Sustainability and Resilience _
(In)Consistencies in Two Design Realms

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ABSTRACT **Sustainable design and design for resilience to climate change emerged independently from each other, but their acknowledged correlation gets an increasing importance. This chapter investigates interrelations between sustainable and resilient design realms by comparing their key postulates and analysing key objectives through the prism of mutual (in)consistencies. In this regard, the work presents both general observations and detailed considerations where specificity and complexity of relations between sustainable and resilient building design are found. Results demonstrate that sustainability and resilience display complementarity rather than inconsistency in relation to each other, which leads to the conclusion that their integration into an outreaching, systemic approach is highly possible. By integrating sustainability and resilience, a building advances from a socio-ecological, i.e. a socio-technical, to a socio-ecological-technical system.**

KEYWORDS environmental issues, climate change, design measure, comparison, integration

1 Introduction

Sustainable design has persisted as an interesting subject matter for researchers and academics over the past few decades. Understanding the complexity, abstract component, and intangible meaning of sustainable design (Kosanović & Folić, 2014) has been proven to be particularly challenging. To describe sustainable design as a tangible approach (Marjaba & Chidiac, 2016), many definitions referring to environmental (technical) sustainability have emerged, while social and economic dimensions are often omitted from consideration. Environmentally sustainable design allows exact understanding, thought, causal explanation, classification, measurement, quantification, standardisation, and optimisation. From the environmental standpoint, sustainable design is brought to a set of well-defined engineering measures and scientific methodology aiming to treat nature as an external pre-given entity to be saved or exploited, even though it should be studied and understood from different perspectives (Guy & Moore, 2005). As these pre-given environmental patterns have been progressively altered in the past, and continue to do so in the present, as a result of human ability to change surroundings and develop technologies (Intergovernmental Panel on Climate Change, 2014; Pawley, 1990), nature is consequently transforming into a system in which stability and balance are accompanied by uncertainty and unpredictability.

Climate change represents a clear evidence of natural shifts. To restore balance by mitigating climate change, sustainable building design provides a significant share of contribution through profound energy considerations. In spite of such measures being taken, climate change continues to reinforce existing and create new risks, and to impact upon people and ecosystems, posing a potential threat to sustainability (Aleksić, Kosanović, Tomanović, Grbić & Murgul, 2016; O'Brien et al., 2012). When affected, the built environment generates new environmental issues. Complex and transformative causal relations between environmental (sustainability-related) issues, climate change, and new environmental issues in the built environment therefore represent a closed loop (Fig. 1.1).

The approach to design for resilience to climate change has been developed independently of sustainable design. This is because of the most commonly accepted meaning of sustainable design, which makes reference to the utilisation of natural resources and to the consequent production of negative environmental impact. On the one hand, the two approaches offer opportunities for synergies and reciprocal benefits, while on the other hand, they potentially hinder individual validity and efficiency (Wilson & Piper, 2010; O'Brien et al., 2012). In technical terms, the achievement of sustainability does not necessarily mean the achievement of resilience. When resilience is not developed, sustainability is called into question. Clearly, contemporary building design should respond to requirements of both sustainability and resilience. This work investigates relations between the two design realms, compares their key postulates and analyses their key objectives through the prism of mutual (in)consistencies. The aim is to provide an insight into critical interrelations and to reveal possibilities for the integration of sustainable and resilient design realms into an outreaching, systemic approach.

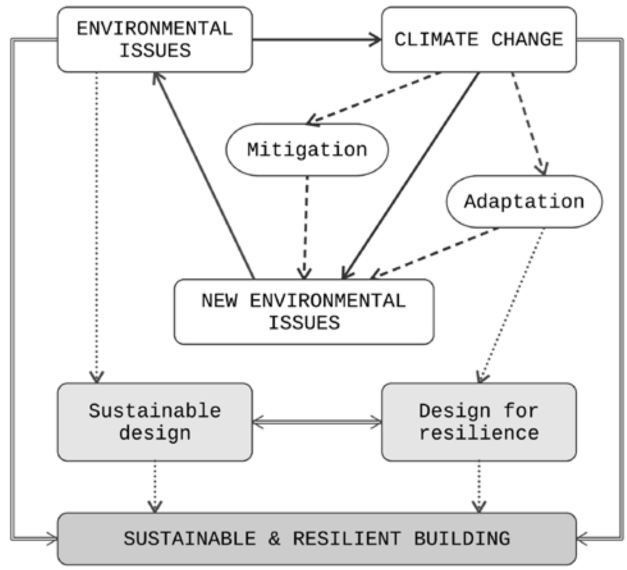

FIG. 1.1 Causal relations between environmental issues, climate change, and design responses

