Rethinking buildings and cities towards climate resilience

Isaac A. Meir, Professor of Desert Architecture

Civil and Environmental Engineering Dept., Faculty of Engineering Sciences | Desert Architecture & Urban Planning, Jacob Blaustein Institutes for Desert Research, Ben-Gurion University of the Negev, Israel, sakis@bgu.ac.il | https://sakismeir.weebly.com/

Abstract

Recent decades have brought on the realization that tomorrow's world will be completely different from the one we know, in terms of pressures on the environment, as well as in terms of their consequences - climatic, economic and social. This paper attempts to assess planning and design challenges and propose feasible ways forward towards climate resilient buildings and cities. It stems from the realization that a business-as-usual scenario is not "yet another option", and that reluctance to deal with the issues at hand, among them climate exacerbation, energy needs and usage, unrestrained urbanization, and the waste of limited resources, endangers our survival chances. This stands in absolute contrast with the Brundtland Report, otherwise known as "Our Common Future", and the definition of sustainability[1] which so many are quoting without realizing its implications. What we should be aiming at is a drastic cut on all fronts – uncontrollable waste in the rich countries, uncontrollable birthrates in the developing countries. Furthermore, we need to learn to plan for the exacerbated unknowns around the corner.

1. Population Growth

The world is facing unprecedented challenges. It took the human race 200,000 years to reach a population of 1 billion; and then another 200 years - to surpass 7 billion. Significant world population growth – from 4.4 billion in 1980, to 7.4 in 2014, projected to reach 9.7 billion by 2050 - has generated growing pressure on natural resources. All need access to safe water, food and shelter. This has worried economists, researchers and politicians through time, from Malthus (1798)[2], through Ehrlich (1968)[3] to Tal (2016)[4]. These and many others have been warning that population is growing geometrically whereas food production is only growing arithmetically, and that the ensuing pressures will bring unprecedented sociopolitical upheavals, as well as potential environmental collapse.[5]

We and our growth are the product of revolutions – the agricultural and subsequent urbanization revolutions, the big discoveries, the Reformation, the French Revolution, the Industrial Revolution, the medical one, the information revolution. These have brought down buffers which had limited population growth.

2. Environmental Degradation

From hunting and gathering and fishing, to agricultural settlement, deforestation, colonization, mining and quarrying, changing the land and diverting the flow of rivers, building cities and megacities, fossil fuel burning, raising the CO_2 concentration in the atmosphere from less than 300 ppm in the year 1900 to over 415 ppm today, from plastics in the stomachs of wild animals to microplastics in the peptic

---

[1] Sustainable development is defined there as that which "meets the needs of the present without compromising the ability of future generations to meet their own needs".
UN (1987) *Report of the World Commission on Environment and Development: Our Common Future. An Overview by the World Commission on Environment and Development*. https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf (last accessed Jan.2022).

[2] Malthus T.R. (1798) *An Essay on the Principle of Population*. J. Johnson.

[3] Ehrlich P.R. (1968) *The Population Bomb*. Sierra Club/Ballantine Books.

[4] Tal A. (2016) *The Land Is Full: Addressing Overpopulation in Israel*. Yale University Press.

[5] Diamond J. (2005) *Collapse: How Societies Choose to Fail or Succeed*. Viking Press.

system of miniscule shrimp in the deepest ravines of the Pacific Ocean, in the atmosphere, the raindrops and through them in groundwater, we have been shaping our environment in every possible way, from the day we developed social skills and tools.

We have been able to settle every existing niche on the planet and develop faculties that allowed us to survive in the most adverse and extreme conditions [6], yet at an environmental price often too high, jeopardizing the mere existence of communities and civilizations [7,8].

A dubious result is that of climate change. The hottest years on record have occurred from the Industrial Revolution on, the ten hottest of them in the 21st century. Think about it for a moment – we're hardy in the first quarter of the 21st century, and have experienced the ten hottest years on record, since the 18th century when systematic measurements started. We try to adjust our indoor climate by using air conditioning, but this needs electricity, which we produce still largely by burning fossil fuels. If anyone tell you that natural gas is a green energy source, do remember it's a fossil fuel, too, the combustion of which produces CO_2, a greenhouse gas, contributing to global warming.

