# Chapter 9
# The Resilience Principles of the Built Environment in Light of Climate Change and the Post-pandemic Era

**Osama Omar and Samer El Sayary**

**Abstract** Several challenges and emerging opportunities were already confronting cities at the time of the COVID-19 outbreak, including climate change, digital transformation, sustainable mobility, regenerating degraded areas, redefining public spaces, promoting social inclusion, and integrating the city. Nevertheless, the immediate pandemic crisis has had a significant impact on the lives of people worldwide. Human wellbeing is adversely impacted by cross-infection, both psychologically and physically. Therefore, private and public spaces for living, working, resting, and travelling have changed drastically. During this time of reopening buildings, neighbourhoods, cities, and countries, it is essential to continue to focus on flattening the curves for energy use and $CO_2$ emissions. The purpose of this chapter is to provide architects or designers with an understanding of the environmental and health issues associated with COVID-19, as well as the high risk of indoor airborne disease transmission. Due to the complexity of the problem and the need for interdisciplinary research, engineering controls, design strategies, and passive architecture techniques should be integrated. This will enable better indoor air quality. Post-coronavirus cities will be built on the foundation of many changes, from the construction materials to the mobility of the citizens. Because neighbourhoods play a crucial role in meeting the needs of their residents under the current pandemic restrictions, they are receiving increasing attention. An important finding in this chapter is the new perspectives for building a healthy environment by combining innovative techniques with passive features of architecture. Meanwhile, this perspective will allow the decision-makers to rethink how they perceive the built environment in light of climate change and the post-pandemic era. To achieve this vision, different disciplines will need to collaborate, and decision-makers will need to participate. The sequence and role of each

O. Omar (✉)
Associate Professor of Architecture, Department of Architecture and Interior Design, College of Engineering, University of Bahrain, Manama, Bahrain
e-mail: oomar@uob.edu.bh

S. El Sayary
Assistant Professor, Faculty of Architecture - Design and Built Environment, Beirut Arab University, Beirut, Lebanon

 
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player in society will change the entire image of the resilience of built environment across the whole world.

**Keywords** Resilience · Built environment · Climate change · Post-pandemic · Zero-Energy

## 1 Introduction

A common disciplinary purpose of public health and city planning is to improve health. According to the US Department of Commerce's Standard City Planning Enabling Act (SCPEA) of 1928 (Chang, 2020), the professional identity of city planning is defined as a guardian of "public interest" the purpose of public planning is to improve the "health, safety, and general welfare" of the people. A public health professional identifies, controls, and prevents illnesses. The physiological metaphors that are often used to describe parks and open spaces—the city's lungs—for example—indicate explicitly the relationship between public health and city planning. Physical planning aims to promote health and prevent occurrences of disease in a city by designing its layout in a manner that promotes health. Theoretical, conceptual, regulatory, and practical elements of urban and regional planning and design emerge from public health crises, such as pandemics, pollution caused by rapid industrialization, congestion caused by urbanization, and loss of green space. During the mid-nineteenth century and around the turn of the twentieth century, sanitary, housing, and social reforms were closely linked to modern city planning, movements that aimed to address issues such as inadequate sanitation, which was itself a pandemic response, and the lack of sunlight and air in crowded tenement housing and dilapidated slums (Banai, 2020).

As a result of the coronavirus pandemic, there has been at least a temporarily reconfigured city life—the relationships between work and residence, leisure, the use of public space, and the safety and security of both public and private transportation—and a promotion of the fundamental equity of access to resources. In a smart planning scenario, the socio-spatial facets of the coronavirus pandemic could not have been anticipated or illustrated this vividly, nor could zoning regulations and comprehensive plans have been applied proactively (Banai, 2013; Kelly, 2010). A better known and more durable pandemic, that of climate change, has a far wider range of tools than the aforementioned planning tool set. Coronavirus pandemics go hand—in—hand with climate change challenges, implying some practical strategies that are commensurate with their dimensions. As it turns out, pandemics make the urban system both more vulnerable and resilient, ironically encouraging people to focus on the durable concepts of urbanism (Banai, 2020).