2 General Key (In)Consistencies

From an environmental perspective, sustainable design refers to resource efficiency and reduced pollution. Sustainable building tends to lower the negative environmental impact to the minimum possible level while also using favourable environmental conditions for that purpose. On the other hand, a resilient system is represented by resistance and recovery (Hodgson, McDonald & Hosken, 2015), i.e. the ability to adjust to an unlucky condition, event, or change (Marjaba & Chidiac, 2016) by absorbing disturbances and adapting to change without passing a threshold into a qualitatively different state (Sterner, 2010). Resilience is the potential of a system to return to a baseline after being disturbed (Zolli & Healy, 2013, p. 7), or to reconfigure itself continuously and fluidly to adapt to ever-changing circumstances, while continuing to fulfil its purpose (Zolli & Healy, 2013, p. 13). Fundamental differences between the notions of sustainable design and design for resilience are underpinned by divergent sets of key features of these two approaches (Table 2.1).

Building performance represents a pivotal matter of concern to both sustainability and resilience, but it is addressed from two different standpoints. While sustainable design aims to reduce the impact of a building on the environment throughout the life cycle, resilience refers to the scope of impact of the environment on a building in the use and maintenance phase. This factual difference is identified as a base from which the potential for integration of sustainability and resilience design realms could be explored.

SUSTAINABLE DESIGN	DESIGN FOR RESILIENCE
Building rather viewed as a socio-ecological system (Guy & Moore, 2005)	Building rather viewed as a socio-technical system
Universally accepted environmental postulates	Postulates laid out in specific climate change manifestations
Reduction of impact from a building towards the environment	Reduction of impact from the environment towards a building
Whole life cycle consideration	Use & maintenance phase consideration
Developed methodologies for evaluation (measurement) of achieved sustainability level	Estimation of future behaviour dependent on predicted climate and weather events; Undeveloped assessment methodology
Contribution to climate change mitigation	Contribution to climate change adaptation
Efficient utilisation of resources	Shift in resources demand, secure supply and reduced dependence on external distribution systems
Bioclimatic and regional design	Regional and transposed regional design
Sustainable site design	Site designed to provide protection from direct and indirect climate change impacts
Sustainable building materials, components, and structures	Climate change-resilient building materials, components, and structures
Recoverability of a building and its parts	Recoverability of building operability
Occupants productivity, health, and wellbeing	Occupants behaviour, safety, and health
Optimised combination of sustainability measures	Robust rather than optimal solutions (Bakker, 2015); Redundancy
Durability and flexibility	Adaptability and transformability

TABLE 2.1 Comparison of key issues of sustainable design and design for resilience

To define, describe, and predict the performance of a designed building, measurement and quantifications are needed from both sustainability and resilience perspectives. To measure the level of achieved sustainability, different life cycle assessment methodologies and assessment systems have been developed. On the other hand, methodologies for measuring the degree of resilience to (predicted) climate change manifestations are yet to be developed. To this end, Marjaba and Chidiac (2016, p. 116) argue that even sustainability systems still lack metrics that are repeatable, reproducible, and a true reflection of the building performance, and that the metrics for assessing the resiliency of buildings should be developed in tandem with sustainability metrics.

By definition, sustainable building aims to preserve natural resources. On the contrary, a building exposed to climate change manifestations displays a shift in resources demand, requiring secure supply and reduced dependence on external distribution systems. Nevertheless, the primary concerns in both approaches are water and energy.

While resilience refers to adaptation to climate change, sustainability targets climate change mitigation, although future climate change hazards may, at the present time, be indirectly addressed through measures for reduction of greenhouse gas emissions. As measures for climate change mitigation interact with measures for climate change adaptation, it is necessary to verify that these two sets are in synergy, and that they will not become contradictory and have negative consequences for each other in the future (Gupta & Gregg, 2012; Hallegatte, 2009; Wilson & Piper, 2010).

