Adaptation, Mitigation, and Smart Urban Metabolism towards the Ecological Transition

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ADAPTATION, MITIGATION, AND SMART URBAN METABOLISM TOWARDS THE ECOLOGICAL TRANSITION

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Abstract
The paper discusses the relationship between adaptation and mitigation in different dimensions (temporal, spatial, economic, political, psychological, social, and finally architectural), to highlight the existing or potential links. The perspective the one of the systemic and multi-scale design approach, capable of integrating its benefits. This strategy is based on widespread technological awareness, on smart metering, and on available IoT technologies, which can be integrated into buildings to govern the metabolism of matter and energy of the urban system. The essay relates disciplinary and specialized scientific approaches, making a synthesis focused on the theme of the relationship between global warming, ecological transition, enabling technologies, and perception of the risks associated with climate change in progress.

Keywords
adaptation, climate mitigation, smart urban metabolism, climate change, ecological transition

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The global crisis induced by the current pandemic event made the fall of trust in the consolidated relationship of domination of humanity over nature evident. The artificial world and the biosphere have manifested themselves in their profound interconnections, which even the advanced technological available means cannot govern. In fact, with the advent of the Anthropocene (Crutzen, 2002), the manipulations induced by the ongoing globalization have made processes governed by biology and chance increasingly accelerated. This acceleration coincides with the ongoing global warming induced by changes in the atmosphere, which are essentially linked to energy production based on fossil fuels and began at the end of the 18th century. To date, on a planetary level, it is estimated that urban areas contribute to at least 70% of the global emissions of carbon dioxide induced by the final use of energy (Seto et alii, 2014). With the growth of cities underway, this phenomenon is inevitably destined to intensify, given the confirmation of the current development models and exploitation of resources.

The urbanization process that involved cities in the twentieth century has intensified since the 1950s (Cui, 2018). In mid-2009, significant was the moment when, for the first time, the population living in cities exceeded that living in rural areas (United Nations, 2010). According to the projections contained in the Report of the Department of Economic and Social Affairs, in 2050 the population that will inhabit the planet will reach 9.7 billion people and 11 billion in 2100, and then will stabilize and, probably, begin to decrease (United Nations, 2019). They forecasted that almost 70% of the world population will live in cities in 2050 (Dijst et alii, 2018). With this scenario in mind, it becomes clear how structural urban planning for the sustainable development of cities (Conke and Ferreira, 2015) – which in many cases will increasingly assume the characteristics of 'megacities' (Kennedy et alii, 2015) – is already today a central issue in the economic and political agenda of all the countries involved, from here to the next decades, in the so-called 'ecological transition'. The concentration of the population in the cities, on the other hand, will make the need to adapt the man-made environment to the sudden and violent changes induced by the global increase in temperatures even more evident.

This scenario requires the architectural project, in all its components and at different scales, to become a synthesis of requests of a profoundly heterogeneous nature, which are correlated by complex interactions, not always tangible or quantifiable. In other words, the project can represent an intervention immediately accomplishable at the social and economic level of policies for long-term mitigation. Although they are still often distinct in national and supranational bodies' strategies, adaptation and mitigation – here intented in the specific meanings of environmental studies and policies – appear in this perspective as closely interrelated (IPCC, 2007a; Locatelli et alii, 2015). The objective of the contribution is to investigate, in a synthetic and non-exhaustive form, the relationship between adaptation and mitigation in their various dimensions (temporal, spatial, economic, political, psychological, social, and finally architectural),

to highlight existing or potential links, in the perspective of a systemic and multi-scalar design approach, capable of integrating the benefits deriving from a combinatorial process rather than disjoint or episodic one.

Adaptation 'versus' Mitigation | The analysis of the relationship between adaptation and mitigation is increasingly at the center of the academic debate (Lee, Yang and Blok, 2020): it has been defined as synergistic and conflictual (McEvoy, Lindley and Handley, 2006), dichotomous (Biesbroek, Swart and van der Knaap, 2008; Huang-Lachmann and Guenther, 2020). With the term 'adaptation', we mean the regulation in human or natural systems to the stimuli or their effects (actual or foreseen/foreseeable) coming from the climate change in progress, aiming to moderate its damage or exploit its benefits (IPCC, 2007a). On the other hand, through 'mitigation' policies, the action is taken directly on the causes of climate change; efforts in this regard aim to reduce the release of climate-changing gases into the atmosphere. Mitigation and adaptation have long been dichotomized at the academic and political levels. However, identifying the link between the two fields of action is complex (and sometimes not even evident in a given space-time dimension). Even when the mitigation produces the desired effects, a certain amount of specific adaptation actions would seem necessary, for example, at the micro-urban scale (McEvoy, Lindley and Handley, 2006).

Essentially, adapting means making the built environment resilient to events, in some ways, inevitable, while mitigating means preventing and, by extension, decarbonizing. In the built environment, this concretely translates into the improvement of buildings' energy efficiency, the reduction of demand peaks, the use of alternative resources for energy needs, the densification of buildings, and the implementation of greenery with a view to carbon sequestration. On the other hand, this excessive simplification runs the risk of posing the question in reductionist terms. For instance, on the one hand, the densification of buildings is desirable for the objectives of mitigation, both directly, since it contributes to improving the energy efficiency of buildings; and indirectly, by shortening distances in the city, promoting healthier lifestyles through less use of private means of transport and with the consequent reduction of the emission of climate-altering gases into the atmosphere. On the other hand, the densification is inevitably destined to subtract areas potentially usable for adaptation in the short term (floodable squares, gardens, green areas). Furthermore, many studies highlight the complex role of vegetation in improving the air quality of urban areas, highlighting the specificities linked to the climatic conditions of the sites, the availability of water, the ability of tree species to affect pollutants (Pollo et alii, 2020; Air Quality Expert Group, 2007).