The majority of people live, work, and play in densely populated environments, which increases their exposure to many pathogens. Airborne transmission is often investigated by infection control specialists as compared to other modes of transmission. Depending on the specific circumstances of exposure, infection can occur via all routes to varying degrees. All possible exposure pathways must be protected to ensure effective infection control. In addition to being a psychological stress factor, cross-infections are also a health issue, worsening human well-being and affecting the economy. To prevent COVID-19 infection, most countries have improved ventilation, quarantined, and socially distanced themselves from those with the disease (Amoatey et al., 2002; Li et al., 2007; Megahed & Ghoneim, 2020; Morawska et al., 2020; Nishiura et al., 2020; Shakil et al., 2020).

A high correlation was found between COVID-19 infection and air pollution, indicating that the combination of high ambient air pollution levels and the virus posed a risk to the population. There is evidence that virus transmission takes place indoors via airborne transmission, especially in poorly ventilated and crowded environments. There is an increased likelihood of infection in cities with poor air quality, particularly in regions with the lowest Air Quality Index. It seems that air quality has played a critical role in the COVID-19 outbreak (Barcelo, 2020; Conticini et al., 2020; Hassan et al., 2020; Lam, 2020; Setti et al., 2020; Van Doremalen et al., 2020).

The built environment poses a significant threat to human health, which is why it's critical to understand the potential dynamics of infection transmission. It is possible for COVID-19 to be transmitted both directly and indirectly as individuals move through the built environment. Airflow patterns, turbulence, and other sources of turbulence in the indoor environment can cause viral particles to be deposited directly on surfaces or suspended (Cirrincione et al., 2020; Dietz et al., 2020; Horve et al., 2020; Megahed & Ghoneim, 2020; Mohammad Hassan Shakil et al., 2020).

As a result of the bidirectional relationship between humans, insects, pets, and other occupants and their built environments, there is a concern for health. Microbiota shed by humans and tracked back from their everyday lives to built environments can also be re-acquired from their surroundings within built environments. Microorganisms in the built environment are affected by environmental factors. Microorganisms living in the indoor environment have been shown to die when exposed to sunlight (both UV light and visible light). In moist places such as bathrooms and sinks, biofilms can form on common surfaces, which can facilitate the spread of bacteria. Microorganisms survive and spread primarily in household environments. A high level of relative humidity, which increases the number of aerosolized microorganisms and spores, is caused by moisture from daily activities, such as cooking. Microorganisms shed at a different rate according to the indoor air temperature. Human skin squamous cells and other nutrients from humans, insects, pets, and other inhabitants of the built environment can be found on regular household items, such as chairs. Carpets provide microenvironments that can create pockets of high relative humidity. This can promote bacterial growth, prolong their survival, and make them easier to transfer from one person to another. By providing the ability to penetrate the indoor environment through windows, microorganisms from the outside are able to access the indoor environment, contributing to each building's unique microbial makeup. By ventilating through windows, you can reduce potential air contamination by allowing air to exchange. Microorganisms from the human, insect, pet, and other occupants' personal microbiomes are exchanged with those from the built environment, contributing to a two-way exchange (Horve et al., 2020; Mehdi Alidadi, 2022).

A wide range of social and spatial implications are examined by architects, planners, and built environment professionals in order to generate new patterns and configurations of use (Paital, 2020; Salama, 2020). Infectious disease epidemics, in relation to architectural and urban spaces, are not just about quarantine on the basis of immediate and precautionary measures, but also about design and planning issues and challenges across all types of buildings and urban spaces. as shown in Fig. 1. Despite serious consequences caused by COVID-19, individuals and collectives can review their priorities and choices. Our physical spaces have been redesigned as a response to infectious diseases in most architecture today. Increasing acceptance of distance learning, online shopping, and online entertainment may bring about a change in the design and planning process due to social distancing (Bourouiba, 2020; Chang, 2020).

The whole process and a brief mapping of the chapter methodology can be divided into three phases as described in Fig. 2. Phase 1, focuses on collecting data from various sources, such as Scoups (Elsevier), Springer link, Google Scholar, etc., collating a large sample of studies including papers, books, articles in recognized conference proceedings, and reports. Phase 2 organized the data through reading, filtering, categorizing and summarizing. Phase 3 extracts the information through inductive analysis and graph to arrive at the finding of this study.