In addition, sustainable design tends to use (sustainable) materials in an efficient way and to preserve free land, while resilient design concurrently aims to provide protection from direct and indirect climate change impacts, inter alia through adequate site design. Although location characteristics and corresponding site design are crucial for both sustainability and resilience, these two approaches tackle different subjects that should be compared and re-examined in order to establish an integration path, identify synergies, and remove potential mutual intrusions (Table 2.2). In general, sustainable design aims to explore site limitations and potentials, while design for resilience primarily concerns risks to a building and threats to its occupants. As a result, integrated design for sustainability and resilience should consider all three key domains: threats, limitations, and potentials, respectively. Design that is adjusted to the wider spatial sustainability context and design that is in line with the wider spatial resilience framework – all round resilient design – together could be added to the 'positive fragment' approach (Aldallal, AlWaer & Bandyopadhyay, 2016).

SUSTAINABLE BUILDING SITE	RESILIENT BUILDING SITE
Climate and microclimate patterns	Changes in climate and microclimate patterns
Existence of urban heat island	Changes in extensiveness and intensity of urban heat island
Surface and relief characteristics, and water management	Surface drainage, flood, and erosion risks
Soil quality and composition	Susceptibility to erosion and the occurrence of landslides and soil subsidence
Distance from and spatial relation to existing pollution sources: traffic, industry, etc.	Identification of potential pollution sources in the case of extreme weather and climate events
Existence and protection of watercourses	Flood risk and water utilisation
Efficient water utilisation and water quality	Water availability
Renewable energy in situ for decreased emissions	Renewable energy in situ for decreased dependence on external sources
Urban infrastructural equipment	Infrastructural independence
Distance to public amenities	Distance and routes to safe locations and food supply grids
Distance to material suppliers to reduce transportation energy use	Distance to material suppliers for quick repair of the damage
Pavement characteristics: environmental quality of used materials, thermal behaviour, albedo, permeability	Pavement characteristics: thermal behaviour, albedo, water-resistance, resistance to extreme heat and cold, resistance to temperature shifts and solar (UV) radiation , permeability, provision of evacuation routes
Density	Porosity; Evacuation
Built structures in immediate surroundings	Hazards from built structures in immediate surroundings
Site reuse	Porosity

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Efficient site occupation; Ratio between green and materialised surfaces; Porosity	Porosity
Characteristics of materialised surfaces: environmental quality of applied materials, thermal behaviour , albedo, permeability	Thermal behaviour, albedo, water-resistance, resistance to extreme heat and cold, temperature shifts and solar radiation, permeability, provision of evacuation routes
Characteristics of green surfaces; Vegetation type, position and surface; Protected and endemic species	Vegetation type and resilience
Outdoor temperature regulation	Reduction of heat load

TABLE 2.2 Key subjects of sustainable vs. resilient site design

Sustainable design largely depends on local context and issues of relevance and urgency (United Nations Educational, Scientific and Cultural Organization, 2005). Similarly, resilient design is driven by both gradual climate shifts and extreme events at a narrowed spatial level, to the micro-context in which a building is positioned (Crawley, 2008; de Wilde & Coley, 2012; Fikfak, Kosanović, Konjar, Grom, & Zbašnik-Sengačnik, 2017). Both sustainability and resilience explore traditional solutions to climatic conditions, with the difference that resilience looks for design responses in spatial contexts in which forthcoming climate change manifestations have already been experienced.

The system of a sustainable building consists of mutually balanced subsystems and elements that together provide optimised performance, even when their isolated behaviour is not preferential (Kosanović, 2009). On the contrary, optimisation is not a priority for resilience (Bakker, 2015); rather, the system of a resilient building employs robustness and redundancy to counter uncertainty regarding future climate change manifestations. For climate proofing of new buildings and infrastructure within the robust approach, Hallegatte (2009) highlights synergy with mitigation, application of no-regret strategy, and reduced decision-time horizons. In such a way, the durability concept in a sustainable design framework could be impacted. Evidently, the discussion on resilience should be extended to include flexibility and durability considerations (Marjaba & Chidiac, 2016). On the positive side, reduced decision-time horizons make way for new technological solutions possibly applied within the lifetime of a designed building (Schouler, 2016).