From these considerations, and because the permanence in the atmosphere of the GHGs already emitted may be more than a century, as in the case of nitrous oxide N_2O – whose permanence in the atmosphere is equal to 114 years and whose concentration, compared to the pre-industrial levels, is now 16% higher (IPCC, 2007a; Treccani, 2007)

– it follows that the effects of climate mitigation are mostly visible in the medium-long term and on a national, if not global scale (Klein et alii, 2007), requiring short and long term economic commitments and global political agreements (Goklany, 2007). Actions for city adaptation require (almost exclusively) short-term investments, but their effectiveness is immediately noticeable. In this sense, adapting the built environment requires a greater economic effort, as large sums of money are needed immediately. On the other hand, even the deferral of expenses to support mitigation policies can cause an increase in the risk linked to the more and more frequent manifestations of the global rise in temperatures, with consequent repercussions also on the same costs in the long term (Kristl, Senior and Temeljotov Salaj, 2020). Besides, mitigation requires the participation of key players responsible for global greenhouse gas emissions, while adaptation occurs from the local to the national level (IPCC, 2007b). Therefore, mitigation and adaptation present significant additional differences concerning the stakeholders involved in managing short- and long-term risks (Table 1).

Adaptation 'feat.' Mitigation | If, on the one hand, mitigation and adaptation appear to affect irreconcilable spaces and times, on the other hand, this dichotomy is denied when both domains are classified as anthropogenic responses to sudden changes, also of human origin, that global warming entails. As such, the combined action of adaptation and mitigation appears to be the answer – the best possible one – to the ongoing climate crisis (Tunji-Olayeni et alii, 2019). It is therefore evident that the scale at which the combined action of adaptation and mitigation policies manifests completed forms of synergy is the micro-urban and local one, as capable of unifying the identification of the causes, actions, and aims of the policies (Grafakos et alii, 2018; McEvoy, Lindley and Handley, 2006). Despite this, few scientific contributions have analyzed the potential deriving from the combined action of adaptation and mitigation policies in the urban environment yet (Grafakos et alii, 2019). Among these, the study by Demuzere et alii (2014) identifies in the realization of green urban infrastructures the way in which the greatest benefits deriving from the combination of adaptation strategies and mitigation policies are manifested, while Grafakos et alii (2019) have identified three areas within which the project of the space, combining the two, obtains significant repercussions, at the local scale, for the management of the risks deriving from global warming.

Among these, in the field of urban greenery, the installation of green roofs is one of the most effective adaptation responses – as it can retain water during violent climatic phenomena, making it possible to decentralize water management (Grafakos et alii, 2019) – and mitigation at the same time (Geneletti and Zardo, 2016) – as an effective tool for the reduction of long-wave radiation that determines the urban thermal field, as well as for the improvement of air quality (Pollo et alii, 2020). Similarly, some green wall technologies are particularly effective for urban drainage (Lau and Mah, 2017), for lowering building surface temperatures – up to 24K (Bianco et alii,

Dimension	Mitigation	Adaptation	Adaptation 'feat.' Mitigation approach
Temporal	Long-term (future decades/centuries)	Immediate	Immediate and long-term
Spatial	From the national to global one	Almost local (micro-urban, urban, regional)	Local (micro-urban, urban, regional), national, global
Economic	Short and long-term investments, deferred over time	Mostly short-term investments	Short and long-term investments, deferred over time
Politic and collaborative	Involvement of the major GHG emitters (global level) and policymakers (national level) Conscious participation/collaboration of the populations is necessary Fields involved: energy production, transport, industry	Involvement of policymakers at local (urban, regional) and national level Fields involved: city project and territorial governance, coastal zone protection, risk and emergency management	Involvement of policymakers at local (urban) and national level Conscious participation/collaboration of the populations is necessary Fields involved: city planning and territorial governance, coastal zone protection, risk and emergency management
Psychological and social	Barriers related to: Limited cognition; Ideological beliefs; Comparison with others; Sunk costs; 'Discredence', radical scepticism; Perceived risks; Limited behaviours (see Gifford, 2011)		Need to adopt an intergenerational approach (Giovannini, 2016) Possibility to overcome some of the barriers thanks to: Perception of the immanence of risk and the effectiveness of actions undertaken to contrast it; Perception of the need to 'cure' the territory; Awareness of the influence of mitigation policies on future scenarios; Involvement of the inhabitants in solidarity actions beyond the emergency
Design	Urban densification Retrofitting Integration of renewable energy sources Blue infrastructure for the abatement of surface temperatures Green infrastructure for the extraction of carbon and the abatement of surface temperatures	Use of urban voids and green infrastructure for decentralized water and risk management Reconfiguration of the public space as the heart of the city (De Carlo, 2019)	Ecosystem services (NBS) Urban and peri-urban green areas (green roofs and walls, urban forestry, forestry) for the decentralization of water management and carbon withdrawal Urban and peri-urban agriculture (urban gardens, vertical farms) for the reduction of the carbon footprint of food Infrastructure scope (redesign of road sections) Balance between densification and public space/areas for adaptation

Tab. 1 | Characteristics of policies for mitigation, adaptation actions and combinatorial approach in the dimensions and fields identified.