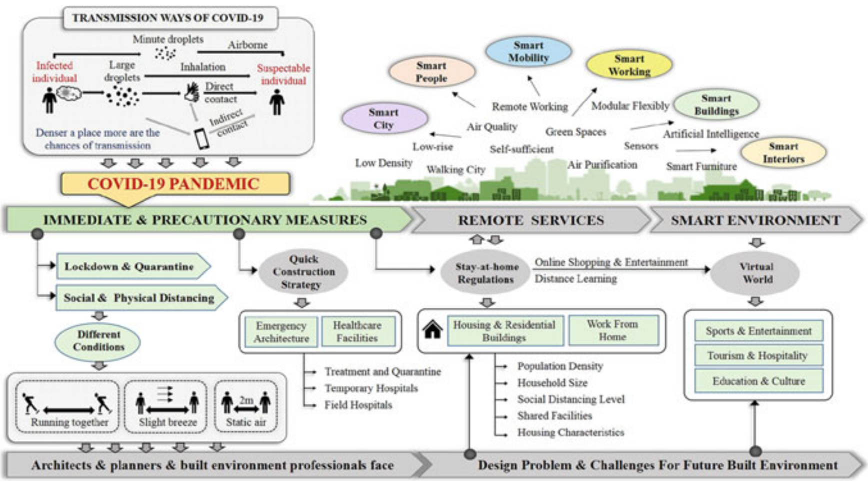


**Fig. 1** The relationship between social distancing and lockdown and the variables under investigation (Megahed & Ghoneim, 2020) (License Number: 5496541405220)

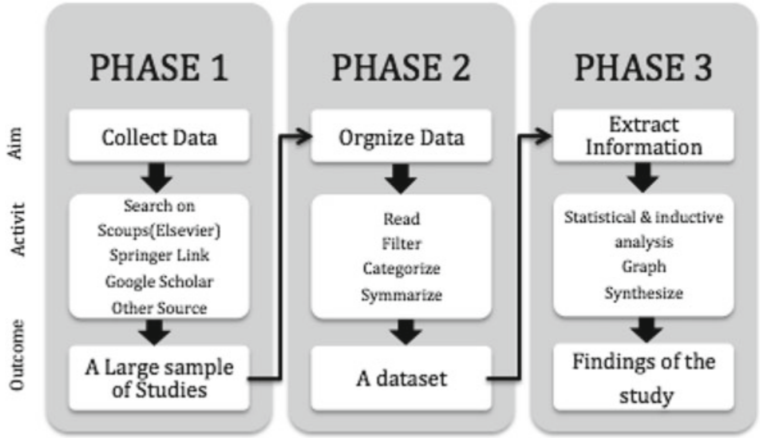


**Fig. 2** A brief mapping of the chapter methodology

## 2 Concept of Resilient Homes

According to findings from Akbari et al. (2021), residents cited quality air and natural light as the most important components of feeling satisfied during COVID-19 quarantine, followed by green landscapes and acoustics. In addition to these environmental factors, spaces and activities (especially the kitchen for the former and gardening for the latter) also play an important role. As a result, residents' satisfaction was strongly influenced by balcony features, green spaces, and outdoor activities. In addition, the study indicated that the availability of balconies, as well as their size, affects the mental health of residents, as homes without balconies have lower levels of mental health than houses with balconies, and homes with balconies with areas of at least five square metres improve their mental health. Furthermore, the study revealed that living in private homes has a beneficial impact on mental health compared to living in multi-storey apartment buildings (Akbari et al., 2021; Elrayies, 2022).

Zarrabi et al. (2020), conducted a study of the population's preferences regarding healthy home indicators in Tehran after epidemics. As well as natural light, air quality, visual and acoustic qualities, and open space, the design of the house and the work space were also found to be important factors. Mental well-being standards are more important than physical health standards, according to the same study. The psychosocial health of apartment occupants is impacted by indoor residential environment quality (IREQ) standards, according to another concurring study. The importance of incorporating mental health into green rating tools such as LEED, BREEAM and other systems was thus highlighted by Zarrabi et al. (2020). These qualitative standards should be mandatory or promoted in the systems categories since they often provide quantitative standards (Elrayies, 2022; Peters, 2020; Zarrabi et al., 2020).