Finally, both sustainability and resilience are future oriented, but led by different scenarios that evidently need unification. To carry out a profound discussion about the relationship between sustainability and resilience, responses to questions such as *Resilience to what?* (Carpenter, Walker, Anderies & Abel, 2001), i.e. *Resilience for where?* are needed. This work therefore presents general observations and deepened considerations where the specificity and complexity of relations between sustainable and resilient building design are found.

3 Building Materialisation and Design

Sustainable design promotes rational spatial organisation, decreased mass flows, and application of materials with satisfying environmental characteristics verified over the life cycle phases. Alternatively, the primary concern of isolated climate change responsive design is material resilience to water, fire, extreme heat or cold, solar radiation, pests, moulds, and other hazards directly or indirectly induced by weather and climate events. Through the systemic considerations, building design should aim to employ materials that are both environmentally friendly and climate resilient, in order to avoid more damage and higher life-cycle impacts due to lower hazard resistance (Matthews, Friedland, & Orooji, 2016). In this necessary integration process, expected climate change manifestations represent a starting point from which sustainability demands should be tackled. The amalgamation is especially challenging in the case of the application of alternative (mainly organic) sustainable building materials because of their resilience related characteristics, and the way in which they are embedded in building components and constructions.

Design that encompasses both sustainability and resilience takes into consideration the exposure of applied materials to weather and climate events. Clearly, climate sensitive materials should be positioned in non-exposed (protected) parts of a building. For example, in areas that are at risk of flood, water-resistant materials will be installed on lower floors of buildings, and flood-sensitive material types on the upper floors. In locations where extreme heat and heat waves are expected or have already been experienced, exposed materials should be resistant to the impact of high temperature, temperature shifts, and solar (ultraviolet) radiation. Regarding long- and medium term temperature increase, the consideration of the thermal properties of applied materials is significant to both sustainability and resilience. In terms of resilience to extreme weather events, building components, constructions, and their connections are given equal importance as materials. Emerged duality between sustainability-related durability, and resilience-related robustness and linked purposeful reduction of service life could possibly be resolved with decreased exposure, increased resistance, and the approaches to design for disassembly and circular design, where particular attention should be given to the optimisation of building envelope characteristics. It is expected that computer software and simulation will play a leading role in this intricate harmonisation process (Andrasek, 2012).

Sustainability and resilience to climate change shift conventional design logic and apply approach-specific design principles. The required integration aims to prevent occurrence of misbalance at the expense of either sustainability or resilience. For instance, to preserve valuable free land, especially in densely built areas, sustainable design promotes vertical development of a designed space, ultimately leading to the design of high-rise buildings (Yeang, 2000). From the standpoint of sole resilience, featured verticality could result in an increased vulnerability to climate change hazards. To this end, Mavrogianni, Wilkinson, Davis, Biddulph, and Oikonomou (2012, p. 123) explain that risk from overheating increases with the floor level, with top floors being warmest, followed by mid floor spaces. Besides temperature, changing wind patterns (such as peak loads or changing frequencies) could also manifest with stronger impact on tall buildings. Other design interventions that influence the achievement of both sustainability and resilience refer to occupant density control by design, determination of surface to volume ratio, definition of the building form, etc.

Flood-proof architecture stands out as the most particular design expression in the context of resilience. The methods for achieving flood resilience encompass the following: design to avoid floodwater (dry flood proofing); design to allow temporary flooding of the lower parts of the building (wet flood proofing); and design for adaptable contact with the water – floating and amphibious structures (Escarameia & Stone, 2013; Escarameia, Tagg, Walliman, Zevenbergen, & Anvarifar, 2012). In accordance with location conditions, level of the risk of floods, building purpose, and chosen flood-proofing method, the design further considers: existence of a basement space; introduction of stilts and mounds; positioning of building entrance, critical equipment, and communications and evacuation routes; drain-out measures; constructions, components and materials that are water-resistant, have good drying ability and low permeability, etc. The inclusion of sustainability-related postulates in design aims to prevent the adverse effects of one-sided choices. For example, the elevation of a building structure on pillars (above expected flood water level) decreases land occupation in conditions when there is no flood, but on the other hand increases the surface of the thermal envelope. Similarly, positioning buildings on artificial hills inevitably generates extensive earthworks; environmentally inadequate materials that get wet during the flood actuate new environmental impact through toxic emissions or leaching of hazardous substances, etc.

