usually accounts for 10–30% of the total waste landfilled. In the European Union (EU), construction waste occupies more than 30% of the total solid waste. (Guo & Huag 2019, 1).

If we consider what is stated, regeneration processes of the build environment could have a central role in shaping the design transition and making more resilient our cities.

An example could be seen in De Ceuvel by Space&Matter. This low-density project, settled on a polluted dock of the former harbor of Amsterdam, restores the abandoned area through a long-term reclamation of the land (Figure 1), designing new public spaces from the reuse of retrofitted houseboats. Here, the studio Space&Matter, together with the landscape architect firm DELVA, applied a long-term reclamation process started in 2014, using nature as a regeneration tool of the ground, specifically through the phytoremediation. This operation tries to regenerate and restore the natural capital of the neighborhood, acting on the removal of pollutants from the dock's ground to make it a renewed common space for the city. The ground reclamation was indeed the starting action that could enable the activities to come back to place. Together with the soil reclamation, Space&Matter decided to apply circular logics by sharing and reusing the city's physical assets. Indeed, the masterplan presets retrofitted houseboats connected through a raised element that configures a promenade that interacts with the neighborhood scale, producing new public spaces. The integration of circular logics displayed by the project aimed at using the local materials, consuming fewer resources and reducing the carbon footprint of the whole regeneration.

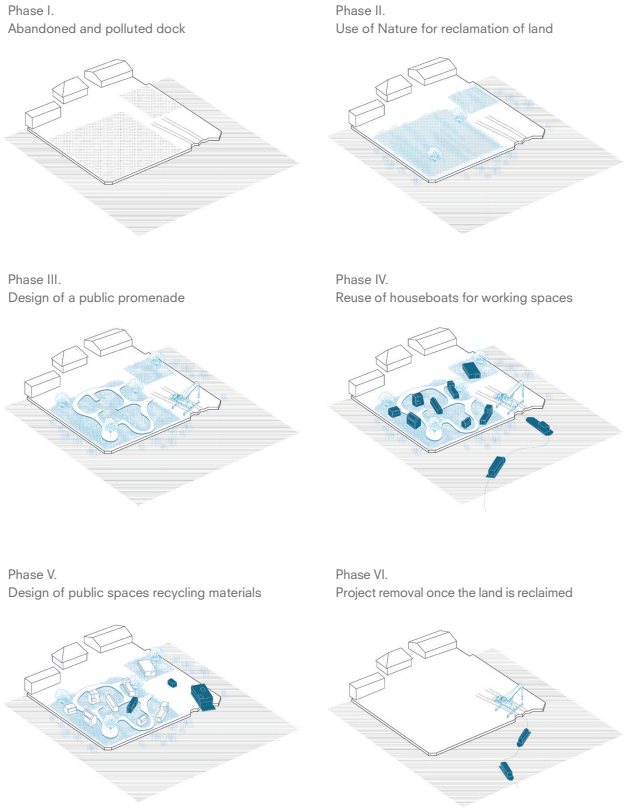

Figure 1: Schematic reinterpretation of various phases of the project, aimed to reclaim the land and reuse the physical asset of the city. Source: (Kevin Santus 2021)

On a similar logic, but at the urban level, works the project designed by ZUS, the Luchtsingel. In this intervention, the reuse of building rooftops and the re-naturalization of some parts of the city soils, generated a new urban ecosystem connected by an urban, dry constructed, wooden bridge. The project is settled in Rotterdam and aims to reconnect three city districts, implementing green public areas, to restore the neglected landscape close to the railway. Highly important in this urban regeneration process is the Luchtpark Hofbogen (Figure 2).