3. Urbanization

Throughout history cities have attracted people because of the occupational, economic, cultural and other possibilities and opportunities they offer. This has brought a growing urbanization process. Yet in recent decades this process has reached unprecedented magnitude. While in 1980 urbanites accounted for 39% of world population, by 2015 they had reached 54% and are projected to surpass 66% by 2050. [9] This has had two spatial impacts – urban sprawl covering agricultural land and pristine natural landscapes, and densification of cities causing overcrowding and high-rise development. Several publications [10,11] have praised the dense, deep, tall city as the greenest possible solution to urban sprawl, yet we have already found out that social problems, infrastructural issues, urban climate exacerbation, pollution, etc., characterize big urban centers, and that such problems become more extreme with city size.

4. Urban Heat Island

Heat is not easy to deal with, and urban heat is even worse. As people move into cities, the latter become denser, higher, more energy intensive per unit area. Urban temperatures tend to be significantly higher than those in the suburbs or in the open areas surrounding a city. This urban heat phenomenon, known as the **Urban Heat Island** (**UHI**), has been documented to reach temperature peaks 10-15°C higher than the agricultural or natural hinterlands. It is caused by the development of dense and deep "urban canyons", streets flanked by high-rise buildings, which trap incoming solar radiation while compromising the dissipation of heat back to the environment. [12,13] By being dense such urban spaces are also responsible for the emission of large quantities of heat, gasses, and particles into the public domain – due to transportation, HVAC, lighting, mechanical systems, etc.

---

[6] Fernandez-Armesto F. (2001) *Civilizations: Culture, Ambition, and the Transformation of Nature*. Free Press (reprint edition).
[7] Diamond J. (1997) *Guns, Germs, and Steel: The Fates of Human Societies*. W.W. Norton
[8] Diamond J. (2005) *Collapse*. Ibid.
[9] UN (2015) *World Urbanization Prospects: The 2014 Revision*. UN Dept. of Economic and Social Affairs, Population Division. ST/ESA/SER.A/366. United Nations, New York.
[10] Glaeser E. (2012) *Triumph of the City: How Our Greatest Invention Makes Us Richer, Smarter, Greener, Healthier, and Happier*. Penguin Books (reprint edition).
[11] Owen D. (2010) *Green Metropolis: Why Living Smaller, Living Closer, and Driving Less Are the Keys to Sustainability*. Riverhead Books (reprint edition).
[12] Oke T.R. (1987) *Boundary Layer Climates.* Methuen: London & New York.
[13] Arnfield A.J. (2003) Two decades of urban climate research: a review of turbulence, exchanges of energy and water, and the urban heat island. *International Journal of Climatology* 23: 1–26.

Thus, dense urban centers become unpleasant, unhealthy, congested areas, very often suffering of microclimatic peculiarities created by the tall dense buildings and their development. Tall buildings overshadow large neighboring areas depriving neighbors of winter sun; block winds or create local wind problems by driving the wind downwards or squeezing it in between adjacent tall buildings, demonstrating the actual implications of the Venturi effect, thus enhancing heat losses through building envelopes [14], but also creating unpleasant and often dangerous conditions on the pedestrian level. [15] Furthermore, since green urban spaces bring little or no profit to developers, the newly developed dense urban centers lack vegetation, thus also lacking exposed soil. These are vital components in the urban space helping to ameliorate temperatures by absorbing sunlight for photosynthesis, shading the ground, but also absorbing rain and runoff water which later evaporates, thus also moderating temperatures. [16]

Cities should, thus, be rethought with guidelines such as solar and wind rights protected from overshading, urban ventilation ensured so that the city can be cooled, and pollution flashed out. Greening the cities is another vital strategy. Green urban areas have been shown to have air temperature lower than the built-up spaces. [17,18] Green roofs and façades are additional UHI mitigation strategies, which also help enrich the urban habitats, and improve human wellbeing by providing something closer to a natural environment, mitigating thermal discomfort.

5. Thermal Discomfort

Extreme climatic events have caused significant numbers of deaths in excess of yearly averages. Such conditions have been documented to be on an exacerbation path which affects thermal discomfort, not least during summer nights, when cities reach minimum temperatures higher than the averages of the past. Such higher night temperatures have been documented to be accompanied by higher relative humidity and weaker wind speed [19]. Put together, these conditions create thermal discomfort for more nights per season, more hours per night. People who can afford to buy and operate HVAC will thus use it for many more hours than they might use it in the past, thus raising energy demand and usage, and subsequently impacting the environment with emissions. However, fuel poverty, a socio-economic condition discussed in the past in the context of cold countries and poor people unable to heat their homes, is becoming all the more prevalent in warmer countries in the context of cooling needs.