By definition, the resilience of a designed building refers to its resistance, recoverability, and adaptability. Although adaptation is traditionally linked to external conditions, adaptable design was developed prior to the resilience approach, as evidenced by various experimental examples of static and dynamic (kinetic) adaptable design solutions that emerged over the course of the 20th century. More recently, adaptable buildings are considered as a possible response to climate change. In this regard, Sterner (2010) distinguishes between 'passive resilience' with given ability to absorb shock and remain in one regime, and 'active resilience' which displays the ability of a system to change its form in order to adjust to changeable external conditions. According to Loonen, Trčka, Cóstola, and Hensen (2013), a static, fixed, or nonflexible system has no in-built capacity to respond to changing conditions. On the contrary, adaptive design (most commonly manifested in climate adaptive building shells) could reconcile robustness, flexibility and multi-ability, but the concept cannot yet be considered mature when regarded in terms of the many current challenges such as design and decision support, operational issues, and human aspects.

Time-scaling approach to resilience allows for the adjustment of architectural responses to temporal climate change variability and leaves space for the development of new adaptation technologies. Indeed, with the advancements in robotics and digital technology, novel dynamic sustainable and resilient models could be developed. To this end, Kohler (2012) proposed the 'aerial architecture' model where "structures can be designed to remain open-ended in order to be partially rearranged and dynamically adjusted over time... It is even possible that large buildings become displaceable 'mobile homes', fully or partially reusable in different locations and contexts, having second or third lives." (Kohler, 2012, p. 31)

4 Energy Issues

Buildings consume energy throughout all phases of their life cycle, but by far the greatest proportion of energy in buildings is used during the phase of use and maintenance (United Nations Environmental Programme, 2007). Increase of average air temperature and the occurrence of heat and/or cold waves raise additional requirements for comfort provision, potentially resulting in impaired operational energy balance and increased energy consumption (Gupta & Gregg, 2012; Wilson & Piper, 2010). According to results of the study that Crawley (2008) carried out by simulating the future impact of climate change in 25 locations around the world, the annual energy consumption in cold climates will be reduced by 10% or more. In tropical climates, total energy consumption in buildings will be increased, in some months even up to 20% compared to current trends. "Temperate, mid-latitude climates will see the largest change, but it will be a swapping from heating to cooling, including a significant reduction of 25% or more in heating energy and up to 15% increase in cooling energy" (Crawley, 2008, p. 91). In accordance with the obtained results, Crawley (2008) emphasised the importance of changing the way buildings are designed, constructed and operated, and, like Hallegatte (2009), indicated an unfavourable relationship between the future price of operational energy and the intensification of climate change. The adaptation to climate change should therefore avoid non-robust, high-energy consuming solutions, and instead aim for integration with mitigation measures and policies (Hallegate, 2009).

Reduced energy demand, energy efficiency, and the use of renewable energy sources account for essential sustainable design attributes, which simultaneously contribute to climate change mitigation by reducing greenhouse gases emissions. Under the impact of climate change, the energy-related quality of a sustainable building may be deteriorated by additional operational requirements, from a small (Crawley, 2008) to a significantly large (Wang, Chen & Ren, 2010) extent. For this reason, even net-zero energy buildings should be designed using weather data that take climate change into account (Robert & Kummert, 2012).

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In a climate-resilient design context, the primary energy requirement concerns the stability of supply during and after the occurrence of weather and climate events. A resilient building responds to this requirement by reducing dependence on external systems and by employing energy systems that are resistant, adaptable, and sufficiently robust to overcome future climate change uncertainty. In this regard, and because of expected future increase in energy consumption, the greatest potential for integrating sustainability and resilience principles lies in the utilisation of available renewable energy sources in situ, i.e. in the application of passive energy-related measures: natural ventilation and cooling, solar air and water heating, thermal mass, insulation, solar control, daylight, among others.