Figure 2: The rooftop of the former Hofplein Station is transformed in a urban field, where the urban and natural experience touches. Source: (Kevin Santus 2021)

This is a green area that regenerated the rooftop of the former Hofplein Station. Greenery and events revitalized the local community and gave a new ecological value to the area, implementing the city's green spaces. The project shows how the re-connection of public spaces, also reusing rooftops as artificial grounds for urban gardens, reactivates a neglected area and displays a complementary use of circularity, embedded in the reuse of the building assets and through the application of nature-based solutions.
A third project, Ilot de l'Arc de Triomphe, settled in the French city of Saintes, displayed the regeneration of a neglected fabric, which was subject to frequent floods events due to the morphology of the territory and to the absence of drainage soils. The regeneration operated a series of demolitions in the internal part of the neighborhood to give a new configuration of the urban fabric and define a new ground permeability, increasing the green areas within the neighborhood. Moreover, debris management from demolitions became an opportunity to reuse stone materials, setting up a circular, technical, and economical approach. The reuse of the debrides becomes an integral part of the regeneration process, giving the material for constructing new buildings and for the paths within the neighborhood. (Figure 3)

Figure 3: Ilot de l'Arc de Triomphe in Saintes: view from above of the general intervention (Source: BNR studio, 2021)

2.1. The complementarity as long-term project

Through these case studies, we could synthesize different approaches and scales. Nevertheless, what is presented is an evident complementarity of nature-based solutions and circular economy, able to blend adaptation and mitigation. These two tools are used in various ways but can represent a straightforward synthesis of the broader application of the two strategies that we could see on a more comprehensive design panorama, and that can be synthesized as an operational set at the urban and architectural scale (Figure 4).

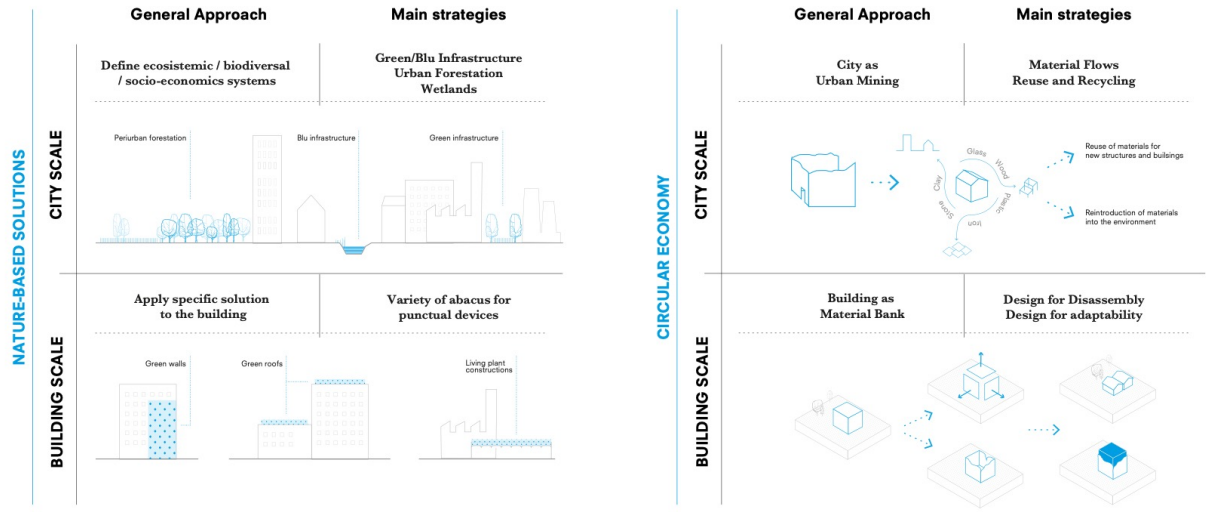

Figure 4: Schematic representation of the different approaches regarding the two design strategies. Source: (Kevin Santus 2021)

The transversal core of these regeneration projects is the idea of double action to deal with the climate emergency. Indeed, an interconnection between adaptation and mitigation is required to design urban space adapted to the new climate condition and, at the same time, contrasting the increasing climate change acceleration (Steffen et al. 2015). In this context, the result that could be foreseen is a fostering of long-term resilience. Therefore, the design action to decarbonize and adapt the urban environment configure an interscalar perspective that requires a complementarity of tools to structure an effective, resilient environment. Hence to curb the carbon emission and adapt the space, making it able to counteract climate hazards.