The World Health Organization recommends reducing psychological pressure and improving home environments during home quarantines in order to make homes suitable for the population. By doing so, homes will be able to provide residents with comfort, privacy, and security while protecting their mental and physical health at the same time (Akbari et al., 2021). It has been shown that a healthy home requires adequate ventilation, indoor air quality (IAQ), natural light, sound insulation (especially in multi-story apartment buildings), and adequate air conditioning, heating, and humidity, in order to maintain thermal comfort (Navaratnam et al., 2022; Tokazhanov et al., 2020; Zarrabi et al., 2020), and views, such as (landscapes, and green spaces (Elsaid et al., 2021). Accordingly, health-oriented guidelines for pandemic-resilient homes have been proposed by (Elrayies, 2022), including the following:

- Indoor environmental quality (IEQ): air (natural ventilation, mechanical ventilation, filtration and purification), sunlight/daylight, natural views, domestic green spaces, and acoustics.
- Space: housing type, apartment size, layout type, home advanced technology (home automation, smart kitchen, finishing materials and touchless technologies), shard spaces (lobbies, stairs, elevators, laundry rooms, etc.)
- Household environmental resources management: energy, water, wastewater, solid waste.

Air, sunlight, daylight, plants, water, weather, and landscape are all included in the design framework for pandemic-resilient homes. Nature is incorporated into a biophilic design element. The study also indicates that pandemic-resilient homes can meet sustainability challenges, including the reduction of climate change, the improvement of biodiversity, the reduction and improvement of air pollution, the improvement of thermal comfort, the maximization of food production, and the improvement of the quality of human health. Pandemic-resilient design principles can be used to achieve sustainable architecture and biophilic designs.

The real challenges posed by COVID-19 remain unaddressed despite the short-term interventions that have been adopted in existing homes. The relocation of spaces and deployment of measures such as multi-purpose furniture, eco-friendly sanitary equipment, and smart energy management systems have not been successful despite the adoption of spatial reorganization and smart measures. HVAC systems should be upgraded to incorporate filters and purification techniques, plants should be added and available windows and balconies should be taken advantage of to let nature in. It remains a challenge, especially for housing in unfavourable conditions, to overcome the dilemmas of pre-pandemic homes, including the rapid spread of infectious diseases, self-inadequacy, and mental, psychological, and physical health problems as shown in Fig. 3. Providing sunlight, daylight and, ventilation, and bringing nature indoors are important components of both pandemic-resistant home design (urban spatial organization and site selection) and, architectural design (obtaining the optimal home size to achieve flexibility, privacy, and safety for each family member, determining the right balcony size, modifying the floor plan to accommodate different functions, providing storage space, etc.).