6. Runoff and Flooding

By covering the land with concrete, asphalt and other impermeable materials, the rain that falls on the city becomes surface runoff. Flattening the natural topography to facilitate the massive construction of tall buildings and highways has blocked what used to be natural rainwater reservoirs and drainage conduits. Coupling this with climatic exacerbation has been leading time and again to urban flooding which disrupts urbanites' daily lives, damages buildings and infrastructures, and often

---

[14] Saroglou S., I.A. Meir , T. Theodosiou, B. Givoni (2017) Towards energy efficient skyscrapers. *Energy and Buildings* 149:1-13.

[15] Saroglou T., H. Itzhak-Ben-Shalom, I.A. Meir (2021) Pedestrian thermal perception: Studies around two high-rise buildings in the Mediterranean climate. *Building Research and Information* RBRI 2007751.

[16] Santamouris M. (2020) Recent progress on urban overheating and heat island research. Integrated assessment of the energy, environmental vulnerability and health impact. Synergies with the global climate change. *Energy and Buildings* 207(2020): 109482.

[17] Wong, N.H., C.L. Tan, D.D. Kolokotsa *et al.* (2021) Greenery as a mitigation and adaptation strategy to urban heat. *Nature Reviews Earth Environment* 2, 166–181.

[18] Sugawara H. (2021) How much do urban green spaces cool cities at night? *IAUC Newsletter* 81:8-12.

[19] Potchter O., H. Itzhak Ben-Shalom (2013) Urban warming and global warming: Combined effect on thermal discomfort in the desert city of Beer Sheva, Israel. *Journal of Arid Environments* 98: 113-122.

causes deaths. Such were the cases during 2021-2022, both in summer and winter, with unprecedented damage and life losses in Europe[20], China[21], Oman[22] and elsewhere.

7. Socio-economic Issues, Gentrification

Whereas densification and high-rise construction are mostly driven by the prospect of financial profits, urban planning, public transportation and public services and amenities are rarely considered within the context of profit driven private initiatives. Thus, a dissonance is created between growing numbers of urbanites and providing for their needs, first and foremost public health, but also transportation, leisure etc. Those who can afford to pay for the new residential and office space in the high-rise buildings, and for the services, will opt to move to the city center – or far away from it to some trendy suburb. It has become a matter of prestige to work and/or live high up in a fully glazed tower guarded by a concierge service, supported by HVAC, differential speed elevators, built-in gyms and spas and swimming pools, as well as private parking, a vital necessity when working and/or living in the city center. This, of course, creates a very clear distinction between the haves and have-nots, and the tall building tenants tend to be rather homogeneous economically. It also affects the relations between individuals, groups, and the local authority. [23]

On the other hand, living high up may well create social isolation, especially for the elder and little children, the latter often experiencing a slow motoric development due to the lack of open space stimuli. Adding to the building height and proximity to main traffic arteries, the lack of appropriate people-oriented public open spaces in the vicinity makes the isolation all the more exacerbated. Which, of course, is very unfortunate, especially vis-à-vis the realizations of the recent Covid19 pandemic, which has clarified the need for proper ventilation and the fact that very often open spaces are safer and healthier than indoors. Which brings us to buildings and the energy they consume.

8. Energy and Buildings

Buildings consume up to 50% of the overall energy used in OECD countries – 40% for running the buildings, which we call Operational Energy (OE), used mainly for heating and cooling, lighting and ventilation, as well as all the appliances, systems and gadgets we keep plugged in 24/7; and another 10% very often overlooked, which we call Embodied Energy (EE) and which accounts for the energy used in the extraction of raw materials, their processing into building materials and components, their transportation to the construction site and the actual construction of the building, and finally the demolition, reuse and recycling of the building and its components and materials. This, though, is not the full story, and we come back to contemporary architectural practices and tall buildings. For some strange reason, contemporary architecture has adopted glass as the main façade material. Fully glazed buildings depend on continuous energy input to keep them reasonably comfortable despite the greenhouse effect which is an obvious outcome of the glazed façade. When such detailing occurs in tall buildings, these become very demanding energy users, not least because of their internal heat sources, and because the climate in which the different levels are located changes with altitude. [24]

9. What's to Be Done? Some Potential Solutions

Are there appropriate solutions to these challenges and, if yes, what are they?