Passive design concept plays an important role in reducing energy consumption, achieving energy efficiency, and decreasing dependence on external energy sources, but the resilience demands could nonetheless change the traditional utilisation of passive systems. To this end, the main research question concerns the functioning of region-typical passive mechanisms in future climatic conditions. In principle, the performance of passive mechanisms applied to a building of certain type in the future, will depend on local climate change manifestation, as well as on their intensity and frequency. For instance, according to the predicted climatic temperature increase in Northern European, the application of passive solar design principles to maximise daylight and achieve solar heat gains will no longer be appropriate (ArupResearch+Development, 2004), and new passive solutions typical of areas in which corresponding climate patterns are experienced, and adequate responses provided, could be used through a *transposed regionalism* approach as a basis for design redevelopment. In some warmer regions, like the Mediterranean, passive mechanisms used to combat increasing heat are already in place, just as the social adaptation that is deeply rooted in regional culture. According to ArupResearch+Development (2004), cultures in Northern Europe will have to alter their lifestyle to accommodate to the emerging climate change. Analogously, transposed regionalism may refer not just to architecture, but also to the culture, meaning that the social dimension of resilience inevitably calls for a change. When the threshold of habits and the capacity of traditional passive systems are exceeded (and for that reason become non-responsive to climate change manifestations), developed adaptation to the emphasised climatic parameters can easily imply new energy demands, which is why the passive measures in today's design for the future should be maximised to the fullest (Gupta & Gregg, 2012).

Passive energy measures in the sustainable design framework refer to the provision of heat, cold, and natural ventilation and daylighting. These measures are embedded in the spatial organisation of a building and in its components. Some passive measures, like solar water heating or daylight provision at the greater depth of a building, require installation of special elements, or utilisation of specialised support equipment that, in the light of climate change, must be resilient. In resilience framework, the objectives of passive measures are translated to combating extreme high and low temperatures, and reducing dependence on external energy supply systems.

In terms of spatial organisation, sustainable design employs spatial zoning and introduces distinctive spatial elements such as atria. Spatial zoning enables the physical separation of building areas that are exposed to variable environmental loads or characterised by different indoor regimes, e.g. the separation of naturally ventilated from mechanically ventilated zones, or the separation of heated from non-heated areas. As such, zoning is applicable to different passive solar heating techniques, enhancing the independence from external heat supply systems. In a world that is getting warmer, the role of spatial zoning in isolating internally generated heat and preventing its transition to other building parts is gaining importance. Alternatively, an atrium nested in building layout aims to enhance natural ventilation and introduce natural light deeper into the building space. With regard to natural ventilation, Lomas and Ji (2009) emphasised that simple natural ventilation methods such as cross ventilation will not be sufficient to combat internal heat gains in the future. Accordingly, advanced ventilation strategies were identified.

The building envelope is the recipient of benevolent outdoor conditions, inter alia by acting as an integral part of passive energy mechanisms. Concurrently, the envelope provides protection from external negative impact. Although these attributes may be given different priorities in the two approaches, they are equally significant in relation to energy considerations and as such require balancing. In the sustainable design framework, envelope plays an important role in reducing operational energy consumption and maintaining indoor comfort. Envelope energy performance is determined by a number of parameters such as heat conductivity, absorption and accumulation, insulation, airtightness, glazing characteristics (size, positioning, U-value), window to wall ratio, reflectivity value, solar control, application of greening systems, and others. In a changing climate, the envelope should be resistant to the damages caused by extreme weather events and responsive to the likelihood of reduced heating and increased cooling energy demands (Kharseh & Altorkmany, 2012). This fact initiates the change in current envelope design practice and, having regard to the uncertainty of future climate change manifestations on the one hand and sustainability-related demands on the other, indicates time-scaled adaptable solutions by which incorrect climate change projections can be dealt with by treating non-structural adaptations as a method of nullifying the risk (Coley, Kershaw, & Eames, 2012). In this context, interest in switchable nanotech materials could be increased in future research (Pacheco-Torgal, 2014). Both heavyweight (high-mass) and lightweight (low-mass) constructions are common passive measures used to achieve thermal comfort in the indoor environment. Lightweight constructions respond quickly to temperature changes. For that reason, and when coupled with other passive measures, low-mass constructions are suitable for current warmer climates with low diurnal changes. Nonetheless, current lightweight systems design should also consider future temperature increase. While Kendrick, Odgen, Wang and Baiche (2012) suggest that it is possible to optimise lightweight buildings to provide thermal comfort using ventilation and shading, ArupResearch+Development (2004) demonstrated in their study that future temperature increase will result in near equalisation of daily peak temperature in a lightweight building and peak external air temperature, and that a heavyweight system performs better when exposed to same warming conditions. Evidently, the estimation of passive system performance in the future depends not only on climate change patterns and building characteristics, but also on what research method is used. In colder climates, climates with both cold and warm seasons, and climates with large diurnal changes, lightweight constructions require more energy for thermal comfort maintenance, wherefore the priority in current practice is given to heavyweight systems. When applied, building thermal mass requires appropriate exposition with regard to orientation, as well as the introduction of other passive measures necessary for its regulation and ventilation.