2017) – and for air temperatures on the soil, although these effects are quantifiable in buildings higher than 10 meters (Ouldboukhitine, Belarbi and Sailor, 2014). According to the area's risk exposure, once the local balance between densification and urban voids for adaptation purposes has been identified, one of the most effective win-win practices is related to urban forestation. In fact, horizontal and vertical greenery makes the environment more resilient and, at the same time, mitigates the causes of climate change through the absorption of carbon and the cooling of air and surface temperatures. The preservation and enhancement of the urban and peri-urban natural capital are of strategic importance, intending to reduce the risks associated with global warming, contribute decisively to reducing pollution, improve air quality, and safeguard the biodiversity and waters (Tucci and Battisti, 2020).

In the field of urban agriculture – also intended as able to guarantee a vital circle based on the integration of work, innovation, production, energy, and resources (Negrello, 2017) – it allows for greater sequestration of carbon dioxide from the atmosphere and the reduction of the carbon footprint of the food produced – mitigation (Grafakos et alii, 2019); to allocate areas of fertile soil to manage the risk of sudden floods – adaptation. In the field of water management in the buildings, the energy retrofit of the built heritage allows a more virtuous use of water, as well as the reduction of the energy used for the operation of the distribution, pumping, and heating systems of the fluid (Grafakos et alii, 2019). Finally, we add that, in the field of urban mobility, the redesign of road sections would make it possible to allocate a greater surface area for urban green, with a view to the renaturalization of the surfaces and the decentralization of rainwater management mechanisms (adaptation), to allow a greater sequestration of carbon dioxide from the atmosphere and, indirectly, to prevent the emission of the share of GHG due to vehicular traffic, encouraging the use of soft mobility (mitigation).

Adaptation, Mitigation and Smart Urban Metabolism | The complexity of unambiguously defining the relationship between mitigation and adaptation strategies derives from the intrinsic articulation of the urban system, a field in which the two's combined action finds the widest possible range of action (Beery, 2019). In particular, the presence of 'core drivers' (Lee, Yang and Blok, 2020) of a political and economic nature determines the effectiveness of the mitigation policies, more evident in the medium-long term, and the need/possibility of combining these with local adaptation actions, whose effects are instead immediately recognizable. As highlighted by Dijst et alii (2018), the presence of these drivers is partly due to consumption patterns consolidated over time; the same drivers, in turn, can influence the future metabolism of cities.

The notion of system complexity is deeply inherent to the urban system. It is well represented in the holistic approach of Urban Metabolism, which looks at cities as a set of complex processes of transformation of matter and energy of the settlement sys-

tems in a space-time dimension. In the perspective that associates the concept of urban metabolism with that of 'organism' (Kennedy et alii, 2015), the latter exerts continuous pressure on the environment, depending on the number of its inhabitants, their consumption and lifestyles, its geographical position and the socio-economic and regulatory context within which it is located (Trane, 2020). In this sense, the urban system components are the 'drivers' of a political, economic, and, therefore, regulatory nature, which influences the manifestation of specific communities' needs by acting as potential 'facilitators' or 'constraints' (Dijst, 2013).

From the perspective of Urban Metabolism, activities of a heterogeneous nature occur through the presence of 'flows' (and 'stocks') of matter and energy. Therefore, drivers, needs, facilitators/constraints, activities, flows/stocks represent the constitutive elements of an urban system's political, social, economic, and regulatory framework. Together, these factors impact cities' institutional and governmental capacity to address the challenges related to mitigation and adaptation, although not necessarily to the same extent or extent (Lee, Yang and Blok, 2020). The drivers that determine the implementation – and the effectiveness – of adaptation actions and mitigation policies may be of a different nature (Burkeley et alii, 2011), considering that they are linked to the socio-cultural, economic (growth or impoverishment), demographic, and climatic sphere of the context considered. The attempt to bring this complex framework back into a set of regulations to contain and prevent the risks associated with climate change is the subject of increasing efforts from a regulatory point of view in many contexts (Lee, Yang and Blok, 2020).

As highlighted by the literature, mitigation policies require constant monitoring (Kristl, Senior and Temeljotov Salaj, 2020); the effectiveness of the adaptation is instead more difficult to monitor or quantify a priori (Huang-Lachmann and Guenther, 2020), as it is essentially linked to sporadic and unpredictable episodes, although increasingly frequent. The adoption of policies related to the mitigation of the causes of climate change, present in much greater numbers on the political and economic agenda of the main European cities than the initiatives aimed at containing the effects of global warming already underway (Lee, Yang and Blok, 2020), therefore introduces the issue of monitoring the effectiveness of these policies, made possible today thanks to the support of widespread and pervasive technologies. This seems essential to optimize the flows of matter and energy into (and out of) urban systems.

With this in mind, Urban Metabolism becomes 'smart' (Shahrokni, Lazarevic and Brandt, 2015), and it is intended as a necessary tool for monitoring flows (aimed at their reduction/optimization), energy and environmental performance of the built environment, together with the real effectiveness of mitigation policies. On the other hand, the introduction of digital technologies in the design and management processes of urban environments allows nowadays to significantly increase the knowledge of the spaces we live in (Giovanardi, Giusto and Pollo, 2020). Consequently, data is intended as a cognitive element for urban design and as widespread and accessible information

on elements, infrastructures, and places of the city itself (Losasso, 2015). In the field of architecture and technological design, the issues related to the management, ownership, and resolution of data appear nowadays as a real possibility to analyze the responses coming from the built environment to violent climatic stimuli. Besides, they are a way to measure the effectiveness of policies and actions undertaken to contain these environmental inputs. Finally, they are intended to be an opportunity for dealing with the emerging scenarios of the digitization of the construction sector, which contribute to determining logics of greater efficiency, linked to enabling technologies for the management of intangible components and information (Losasso, 2018).