---

[20] https://www.efas.eu/en/news/widespread-european-flooding-july-2021 (last accessed Jan.2022).

[21] https://www.whatsonweibo.com/zhengzhou-stand-strong-devastating-henan-floods-send-shockwaves-on-social-media/ (last accessed Jan.2022).

[22] https://floodlist.com/asia/oman-iran-cyclone-shaheen-october-2021 (last accessed Jan.2022).

[23] Garfunkel D. (2017) High-rise residential condominiums and the transformation of private property governance. *UBC Law Review* 50(4): 891-934.

[24] Saroglou S., I.A. Meir , T. Theodosiou, B. Givoni (2017). Ibid.

Buildings should be designed with human comfort in mind – thermal, visual, acoustic, psychological, as well as Indoor Environment Quality (IEQ). This calls for planning practices which ensure **solar rights** (the right of each building to be exposed to the low winter sun) and **wind rights** (ensuring summer night breezes ventilation). Night ventilation can also contribute much to **structural cooling**. Appropriate spacing is, thus, necessary, which will allow to deal with ventilation of the urban space, but also with the creation of **green open spaces** in the city. These can serve as surface runoff containment systems, minimizing flooding problems, promoting aquifer replenishment, serving as space for leisure. The concept of "**sponge cities**" has been put forth as one of the possible practices, providing for inter and intra urban runoff channeling and containment. [25]

Building envelopes need to be rethought so that they provide thermal comfort while minimizing energy needs. **Thermal insulation** as well as **thermal mass** are imperative and need to be designed and sized appropriately in each location relative to the **local climate**. This, of course, calls for a very responsible reevaluation of the curtain wall façade practice. Whereas **Double Skin Façades** (**DSF**) provide solutions to a better control of heating and cooling loads, their cost should be assessed on a **Life Cycle Energy Analysis** (**LCEA**) basis, to evaluate if their benefits over the lifetime of a building are equal or close to their costs. What is obvious, though, is that they enlarge the built-up space and envelope size, imposing additional costs on the construction and taxation budget of buildings. Obviously, glass should be sparingly used only where eye contact with the outdoors and solar penetration are needed. New materials, e.g., **Low-E glazing** and **cool materials and coatings** can improve the thermal behavior of buildings and cities, but must be assessed by LCEA or an **environmental cost-benefit analysis**. Technologies and practices such as **green façades** and **green roofs** need to be assessed on the basis of LCEA, which will take into account not only their benefits for the individual building on which they are applied, but rather for the city as a whole, its microclimate, air quality and ecosystems. [26] Building materials need to be rethought. Concrete, the most ubiquitous construction material worldwide, is energy intensive in the production of cement, its main component. For each ton of cement produced about one ton of CO_2 is emitted in the atmosphere. Similarly, many of the more widely used insulation materials (e.g., expanded and extruded polystyrene – EPS and XPS) are oil based, energy intensive products. Alternative building materials are being developed constantly based on natural materials, many of them using vegetative waste (e.g., hempcrete), thus having a negative embodied carbon balance due to carbon sequestration. [27,28] A different way of minimizing the Embodied Energy in building materials is that of relating to cities as the quarries and mines of building materials coming from the demolition of older buildings. [29]

Recent years have seen a shift towards **Zero Energy Buildings** (**ZEB**) and **Communities** (**ZEC**), and different countries are already enforcing relevant policies (e.g., the European **EPBD**) [30] not only for the construction of new buildings, but also for the **retrofit** of existing ones. Such policies and practices imply that buildings and communities are designed so that they provide their users' needs while conserving energy and producing electricity from **Renewable Energy Sources** (**RES**). The expectation

---

[25] https://wle.cgiar.org/thrive/2018/02/07/fighting-floods-sponge-cities (last accessed Jan.2022).

[26] Gabay H., I.A. Meir, M. Schwartz, E. Werzberger (2014) Cost-benefit analysis of green buildings: An Israeli office buildings case study. *Energy and Buildings* 76: 558-564.