Nadja Kabish in her book *Nature-Based Solutions to Climate Change Adaptation in Urban Areas: Linkages between Science, Policy and Practice* (2017) reflected upon the essential concept of long-term resilience that:

> should not only be considered to be beneficial for current and immediate pressures from climate change but also be able to withstand potential future changes […], both environmental and socio-political changes. Long-term resilience thinking […] is of particular importance because challenges from climate change will further impact on urban society during the upcoming decades and require long-term adaptation thinking. p. 325.

Creating long-term resilience can produce a renewed stability capable of socio-economic repercussions, producing a sustainable transition within the new system we live in.

In this perspective, it is, therefore, necessary to think of strategies capable of working on a transversal level, in which a complementarity of tools is crucial to involve ecosystemic repercussions (Dawson 2019). The concept of resilience itself can then be achieved only through an action that implements mitigation processes to climate change, so related to the decarbonization of the built environment, and at the same time act to adapt our cities and territories, making them able to cope with climate hazards.

It is evident, that a concrete path toward a decarbonization of the built environment and a more resilient design approach should be addressed and verified both in a quantitative and qualitative way. Nevertheless, if on one hand we already have technical instrument to test the quantitative impacts of projects (e.g. LCA to assess the environmental impacts of all the stages of the life cycle), it is still to be investigated which could be a qualitative impacts of a resilient attitude of the project, in which nature-based solution and circular economy are not framed just as technical solution rather as potential tools to renovate the architectural language and environment.

3.0 A MORPHO-TYPOLOGICAL INQUIRY: AN OPEN QUESTION

Already in 2008, Dean Hawkes highlighted in his introduction to *The Environmental Imagination* how the quantitative and measurable impacts of climate strategies should not avoid “the poetic interpretation of the nature of the architectural environment”, in which the technical issue of climate can be part of the aesthetic of the design form and experience.

However, looking at projects that applied nature-based solutions and/or circular economy, makes clear a lack in the design, where nature-based solutions and circular economy are interpreted more as technical solution rather than an integral part of the project. Nevertheless, as stated by Kenneth Frempton in his text *Urbanization and Its Discontents: Megaform and Sustainability* (2011):

> There is no manifest reason why environmentally responsive and sustainable design should not be culturally stimulating and aesthetically expressive. Sustainability and its implicit aesthetics ought to be rightly regarded as a prime inspiration to enrich and deepen our emergent culture of architecture, rather than as some kind of restriction upon, or as something separate from, the fullness of its aesthetic and poetic potential. p. 108

Indeed, if climate change defines the new normality of contemporaneity, and the necessity to structure a design discourse related to resilience, adaptation and mitigation takes the core of this transition, it is still vague which could be the morpho-typological effects of this transition.

This urging question is strictly related to the role of architects when dealing with nature-based solution and circular economy. Indeed, in this changing design panorama, architects have to cope with adaptation and mitigation and, at the same time, acquire new expertise and know-how to cope with them.

Sang Lee, in his book *Aesthetics of Sustainable Architecture* points out that:

> In recent years, the so-called greening of architecture has produced a new class of experts and professionals. Sometimes they work in parallel with architects, while other times they perform in the background the work of effectively making a building design green after the architect’s work is done. Given these trends, it is important to ask whether sustainability is indeed an area that is best left to this new class of experts and professionals or if every architect should engage it as an integral part of the design process.

Define a long-term resilience, dealing with the complementarity of tools means to cope with the *form of resilience*, stating how to design new building and activate regeneration processes not as technical solution but as a design action. Indeed, architects are the figures that *give form to space*, and as designers, we should investigate how the changing condition of our practice is having relapses on the *form of architecture*.

