Innovative Renewable Energy
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Ali Sayigh *Editor*

Towards Net Zero Carbon Emissions in the Building Industry

Springer

Innovative Renewable Energy

Series Editor

Ali Sayigh, World Renewable Energy Congress, Brighton, UK

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World Renewable Energy Congress
Brighton, UK

ISSN 2522-8927 ISSN 2522-8935 (electronic)
Innovative Renewable Energy
ISBN 978-3-031-15217-7 ISBN 978-3-031-15218-4 (eBook)
https://doi.org/10.1007/978-3-031-15218-4

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

What is Net Zero? What does it really mean? It means that the sum of emissions by fossil fuels are balanced out by a reduction in their production and natural absorption by the oceans and land. There are multiple ways that industry, transport, and agriculture can achieve this reduction with the ultimate aim of leading to Net Zero. Of course, this is now a matter of utmost urgency, and as Helen Pirot of Fridays for Future, Berlin, has said, “it requires a drastic change from the ‘we will do what we can’ mentality to ‘we will do what is necessary right now’.” In Germany, for instance, Robert Habeck, German Minister for the Economy and Climate Protection has said that there needs to be a radical overhaul of planning and building processes in Germany and advocates a threefold increase in the speed at which CO_2 emissions are reduced. However, it is not just Germany that needs to make these changes – every country must make them.

This book shows the contribution that the building industry can and must make to achieve Net Zero. Twenty contributors from 15 countries focus on building design strategy; choice of materials and the encouragement of the use of local materials with a low carbon footprint; the use of renewable energy; energy conservation; use of greenery and appropriate aesthetics; building size and scale; building suitability for given climate; building functionality and comfort; the recycling of building materials; and adoption of appropriate green policies. No matter how small the individual reduction, each one counts towards the overall CO_2 reduction.

Brighton, UK — Ali Sayigh

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Carolina Ganem-Karlen, Gustavo Javier Barea-Paci, and Soledad Elisa Andreoni-Trentacoste

Introduction: Net Zero in the Building Industry: Why Aren't We There Yet?

Net zero is intrinsically a scientific concept. It is just a number, begging the question, 'net zero what?' For CO_2, the answer emerged in the late 2000s from understanding what it would take to halt the increase in global average surface temperature due to CO_2 emissions. If the objective is to keep the rise in global average temperatures within certain limits, physics implies that there is a finite budget of carbon dioxide that is allowed into the atmosphere, alongside other greenhouse gases. Beyond this budget, any further release must be balanced by removal into sinks [1].

The acceptable temperature rise is a societal choice but one informed by climate science. Under the Paris Agreement, 197 countries have agreed to limit global warming to well below 2 °C and make efforts to limit it to 1.5 °C. Meeting the 1.5 °C goal with 50% probability translates into a remaining carbon budget of 400–800 $GtCO_2$. Staying within this carbon budget requires CO_2 emissions to peak before 2030 and fall to net zero by around 2050 [2].

To limit climate change to 1.5 °C, global carbon emissions from energy supply and demand need to be reduced, and any remaining carbon emissions may need to be offset to prevent further warming. Carbon neutrality in the building industry can be achieved by lowering energy consumption with energy efficiency measures in the entire life cycle of a building and, at the same time, by generating energy from renewable sources to cover the baseline energy demand.

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A. Sayigh (ed.), *Towards Net Zero Carbon Emissions in the Building Industry*, Innovative Renewable Energy, https://doi.org/10.1007/978-3-031-15218-4_10

Notably, net zero energy systems imply using less energy overall and/or using energy more efficiently, as well as shifting to low-carbon energy sources (e.g. renewable energy) and technologies (e.g. solar water heater/electric vehicle). It is therefore crucial to find the sweet spot in the balance between lowering energy use on the one side and generating renewable energy on the other side.

However, net zero is much more than a scientific concept or a technically determined target. It is also a frame of reference through which global action against climate change can be (and is increasingly) structured and understood.

Achieving net zero requires implementation in varied social, political and economic spheres. There are numerous ethical judgements, social concerns, political interests, fairness dimensions, economic considerations and technology transitions that need to be navigated and several political, economic, legal and behavioural pitfalls that could derail a successful implementation of net zero [1].