The future paradigm of data as a constitutive element, albeit immaterial, of the built environment, capable of influencing its dynamics, processes, and way of use, has an intrinsic link with the social dimension of the architectural project for adaptation, as well as with the more extensive monitoring of the effectiveness of decarbonization measures, and therefore of mitigation.

Adaptation, Mitigation and psychological-social dimension | The pervasive diffusion of technologies for the aspects related to simulation, modelling, digital design, digital fabrication (Losasso, 2018), and the real-time monitoring of urban systems presupposes an integrated systemic and procedural approach (Losasso, 2018). The need to mitigate/adapt is closely related to the approaches of governance, knowledge, designing of physical aspects, but also intangible and behavioural values of relational aspects between individuals and the environment (Losasso, 2018). With this in mind, the environmental psychologist Robert Gifford (2011) underlined, in an eloquently titled contribution (The Dragons of Inaction), the psychological limits to full individual awareness of the risk deriving from climate change, as well as to the social acceptance of urgency of the adoption of policies related to climate mitigation and the adherence to 'pro-environmental' behaviours (Lacroix and Gifford, 2017).

For instance, the category of cognitive psychological limits includes barriers related to ignorance concerning the very existence of the problem or how to deal with it once greater awareness of these issues is achieved. Besides, it includes indifference to the need for the problem's solution, especially when it does not have repercussions that can be placed in a dimension close to one's perception, in spatial and time terms. It finally includes an excess of optimism or, on the contrary, a sense of powerlessness for dynamics that take place on a global level. Alongside this, the category of ideologies and individual views (political and religious ones) constitute another major limitation in this sense.

In particular, those linked to the excessive and mystifying trust in the 'self-regenerative' capacity of the natural ecosystem, or in a sort of false self-regulating equilibrium of current production systems (a kind of 'derivate' of the capitalist economic dimension in ecological key), often involve an overestimation of the ability of technology to make up for the lack of contribution that each individual must pro-

vide in behavioural terms from an environmental point of view. Finally, as regards the purely social dimension of 'non-action', complex dynamics come into play that concern the category of competitive confrontation with other individuals (which often leads to reduce or deny pro-environmental attitudes), as well as the tendency 'man to seek certain behavioural stability, avoiding the risks associated with the demolition of his own cognitive-relational comfort zone (among which the possibility of being derided following the adoption of a virtuous behavioural dimension from an environmental point of view), with evident repercussions also on the individual or collective psychological level.

Another interesting study links the theory of cultural cognition to the risks associated with climate change and psychological barriers previously introduced. Starting from an analysis of the literature, this research showed that there are no substantial links between adopting virtuous behavioural dynamics and age or gender differences. At the same time, higher education is more closely correlated with greater awareness of these issues (Lacroix and Gifford, 2017). The removal of structural barriers that do not allow the adoption of behavioural dynamics aimed at reducing GHG emissions into the atmosphere (such as, for example, widespread access to public transport) is, on the other hand, considered necessary but not sufficient for purposes of mitigation, made possible only through an effective change in individual behaviour.

The research, also conducted in an experimental form on a Canadian population sample, also highlighted how people who identify themselves in a 'community' dimension, which emphasizes the connection between the individual and the community to which they belong, perceive more the risks associated with the changes induced by the global rise in temperatures. Also, the aforementioned psychological barriers identified by Gifford seem to partially decrease in intensity to the tangible perception of the risk linked to climate change; in the same way, individual faith concerning the anthropogenic climate changes underway is closely related to the perception of the risks that derive from it (Safi, Smith and Liu, 2012).

With respect to these considerations, the well-known analysis by Alexander Langer (1994), according to which ecological conversion can only succeed if it appears socially desirable, underlines the interrelationships between individuals, society, technology and the environment, thus identifying the field of the urban and architectural design as a component of that 'social desirability', between adaptation and mitigation, risk reduction and improvement of the quality of the living environment. However, such recognition would require a major change in many sectors, making it difficult to be implemented, even if necessary. Only in a radically changed economic and social context – and, therefore, socially accepted – the action of the architectural project will will be possible and effective.

Adaptation can therefore be understood as implementation and prefiguration of the transformation and governance of space, capable of significantly affecting environmental quality through its ability to clearly contain the effects due to the occurrence of

discomfort phenomena in the urban environment. Thus, the perspective of mitigation becomes intrinsically systemic and no longer episodic, pursued through integrated interventions, which can be effectively measurable. In other words, the tangibility of the effectiveness of the adaptation of cities to the changes already underway (close to the user in spatial, economic, temporal, functional, and sensorial terms) could be configured as a 'flywheel' for the promotion of 'pro-environmental' behavioural dynamics and in terms of mitigating the causes of climate change finally.

The conscious contribution of the populations to achieve the decarbonization objectives set by national and/or global bodies could thus be more encouraged and shared. The effectiveness of adaptation at the local (micro-urban) level, also obtained through a conscious architectural project, would be maximized when this coincides with achieving the objectives related to mitigation (Tab. 1). However, it is clear that this perspective needs to be pursued radically and at a level that, in the first instance, is independent of the architectural project, but actually concerns the development of alternative economic models, territorial governance, policies for the ecological transition.