[27] Haik R., G. Bar-Nes, A. Peled, I.A. Meir (2020) Sustainable lime hemp concrete (LHC): Alternative unfired binders as lime replacement. *Construction and Building Materials* 241(2020) 117981.

[28] Haik R., A. Peled, I. A. Meir (2021) Thermal performance of a lime hemp concrete (LHC) building with alternative binders: a comparison with conventional building materials. *Building Research and Information* 49:7, 763-776.

[29] Peled Y., T. Fishman (2021) Estimation and mapping of the material stocks of buildings of Europe: a novel night-time lights-based approach. *Resources, Conservation and Recycling* 169: 105509.

[30] EU (2010) Directive 2010/31/EU of the European Parliament and the Council on the Energy Performance of Buildings (recast). https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A32010L0031 (last accessed Jan.2022).

is that RES incorporated in buildings and communities will provide much more electricity to the grid than their consumption, thus becoming positive players in the energy market. Integrating green technologies can often turn economically marginal ones into positive through synergies, if appropriately designed in advance. [31,32]

This, though, is not enough. As climatic exacerbation causes power shortages and instantaneous peak needs, **smart grids** become vital, to ensure power availability to risk groups (elderly, sick, babies) and facilities (hospitals, elderly hostels, emergency evacuation centers, etc.) during extreme weather events. The summer of 2003 was a landmark in this respect. In France alone, during the month of August alone, more than 15,000 people died in excess of the yearly average for that month. They were elderly, isolated in small apartments on the upper stories of old buildings. This massive event was attributed to a "combination of […] social, architectonic and cultural factors". [33] That summer was considered the hottest on record back then, and anthropogenic contribution to the extremes was identified and even quantified, [34] yet since then we have experienced even more extreme conditions.

These very lines are written after an exceptionally hot summer that broke heat records, was marked by catastrophic fires from Canada to Australia, hurricanes and tornadoes, followed by unprecedented rainstorms and floods across the globe. Yet this summer was followed by an exceptionally cold and snowy winter in the eastern Mediterranean and elsewhere. All these occur alongside desertification which brings the deserts into what used to be temperate and fertile areas, but now suffer from drought and all-the-more frequent dust and sandstorms, which raise morbidity and mortality hundreds and thousands of kilometers away from the deserts themselves. [35],[36] Such events, which are becoming more common and extreme, make it imperative to rethink what is **manageable growth** and **sustainable development**, what are the **limits of growth** and how we can try to **ensure our survivability** in what is becoming a less human-friendly environment.

Whoever thinks these are alarmist histrionics need just look at the data of the past 50 years and the graphs and rethink their responsibility towards their children and grandchildren.

Thus, the way we design our buildings and cities for the future cannot be based on what we know from the past, but rather aim at the unknowns of the future. Hard to do, but it seems to be the only way towards survivability and climate resilient communities.

---

[31] Meir, I.A. (2013) Constraints to assets, waste to resources: integrating green technologies in a novel pilot project for drylands. *International Journal of Sustainable Energy* 34(3-4): 154-165.

[32] Meir I.A. (2015) Green technologies in planning and design vis-à-vis climatic uncertainty. *Encyclopedia of Energy Engineering and Technology* (2nd Edition). Taylor & Francis. pp.796-803.

[33] Svoboda M. (2015) New analysis of '03 fatal Paris heat wave. *Science*, August 27, 2015. Yale Climate Connections.

[34] Schär C., G. Jendritzky (2004) Hot news from summer 2003. *Nature* 432: 559-560.

[35] Goudarzi G., S.M. Daryanoosh, H. Godini, P.K. Hopke, P. Sicard, A. De Marco, H.D. Rad, A. Harbizadeh, F. Jahedi, M.J. Mohammadi, J. Savari, S. Sadeghi, Z. Kaabi, Y. Omidi Khaniabadi, Y. (2017) Health risk assessment of exposure to the Middle-Eastern dust storms in the Iranian megacity of Kermanshah. *Public Health* 148: 109-116.

[36] Chen Y.S., P.C. Sheen, E.R. Chen, Y.K. Liu, T.N. Wu, C.Y. Yang (2004) Effects of Asian dust storm events on daily mortality in Taipei, Taiwan. *Environmental Research* 95 (2): 151–155.