Besides (changing) microclimate characteristics, and the interaction of building systems with climatic parameters and weather events, the decision-making between lightweight and heavyweight constructions should be informed by their sustainability quality throughout the life cycle. In comparison with heavyweight passive systems, lightweight constructions in general have less embodied energy and are less material intensive, but often require more maintenance, are more susceptible to damages during the extreme weather events, and have a shorter service life which, on the one hand, enables a robust approach to resilience, but on the other hand raises new material demands and therefore requires additional circularity studies. A construction that contributes to reduced energy consumption and comfort maintenance in a passive way, now and in future, should therefore reflect a solution that is optimised for robustness, and energy and material issues.

The parameters of air, heat, and light comfort, due to their inter-connectedness, require simultaneous consideration in sustainable design. The interactions between comfort parameters, however, are compounded by the impact of the changing climate and the behaviour of occupants whose role in achieving even energy sustainability is still insufficiently predictable. In spite of all design efforts to meet sustainability and resilience demands at the same time, it remains possible that climate change will cause the comfort zone to be extended, especially at locations characterised by significant temperature increase and the existence of urban heat island phenomenon. The recognised doubt can be resolved only by creating a new balance between design interventions and through profound new studies on whether the passive systems will be able to reach even expanded comfort conditions (Ascione, Bianco, De Masi, Mauro, & Vanoli, 2017; Gupta & Gregg, 2012). To that end, it is important to initiate change in occupants' behavioural, physiological, and psychological responses (Levin, 2003), and to concurrently consider the application of robust solutions that show little variation with alternating occupant behaviour patterns (Buso, Fabi, Andersen & Corgnati, 2015).

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5 Discussion and Conclusions

According to the Intergovernmental Panel on Climate Change (2014), "comprehensive strategies in response to climate change that are consistent with sustainable development take into account the co-benefits, adverse side effects and risks that may arise from both adaptation and mitigation options" (p. 91). Hence, the notions of sustainability and resilience are built on different foundations. To this regard, Zolli (2012) observes, "Where sustainability aims to put the world back into balance, resilience looks for ways to manage in an imbalanced world".

The integration of sustainability and resilience design principles represents a challenging research topic. This work has demonstrated that sustainability and resilience display complementarity rather than inconsistencies in relation to each other, which leads to the conclusion that their integration is highly possible. Definitions and descriptions of such integration are yet to be developed. Among the few schemes proposed so far, for holistic understanding of sustainability and resilience, Sterner (2010) argues that resilience will be integrated into a holistic approach only when sustainable design is observed from the perspective of complex systems characterised by dynamics and nonlinear structure. In more general context, O'Brien at al. (2012, p. 444) introduce the term 'sustainable adaptation', referring to a process that addresses the underlying causes of vulnerability and poverty, including ecological fragility.

Sustainable and resilient buildings are not new architectural typology. Instead, they represent the essential quality of any building type. Until the principles of sustainability and resilience are fully merged with conventional architectural design, their character will be accentuated. At that point, the terminology used to describe the two approaches will become a part of regular designers' vocabulary. For the importance that sustainable and resilient approaches to design no doubtfully have, and the intricacies in current times (Roche, 2012), their incorporation into common design process and methodology is critical.

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