Conclusions | Although research in the field of climate change, as well as global political agreements (United Nations Framework on Climate Change Convention), have often understood the mitigation of the causes of climate change and adaptation to climate change as separate domains (Huang-Lachmann and Guenther, 2020), the complexity of managing the climate crisis, that cities will have to face in the coming decades, requires the synergistic combination of the two approaches. The effects deriving from the coexistence of adaptation and mitigation allow a more effective reduction of the flows of matter and energy in the urban environment. However, this result necessarily needs a monitoring phase that requires the collection and management of data, capable of highlighting, stimulating, and governing the patterns of consumption and exploitation of resources, connecting them with habits, lifestyles, social instances, technological and urban context.

On the other hand, as Enrico Giovannini (2016) recalls, what we cannot measure, we cannot even manage. Although it is a field clearly identified and described in scientific literature, actually, sustainability is challenging to measure (Giovannini, 2018). In other words, it is tough, both for citizens and for political decision-makers, to know and evaluate the consequences of choices, behaviours, and ways of producing on the urban environment. In this context, the development and refinement of the concepts and tools of Urban Metabolism can provide an important contribution to the ecological transition project. From this point of view, 'Smart' urban districts in a 'Smart' Environment describe a 'Smart' Urban Metabolism: the coexistence of ICT and 'stone cities' produces 'urban assets' which are constitutively different from those that history has given us (Faroldi, 2018).

Adaptation and mitigation together can allow decarbonization and orient the economy towards the change in the energy paradigm. To be clear, recent studies by Stanford

University (USA) have shown how the decarbonization of energy production is now technologically feasible on a planetary level (Jacobson et alii, 2017). However, effective climate neutrality can only be achieved through a radical transformation of current socio-technical structures, including energy and urban ones (EEA, 2019; Kristl, Senior and Temeljotov Salaj, 2020). Cities, in fact, constitute the place within which this transition must necessarily assert itself: « [...] There are no doubts cities play a decisive role both in the unsustainable aspects of current development and in the changes dictated by the transition to a green economy» (Tucci and Battisti, 2020, p. 1).

On the other hand, the energy transition requires a reversal of the current economic models since it is evident that there is a close connection between the practicability of mitigation strategies, which can no longer be postponed, and the transformation of the way of producing, therefore of living. In this sense, it is necessary to overcome the paradigm of growth at all costs. The key-point, emerging in the disputes between economics and health that fuel the public debate in this pandemic period, is represented by the inadequacy of an economic model which is now exclusively based on the quantitative growth of production and consumption. Without any social development, the changes in society are more apparent than real (Lefebvre, 2014). From this point of view, the general improvement of living and health conditions can become a key element with respect to the full effectiveness of mitigation strategies, as a promoter of a radically changed context, in which the 'pro-environmental' behavioural dynamics can find greater diffusion and consent. The energy and ecological transition, in fact, cannot fail to be based on an individual and general consensus, which overcomes the current condition of division between increasingly restricted economic and cultural elites and impoverished middle classes. Therefore, it appears unlikely that this process will start without overcoming the current concentration of wealth and political power (Milanovic, 2019).

Finally, the planetary scale of global warming processes requires a renewed vision of the relationships between nations, communities, and groups. As Bauman (2017) stated, a relationship between 'us' and 'them' takes note of the communion of interests that marks the Anthropocene era. The perspective through which the climate crisis must be faced can no longer be local (attachment to the small group) or global (progress that cancels diversity), but, as Bruno Latour (2018) would say, 'terrestrial', conscious the nature and extent of the ecological problem. Therefore, we can consider adaptation actions as a local expression of global mitigation strategies. Pursuing the objectives of mitigation requires, on the one hand, integration with specific adaptation actions, and on the other hand, the adoption of shared policies in a perspective of community development.

This development, put in crisis by the impact of global growth on the environment, brings into play widespread and diversified projects, including architects and urban planners' ones, which must find stimulus from transforming the economy towards decarbonization and closing the matter cycles. These are ambitious objectives,

not autonomously oriented by the economic system in its various contemporary declinations, from Western liberal capitalism to the Asian political one. In this context, the contribution of Smart Urban Metabolism to territorial governance and environmental design in the field of architecture (Losasso, 2018) can constitute an element of advancement towards this complex challenge. In this context, both the possibility of measuring and evaluating the effectiveness of adaptation and mitigation through the adoption of the concept of urban metabolism and the use of enabling technologies of Smart Urban Metabolism perimeter the field of action of the urban project. Therefore, it represents the most promising areas in the research development in the field of environmental design.

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References

Air Quality Expert Group (2007), *Air Quality and Climate Change – A UK Perspective*. [Online] Available at: uk-air.defra.gov.uk/library/assets/documents/reports/aqeg/fullreport.pdf [Accessed 10 November 2020].

Bauman, Z. (2017), *Retrotopia*, Laterza, Bari.

Beery, T (2019), "Exploring the role of outdoor recreation to contribute to urban climate resilience", in *Sustainability*, vol. 11, issue 22, article 6268, pp. 1-22. [Online] Available at: doi.org/10.3390/su11226268 [Accessed 20 November 2020].

Biesbroek, G. R., Swart, R. J. and van der Knaap, W. G. M. (2008), "The mitigation-adaptation dichotomy and the role of spatial planning", in *Habitat International*, vol. 33, issue 3, pp. 230-37. [Online] Available at: doi.org/10.1016/j.habitatint.2008.10.001 [Accessed 20 November 2020].

Conke, S. L. and Ferreira, T. L. (2015), "Urban metabolism – Measuring the city's contribution to sustainable development", in *Environmental Pollution*, vol. 202, pp. 146-152. [Online] Available at: doi.org/10.1016/j.envpol.2015.03.027 [Accessed 20 November 2020].