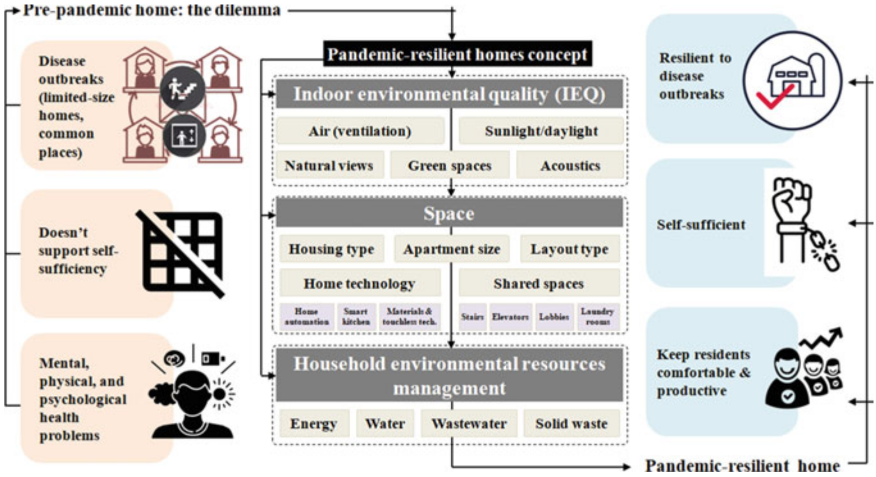


**Fig. 3** The concept of pandemic-resilient home (Elrayies, 2022)

In addition to interior design (open layouts allowing for adaptive configurations, modular, collapsible furniture, and multipurpose furniture), the home infrastructure should be equipped with the necessary information and communication technologies, which can create a new lifestyle that is egalitarian, flexible, and efficient both in the aftermath of and during a pandemic. As pandemic shocks become more frequent, homes must become more resilient in order to withstand them. Especially with the widespread adoption of teleworking, the most sought-after housing market in the new scene is that which provides size, luxury, and openness to nature, far away from dense urban centres. A pandemic may have highlighted urban shortcomings in general, but it has enabled a new focus on sustainability and accelerated urban planning. (Elrayies, 2022).

## 3 Climate-Resilient Strategies and Implications at the City Scale

A question is the beginning of everything! Is building efficiency sufficient to meet energy demands and use renewable energy sources to generate clean energy? The climate crisis has recently prompted the use of terms like "low-carbon city" and, "zero energy cities" which includes low-carbon and zero energy buildings. This claim is simply not true, and today buildings consume an enormous amount of energy and emit a tremendous amount of greenhouse gases (GHG), principally carbon dioxide ($CO_2$). However, a building constructed from locally sourced materials would use less energy and emit less carbon dioxide compared to one constructed using imported materials (Aboulnaga & Elsharkawy, 2022; El Sayary & Omar, 2017).

In the third quarter of 2021, the energy crisis, in combination with skyrocketing prices and shortages of supply, will forced city leaders and local governments to rethink and develop cities to meet climate neutrality, as well as the impact of COVID-19 and rapid population growth. As a result of the Russian-Ukrainian war in 2022, the crisis has becomes catastrophic not only because oil price have reached around 120.00 US$ since 6 June 2022, but also because global energy and food supplies have been severely disrupted and/or halted (IEA, 2022).

With the growing consciousness about environmental awareness and the depletion of resources in the construction industry, sustainability is becoming more and more important to any building in term of climate mitigation (Liu et al., 2022). Buildings across all types are embracing climate neutrality concepts to reduce and offset $CO_2$ emissions to a minimum. As long as buildings are not emitting greenhouse gases, they are considered to be "climate-neutral". One of the most important steps in pushing cities to create climate action plans is to encourage global initiatives that aim to enhance climate neutrality and achieve net-zero energy levels. For each city, an action plan identifies specifically what solutions and guidelines are required to mitigate climate change (Grafakos et al., 2002; Höhne et al., 2015).

The concept of climate neutrality refers to the total amount of emissions across embodied energy, operational energy and, industrial processes, as well as non-$CO_2$ greenhouse gas emissions (Liu et al., 2022). Climate change and the end of the fossil fuel era suggest a period of major, transformative change that will require a rethink of the most fundamental urban systems. Existing communities have a hard time negotiating rapid structural change. It has been found necessary to bring that process from vision to intervention, so that rapid transformation of an existing urban environment can be achieved, so as to develop a new method of urban design—eco-acupuncture—for working with local precincts in metropolitan cities as well as regional towns. Using eco-acupuncture, multiple small interventions in a precinct can shift community perceptions about what is possible, desirable, and permissible, providing a path to a low-carbon future as the community's expectations evolve. Climate change adaptation programmes will be essential no matter what the pace of global action is. A cohesive and mutually reinforcing policy is required for mitigation and adaptation (Ryan, 2013). All urban theories lead to small interventions on different level of urban fabric in order to make positive changes in the face of climate change, which relates to the sustainable development goals (SDGs), particularly SDG number 11 (sustainable cities and communities) as a new vision of future cities.

## 4 New Resilience Principles of the Built Environment

The proposed design framework was tested in several architectural competitions and awards judged by world—renowned experts, with judging based on principles of health and well being, and the indoor environmental design dealing with several climate zones to enhance the resiliency of the built environment in different geographical locations. As a response to post-pandemic architecture, a decentralized housing model is being developed to express the myriad and vast spectrum of cultural and environmental identities. A large vertical courtyard window acts as a semi-indoor/outdoor space expressing the intangible and hidden values of local societies in a way that is flexible and adaptable to any local culture and changing family needs as shown in Figs. 4 and 5.