Starting with an analysis of the presented projects, we could argue that circularity and nature-based solutions could imply a reconsideration of the conception and configuration of architecture, primarily referring to the ground and to the possible implication that reused materials could produce upon the spatial form. The ground, especially in urban areas, represents a crucial issue. Often depleted and polluted, it is an essential resource for a safe urban environment, host human activities, and counteract climate hazards. Because of these reseasons, regeneration projects usually act on it, applying nature-based as technical tools to restore the soils. Nevertheless, from a design perspective, modifying it is

not related to the number of plants we are planting. Indeed, operating with the ground means establishing the relationship between humans, building and open space. Thus, acting in a resilient perspective also means shaping our cities' renewed urban landscape, so working with the ground as a new typological element, connecting the single building with the city.
The materials implication, derived from a circular use of the resources, is open to a broad discussion. Indeed, examples such as De Ceuvel show how the reuse of the entire houseboat highly impacts the design form of the project. Starting from this specific case study, we could frame a more generic perspective, thinking of extending the concept to the reuse of entire buildings or fabrics. This new possibility for the project directly implies a typological permanence of the form, in which the regeneration processes must work upon a given shape/structure. At the same time, reuse of materials, as shown in Ilot de l'Arc de Triomphe, means to rethink the design process, that has to develop the project accurately relating materials and possible forms. In this sense, it is evident how reusing the building resources need to re-establish a strong relationship between material and form, representing a viable future for the practice, always present in the design culture, but nowadays more than needed.

4.0 CONCLUSION

Given the above, one of the main contribution of this work is to open the discussion upon design strategies that could be used together to design and regenerate the urban built environment and increase the resilience of metropolitan systems. Specifically, the usage of nature-based solutions envisions the possibility of reclaiming polluted soils to settle a renewed dialectic between the urban minerality and nature, tackling the adaptation of the urban space. At the same time, applying a circular perspective upon the project focuses the discussion on the project's resources, stressing the necessity to deal with what has been built in the previous decades and imposing new reflection regarding what we can do with what we already have. Together, these two strategies could establish a long-term project where the design action gains a clear role in the resilience definition.
Considering the unbalanced framework stated at the beginning of the article, it is crucial to rethink the design practice, implementing themes such as adaptation of the urban space, mitigation of the climate effects in a contextual path toward the decarbonization of cities.
Specifically, the projects shown in the article displayed how the regeneration could embody new ecological values, where the complementarity of nature and circularity exemplify the possibility for a spatial regeneration toward a new paradigm of urban ecology.
Rethinking the design action in a perspective of long-term resilience must be at the center of the architectural debate; nevertheless, it is still unclear how the presented strategies could impact the form of the project, generating a proper transition of the design practice.

ACKNOWLEDGEMENTS

The present article is part of an ongoing doctoral research by Kevin Santus, mentored by Professor Ilaria Valente (Supervisor) and Monica Lavagna (Co-Supervisor).
The author thanks Agence d'architecture Thibaud Babled Architectes Urbanistes for the image of the project Ilot de l'Arc de Triomphe, which remain their property.

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ENDNOTES

[1] More specifically, some notable documents to reference to are: the Strategic Research and Innovation Agenda (SRIA); The European Green Deal (European Commission 2019); COM 662, 2020 - A Renovation Wave for Europe - greening our buildings, creating jobs, improving lives (European Commission 2020); COM 98, 2020 - A new Circular Economy Action Plan. For a cleaner and more competitive Europe (European Commission 2020); COM 562, Stepping up Europe’s 2030 climate ambition. Investing in a climate-neutral future for the benefit of our people (European Commission 2020); the international guidelines “Roadmap to 2050 A Manual for Nations to Decarbonize by Mid-Century”.