Crutzen, P. J. (2002), "The Anthropocene", in *Journal de Physique IV*, vol. 12, issue 10, pp. 1-5.

Cui, X. (2018), "How can cities support sustainability – A bibliometric analysis of urban metabolism", in *Ecological Indicators*, vol. 93, pp. 704-717. [Online] Available at: doi.org/10.1016/j.ecolind.2018.05.056 [Accessed 18 November 2020].

Demuzere, M., Orru, K., Heidrich, O., Olazabal, E., Geneletti, D., Orru, H., Bhave, A. G., Mittal, N., Feliu, E. and Faehnle, M. (2014), "Mitigating and adapting to climate change – Multi-functional and multi-scale assessment of green urban infrastructure", in *Journal of Environmental Management*, vol. 146, issue 15, pp. 107-115. [Online] Available at: doi.org/10.1016/j.jenvman.2014.07.025 [Accessed 5 November 2020].

Dijst, M. (2013), "Space-Time Integration in a Dynamic Urbanizing World – Current Status and Future Prospects in Geography and GIScience", in *Annals of the Association of American Geographers*, vol. 103, issue 5, pp. 1058-1061. [Online] Available at: researchgate.net/publication/263570108_Space-

Time_Integration_in_a_Dynamic_Urbanizing_World_Current_Status_and_Future_Prospects_in_Geography_and_GIScience_Space-Time_Integration_in_Geography_and_GIScience [Accessed 7 October 2020].

Dijst, M., Worrel, E., Böcker, L., Brunner, P., Davoudi, S., Geertman, S., Harmsen, R., Helbich, M., Holtslag, A. A. M., Kwan, M. P., Lenz, B., Lyons, G., Mokhtarian, P. L., Newman, P., Perrels, A., Ribeiro, A. P., Carreon, J. R., Thomson, G., Urge-Vorsatz, D. and Zeyringer, M. (2018), "Exploring urban metabolism – Towards an interdisciplinary perspective", in *Resources Conservation and Recycling*, vol. 132, pp. 190-203. [Online] Available at: doi.org/10.1016/j.resconrec.2017.09.014 [Accessed 4 November 2020].

EEA – European Environment Agency (2019), *Trends and projections in Europe 2019 – Tracking progress towards Europe's climate and energy targets*, EEA Report, n. 15/2019. [Online] Available at: eea.europa.eu/publications/trends-and-projections-in-europe-1 [Accessed 30 September 2020].

Faroldi, E. (2018), "Prologue", in *Techne | Journal of Technology for Architecture and Environment,* special issue 01, pp. 7-8. [Online] Available at: doi.org/10.13128/Techne-23561 [Accessed 21 October 2020].

Geneletti, D. and Zardo, L. (2016), "Ecosystem-based adaptation in cities – An analysis of European urban climate adaptation plans", in *Land Use Policy*, vol. 50, pp. 38-47. [Online] Available at: doi.org/10.1016/j.landusepol.2015.09.003 [Accessed 19 October 2020].

Gifford, R. (2011), "The Dragons of Inactions – Psychological Barriers that limit climate change mitigation and adaptation", in *American Psychologist*, vol. 66, issue 4, pp. 290-302. [Online] Available at: researchgate.net/publication/254734365_The_Dragons_of_Inaction_Psychological_Barriers_That_Limit_Climate_Change_Mitigation_and_Adaptation [Accessed 18 October 2020].

Giovanardi, M., Giusto, R. and Pollo, R. (2020), "Infrastrutture digitali nei componenti di involucro per la gestione degli edifici", in Perriccioli, M., Rigillo, M., Russo Ermolli, S. and Tucci, F. (eds), *Design in the Digital Age – Technology, Nature, Culture*, Maggioli Editore, Sant'Arcangelo di Romagna, pp. 238-242. [Online] Available at: sitda.net/8-avvisi-sitda/769-pubblicazione-volume-design-in-the-digital-age-technology-nature-culture.html [Accessed 14 December 2020].

Giovannini, E. (2018), *L'Utopia sostenibile*, Laterza, Bari.

Giovannini, E. (2016), *L'Agenda globale per lo sviluppo sostenibile – Una sfida straordinaria per il futuro del pianeta e dell'umanità*. [Online] Available at: fondazioneunipolis.org/Documents/Notizie/PAPER_GIOVANNINI.pdf [Accessed 11 September 2020].

Goklany, I. M. (2007), "Integrated strategies to reduce vulnerability and advance adaptation, mitigation, and sustainable development", in *Mitigation and Adaptation Strategies for Global Change*, vol. 12, issue 5, pp. 755-786. [Online] Available at: researchgate.net/publication/225469151_Integrated_strategies_to_reduce_vulnerability_and_advance_adaptation_mitigation_and_sustainable_development [Accessed 5 November 2020].

Grafakos, S., Pacteau, C., Delgado, M., Landauer, M., Lucon, O. and Driscoll, P. (2018), "Integration of climate mitigation and adaptation – Opportunities and challenges", in Rosenzweig, C., Solecki, W., Romero-Lankao, P., Mehrotra, S., Dhakal, S. and Ibrahim, S. A. (eds), *Climate change and cities – Second assessment report of the urban climate change research network*, Cambridge University Press, Cambridge, pp. 1-28.

Grafakos, S., Trigg, K., Landauer, M., Chelleri, L. and Dhakal, S. (2019), "Analytical framework to evaluate the level of integration of climate adaptation and mitigation in cities", in *Climatic Change*, vol. 154, pp. 87-106. [Online] Available at: doi.org/10.1007/s10584-019-02394-w [Accessed 6 November 2020].