A key element of the proposed design is also adaptability and flexibility, as most Middle Eastern families' needs change as time passes and more space is needed. This was solved by creating a multi-purpose space on the ground floor, with large storage units for storing furniture. As a result, the design was able to be used in a variety of ways.

It is premised that Egyptian rural areas suffer from problems with non-healthy housing problems and extreme levels of poverty, and this proposed design aims to address both of these urgent issues while emphasizing social values. The sustainability goals of the United Nations were also incorporated into the design criteria for building a cultural habitat with and for the community.

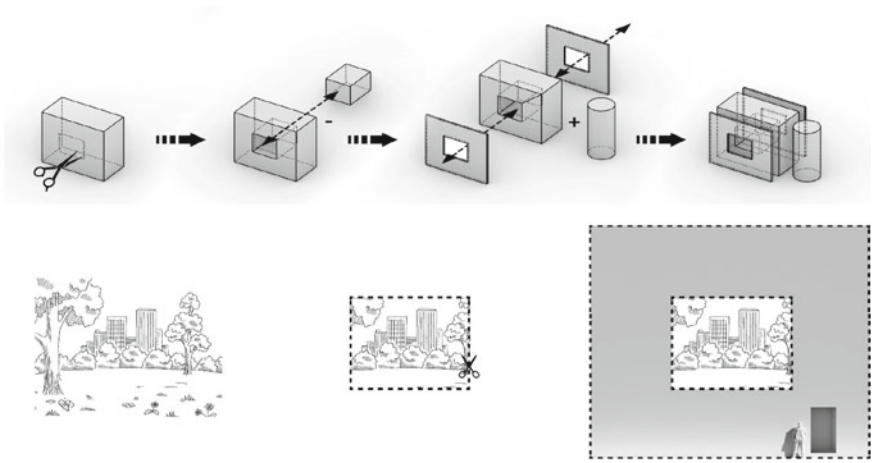

**Fig. 4** The concept of the vertical courtyard (design by author. Samer El Sayary)

**Fig. 5** Fenaa' project (design by author. Samer El Sayary)

A zero-energy house producing its own water and food was also studied as part of the environmental agenda to push the boundaries of sustainable living. The environmental approach relied on the latest technologies for energy self-sufficiency and renewable resources that were climate-appropriate (Omar, 2020; Samer El Sayary, 2021).

As part of the social approach, interviews and meetings with different social classes were conducted (a human-centered design approach; users were part of the design team) to come up with a design manifesto for an Egyptian contemporary house that reflects Egyptian family aspirations as well as contemporary life-styles, in a perfect square house framing Egyptian views.

Even though the concept design is flexible and adaptable, all calculations for the environment, energy modeling, and CFD simulations were performed in the Giza village quarter area. Using a multi-resource approach, the 50 design criteria combine various Egyptian micro-cultures in a harmony of "**a unity within diversity**" as shown in Figs. 4 and 5 (Table 1).

**Table 1** The 50 design criteria for the proposed design

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|---|---|
| A. Developing our legacy on scale of programmatic study | 1. Vertical courtyard with all benefits of traditional courtyard housing and as a healthy open-air container of all social activities in post-pandemic era<br>2. Reviving and developing the traditional house programme (Maqaad, court, wind-catchers and Majaz, etc.)<br>3. Flexible plan layout to respond to changing needs of the family<br>4. Free open plan with modularity concept (column free space) |
| B. Social core values | 5. Human centred design (considering users as members of the design team)<br>6. Promoting privacy in design as a core Egyptian cultural value<br>7. Adaptability to social design and life styles<br>8. Social sustainability for future generations<br>9. Minimalism life-style (living with less leaving you debt-free and with extra time to work on personal relationships)<br>10. Answering and fulfilling all functional requirements for places where they both live and work<br>11. Social equity by enabling access of users to clean water, fresh air and sunlight in their residential units<br>12. Achieving social sustainability by reviving ancient experiences and building practices<br>13. Building social connections of many residents in local communities as a by products of a sense of place and connection to the land or "home place" |
| C. Environmental agenda | 14. Passive cooling (two wind catchers)<br>15. Decreasing carbon foot print by producing its own energy needs<br>16. Increasing green vegetation rate in urban contexts<br>17. Using double walls and louvers to decrease sun radiation<br>18. Decreasing the urban heat island by designing a permeable urban mass for all wind breeze to flow through<br>19. Each new housing unit will be associated with planting a new tree inside the building |
| D. Clean water | 20. Natural water harnessing (fog nets and rainwater collections) |
| E. Economic sustainability | 21. Eliminating poverty through founding an economic activity inside the house |