IPCC (2007a), *Climate Change 2007 – Impacts, Adaptation and Vulnerability – Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge. [Online] Available at: ipcc.ch/site/assets/up-

loads/2018/03/ar4_wg2_full_report.pdf [Accessed 13 September 2020].

IPCC (2007b), *Climate Change 2007 – Mitigation of Climate Change – Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge. [Online] Available at: ipcc.ch/site/assets/uploads/2018/03/ar4_wg3_full_report-1.pdf [Accessed 25 November 2020].

Huang-Lachmann, J. T. and Guenther, E. (2020), "From Dichotomy to an Integrated Approach – Cities' Benefits of Integrating Climate Change Adaptation and Mitigation", in *Sustainability*, vol. 12, issue 18, article 7591, pp. 1-17. [Online] Available at: doi.org/10.3390/su12187591 [Accessed 5 September 2020].

Jacobson, M. Z., Delucchi, M., Bauer, Z., Goodman, S. C., Chapman, W., Cameron, M., Bozonnat, C., Chobadi, L., Clonts, H. A., Enevoldsen, P., Erwin J. H., Simone, N., Fobi, S. N., Owen, K. Goldstrom, O. K., Hennessy, Liu, J., Lo, J., Meyer, C. B., Morris, S. B., Moy, K. R., O'Neill, P. L., Petkov, I., Redfern, S., Schucker, R., Sontag, M. A., Wang, J., Weiner, E., and Yachanin, A. S. (2017), "100% Clean and Renewable Wind, Water, and Sunlight – All-Sector Energy Roadmaps for 139 Countries of the World", in *Joule*, vol. 1, issue 1, pp. 108-121. [Online] Available at: dx.doi.org/10.1016/j.joule.2017.07.005 [Accessed 5 October 2020].

Kennedy, C. A., Stewart, I., Facchini, A., Cersosimo, I., Mele, R., Chen, B., Uda, M., Kunsal, A., Chiu, A., Kim, K. G., Dubeux, C., Lebre La Rovere, E., Cunha, B., Princetl, S., Keirstead, J., Barles, S., Pusaka, S., Gunawan, J., Adegbile, M., Nazariha, M., Hoque, S., Marcotullio, P. J., Gonzalez Otran, F., Genena, T., Ibrahim, N., Farooqui, R., Cervantes, G. and Duran Sahin, A. (2015), "Energy and material flows of megacities", in *PNAS Proceedings of the National Academy of Sciences of the United States of America*, vol. 112, issue 19, pp. 5985-5990. [Online] Available at: doi.org/10.1073/pnas.1504315112 [Accessed 5 September 2020].

Klein, R. J. T., Eriksen, S. E. H., Naess, L. O., Hammill, A., Tanner, T. M., Robledo, C. and O'Brien, K. L. (2007), "Portfolio screening to support the mainstreaming of adaptation to climate change into development assistance", in *Climatic Change*, vol. 84, pp. 23-44. [Online] Available at: researchgate.net/publication/225411235 [Accessed 13 October 2020].

Kristl, Z., Senior, C. and Temeljotov Salaj, A. (2020), "Key challenges of climate change adaptation in the building sector", in *Urbani Izziv*, vol. 31, issue 1, pp. 101-111. [Online] Available at: jstor.org/stable/26928561 [Accessed 7 October 2020].

Lacroix, K. and Gifford, R. (2017), "Psychological barriers to energy conservation behavior: the role of worldviews and climate change risk perception", in *Environment and Behavior*, vol. 50, issue 7, pp. 749-780. [Online] Available at: web.uvic.ca/~esplab/sites/default/files/Lacroix.pdf [Accessed 20 November 2020].

Langer, A. (1994), "La conversione ecologica potrà affermarsi soltanto se apparirà socialmente desiderabile", in *cencicasalab*, 01/08/1994. [Online] Available at: cencicasalab.it/node/18 [Accessed 14 October 2020].

Latour, B. (2018), *Tracciare la rotta – Come orientarsi in politica*, Raffaello Cortina Editore, Milano.

Lau, J. T. and Mah, D. Y. S. (2017), "Green wall for retention of Stormwater", in *Science & Technology*, vol. 26, issue 1, pp. 283-298. [Online] Available at: ir.unimas.my/id/eprint/19550 [Accessed 6 October 2020].

Lee, T, Yang, H. and Blok, A. (2020), "Does mitigation shape adaptation? The urban climate mitigation adaptation nexus", in *Climate Policy*, vol. 20, issue 3, pp. 341-353. [Online] Available at: doi.org/10.1080/14693062.2020.1730152 [Accessed 6 October 2020].

Lefebvre, H. (2014), *Il diritto alla città*, Ombre Corte, Verona.

Locatelli, B., Pavagenau, C., Pramova, E. and Di Gregorio, M. (2015), "Integrating climate change mitigation and adaptation in agriculture and forestry – Opportunities and trade-offs", in

Wires Climate Change, vol. 6, issue 6, pp. 585-598. [Online] Available at: doi.org/10.1002/wcc.357 [Accessed 9 November 2020].

Losasso, M. (2018), "Contenuti disciplinari e competenze innovative per la formazione e la ricerca nell'area tecnologica | Educational contents and innovative competencies for training and research in technology industry", in *Agathón | International Journal of Architecture, Art and Design*, vol. 3, pp. 23-28. [Online] Available at: doi.org/10.19229/2464-9309/332018 [Accessed 19 November 2020].