(continued)

**Table 1** (continued)

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|---|---|
| F. Energy | 22. Net zero-energy building (calculations)<br>23. Considering shades and shadows as a principle of design<br>24. Using ambient daylight and indirect lights<br>25. Minimizing energy use by including low energy materials manufacture as well as considering using local building materials to decrease the need for one of the largest energy use - transport |
| G. Food production | 26. Pigeons tower (to ensure both an economic activity and food production)<br>27. Zero hunger by designing a Food production unit (hydroponics) |
| H. Urban regeneration | 28. Modular design (expanding both vertically and horizontally) with possibility to join more than one unit (vertically and horizontally)<br>29. Permeable built mass allowing wind breeze to flow through the urban context and decreasing urban heat island<br>30. Increasing vertical gardens in the city |
| I. Aesthetical values | 31. Adaptation to several Egyptian contexts (unity within diversity principles)<br>32. Promoting individuality by allowing expression of culture on white facades<br>33. Framing the natural scenery through the large central window<br>34. Biophilic design<br>35. The dynamic effect, where the white facades reflects the changing colours of the day and can absorb any lightscape at night<br>36. Creating sustainable, successful places that promote wellbeing and trigger innovation and creativity<br>37. Integrating local pop art in the architecture of the housing unit (night lightscape study) |
| J. Physical and psychological well being | 38. Reducing health risks from pollutants associated with building energy use<br>39. Designing a healthy environment that achieves the connection with natural phenomena like air and, sunlight, in addition to flora and fauna<br>40. Creating a stress-free built environment to eliminate pressure causing any social instability<br>41. Increasing the tolerance of the house users to long stays due to pandemic lockdowns by inserting elements of nature into the built environment |

(continued)

**Table 1** (continued)

| | |
|---|---|
| K. Flexibility and adaptability | 42. Designing column free interior spaces to be flexible enough to adapt to any everyday changing and growing family need<br>43. The possibility to construct the house in a place that has no infrastructure yet (total self-sufficiency and off-grid construction)<br>44. Designing a unit that could be assembled according to numerous urban scenarios based upon the urban density of the location by following the rules of modular design<br>45. Adapting easily to the local building material available on the site context without major changes in the design |
| L. Zero waste | 46. Elimination of the unnecessary use of resources by limiting the construction materials to only three materials in the whole building<br>47. A low-tech, durable and high quality design that need minimum maintenance by increasing the whole building cycle with the adaptability to use any local building materials for decreasing the depletion of natural resources<br>48. Design concept to maximize and re-use any one limited space via many other uses |
| M. Bio-diversity | 49. Protecting the local flora and fauna by replanting any tree that was removed from the site for construction processes inside the vertical courtyard<br>50. The large, open vertical courtyard window will help the free movement of the seasonal and permanent birds through the urban mass |

## 5 Conclusion

The availability of traditional energy sources, which could become a risk to existence, is one of today's most important global challenges. In 2020, many countries suffered a severe economic crisis, followed by stagnation and the collapse of the energy infrastructure as well as the whole sector due to pandemic lockdowns. Since necessity is the mother of creativity, the energy crisis served as the impetus for both private and public attempts to switch to free renewable energy sources. With the outbreak of the Ukrainian—Russian war in Europe, the issue began to spread to other geographical areas, resulting in even more severe global energy shortages. The need for energy is expanding as humanity's population has reached the eighth billion. New ideas in energy and the built environment have been developed as a result of this demand. Under the larger rubric of the earth habitation system, ideas like decentralized housing models that are grid independent, zero-energy housing, urban acupuncture in built environments to harness electrical energy from the user's movements, and democratizing energy to all social classes have been developed. This is a promising approach, but one that also needs a legal framework with which to organize it.

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