Losasso, M. (2015), "Rigenerazione urbana – Prospettive di innovazione | Urban regeneration – Innovative perspectives", in *Techne | Journal of Technology for Architecture and Environment*, vol. 10, pp. 4-5. [Online] Available at: doi.org/10.13128/Techne-17492 [Accessed 6 October 2020].

McEvoy, D., Lindley S. and Handley, J. (2006), "Adaptation and mitigation in urban areas: synergies and conflicts", in *Municipal Engineer*, vol. 159, issue 4, pp. 184-191. [Online] Available at: doi.org/10.1680/muen.2006.159.4.185 [Accessed 6 October 2020].

Milanovic, B. (2019), *Capitalism – Alone – The future of the system that rules the world*, The Belknap Press of the Harvard University Press, Cambridge.

Negrello, M. (2017), "Architettura, cibo e agricoltura – Assaggi della città autosufficiente", in *ilgiornaledell'architettura.com*, 16/05/2017. [Online] Available at: ilgiornaledellarchitettura.com/web/2017/05/16/architettura-cibo-e-agricoltura-assaggi-della-citta-autosufficiente/ [Accessed 19 October 2020].

Ouldboukhitine, S., Belarbi, R. and Sailor, D. J. (2014), "Experimental and numerical investigation of urban street canyons to evaluate the impact of green roof inside and outside buildings", in *Applied Energy*, vol. 114, pp. 273-282. [Online] Available at: doi.org/10.1016/j.apenergy.2013.09.073 [Accessed 16 November 2020].

Pollo, R., Biolchini, E., Squillacioti, G. and Bono, R. (2020), "Designing the Healthy City – An Interdisciplinary Approach | Progettare la Città che Produce Salute – Un Approccio Interdisciplinare", in *Sustainable Mediterranean Construction*, vol. 12, pp. 150-155. [Online] Available at: sustainablemediterraneanconstruction.eu/SMC/The_Magazine_n.12_files/1223.pdf [Accessed 14 November 2020].

Safi, A. S., Smith, W. J. and Liu, Z. (2012), "Rural Nevada and climate change – Vulnerability, beliefs, and risk perception", in *Risk Analysis*, vol. 32, pp. 1041-1059. [Online] Available at: doi.org/10.1111/j.1539-6924.2012.01836.x [Accessed 14 November 2020].

Seto, K., Shobhakar, D., Anthony, B. et alii (2014), "Human Settlements, Infrastructure and Spatial Planning", in *Climate Change 2014: Mitigation of Climate Change – Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, pp. 923-1000. [Online] Available at: ipcc.ch/report/ar5/wg3/human-settlements-infrastructure-and-spatial-planning/ [Accessed 12 September 2020].

Shahrokni, H., Lazarevic, D. and Brandt, N. (2015), "Smart Urban Metabolism – Towards a Real-Time Understanding of the Energy and Material Flows of a City and Its Citizens", in *Journal of Urban Technology*, vol. 22, issue 1, pp. 65-86. [Online] Available at: researchgate.net/publication/275281721_Smart_Urban_Metabolism_Towards_a_Real-Time_Understanding_of_the_Energy_and_Material_Flows_of_a_City_and_Its_Citizens [Accessed 21 October 2020].

Trane, M. (2020), "Metodologie e strumenti per una valutazione dei flussi di materia e di energia alla scala micro-urbana", in Perriccioli, M., Rigillo, M., Russo Ermolli, S. and Tucci, F. (eds), *Design in the Digital Age – Technology, Nature, Culture*, Maggioli Editore, Sant'Arcangelo di Romagna, pp. 77-79. [Online] Available at: sitda.net/8-avvisi-sitda/769-pubblicazione-volume-design-in-the-digital-age-technology-nature-culture.html [Accessed 14 December 2020].

Treccani (2007), *Enciclopedia degli idrocarburi*, Istituto della Enciclopdia Italia. [Online] Available at: treccani.it/export/sites/default/Portale/sito/altre_aree/Tecnologia_e_Scienze_appli-

cate/enciclopedia/italiano_vol_3/idro_vol_3_ita.pdf [Accessed 14 November 2020].

Tucci, F. and Battisti, A. (2020), "Green Economy for Sustainable and Adaptive Architectures and Cities – Objectives, Guidelines, Measures, Actions", in *IOP Conference Series – Earth and Environmental Science*, vol. 503, pp. 1-8. [Online] Available at: doi.org/10.1088/1755-1315/503/1/012022 [Accessed 6 November 2020].

Tunji-Olayeni, P. F., Omuh, I. O, Afolabi, A. O., Ojelabi, R. A. and Eshofonie, E. E. (2019), "Climate change mitigation and adaptation strategies for construction activities within planetary boundaries: Limitations of developing countries", in *Journal of Physics, Conference Series*, vol. 1299, pp. 1-8. [Online] Available at: doi.org/10.1088/1742-6596/1299/1/012006 [Accessed 12 October 2020].

United Nations – Department of Economic and Social Affairs, Population Division (2019), *World Urbanization Prospects – The 2018 Revision,* ST/ESA/SER.A/420, United Nations, New York. [Online] Available at: population.un.org/wup/Publications/Files/WUP2018-Report.pdf [Accessed 10 September 2020].

United Nations – Department of Economic and Social Affairs, Population Division (2010), *World Urbanization Prospects – The 2009 Revision – Highlights*, ESA/P/WP/215, United Nations, New York. [Online] Available at: ipcc.ch/apps/njlite/ar5wg2/njlite_download2.php?id=10148 [Accessed 21 December 2020].