The financial, socio-economic and environmental costs of switching from fossil fuels to solar electricity, or other renewable energy sources, eventually need to be offset by savings or new 'benefit streams'. Some scenarios carry the risk that for one or more of the indicators the balance never moves into the positive.

Moreover, net zero energy systems are not limited to one type of behaviour, technology or region. Instead, it is a system-level transition of a global scale that requires multiple solutions tailored to different cultural, economic, geographic, historical, political and social structures across different countries and regions [3].

It is imperative to understand what motivates people to change their behaviours to reduce carbon emissions and what influences public acceptability and adoption of low-carbon technologies and energy system changes. Therefore, human dimensions are at the heart of net zero energy systems, and the conjunction of aspects must contribute setting the agenda for future research.

This chapter discusses four key challenges to achieve net zero in the building industry: (1) the global challenge referred to climate change and future climates according to the 6th IPCC report, (2) the technical challenge related mainly to the achievement of net zero energy parameters in new and existing buildings and the difficulties to certify energy efficiency in a massive attempt, (3) the social challenge contending with the human angle of net zero perception and commitment (different net zero configurations imply different system and lifestyle changes, and strongly depends on people supporting and adopting these changes) (4) the future challenge in the next transition from the building itself to a low carbon community and energy-positive buildings.

The Global Challenge: Climate Change and Future Climates

About 100 years ago, only 14% of the population lived in cities, and in 1950, less than 30% of the world population was urban [4]. Nowadays, around 3.5 billion people live in urban areas around the world, and by 2050 more than two-thirds of the urban population will live in cities [5].

Today, at least 170 cities support more than one million inhabitants each. The situation is even more dramatic in developing countries. Already, 23 of the 34 cities with more than five million inhabitants are in developing countries, and 11 of those cities have populations of between 20 and 30 million inhabitants. Estimations show that urban populations will occupy 80% of the total world population in 2100 [6].

Since the 1950s many of the changes observed are unprecedented. Numerous studies by the Intergovernmental Panel on Climate Change (IPCC) confirm that climate change is caused by human activity and warn that the associated risks are significant. Its latest report [7] states that global surface temperatures will continue to rise until at least mid-century under all emissions scenarios studied. Global warming of 1.5 °C and 2 °C above pre-industrial levels will be exceeded during the twenty-first century unless there are deep reductions in CO_2 and other greenhouse gas emissions in the coming decades.

The Intergovernmental Panel on Climate Change has developed climate scenarios to improve our understanding of how future climate might change [8]. In the 5th Assessment Report (AR5), four emissions scenarios called Representative Concentration Pathways (RCPs) were published. These emissions scenarios are incorporated into general circulation models (GCMs) and regional circulation models (RCMs), which are models used to understand climate behaviour and to forecast likely changes [9]. GCMs/RCMs simulate changes in climate over time and illustrate how the components of climate (surface, atmospheric and oceanic) interact with each other to develop an understanding of its variability. They are called projections because future GHG emissions are unknown. Projections present a snapshot of the possibilities that may occur in the future based on the current state of emissions and assumptions about socio-economic factors such as population, economic and technological developments [10].

Recently, a group of experts from the IPCC [11] set out the results of their assessment of the impact of climate change (1 °C increase above pre-industrial levels in 2017) and the associated risks of exposure of natural and human systems to climate hazards. The same study also shows how these risks would increase significantly under the scenario of a 1.5 °C increase between 2030 and 2052.

While it is theoretically possible that we can keep global warming under 1.5 °C above pre-industrial temperatures, that task is monumental. In fact, models struggle to generate future scenarios that 'keep' warming below 1.5 °C but can pull temperatures back under 1.5 °C after they have overshot that target. Even then, some of these models assume that there has been a global carbon tax in place since 2010 (and there has not) [12].

Robbie Andrews' statements are based on IPCC [7] and GCP [13] projections, in which constant emissions for 8 years will use up the remaining carbon budget. In his projections of CO_2 mitigation curves, assuming a 1.5 °C increment in temperatures by 2100 (Fig. 1) shows a rate of about 4%/year if mitigation would have started in 2000.

Keeping global surface temperatures no more than 1.5 °C above pre-industrial levels entails primarily achieving near zero greenhouse gas (GHG) emissions by 2050. Fossil fuels became the main source of energy after the industrial revolution.

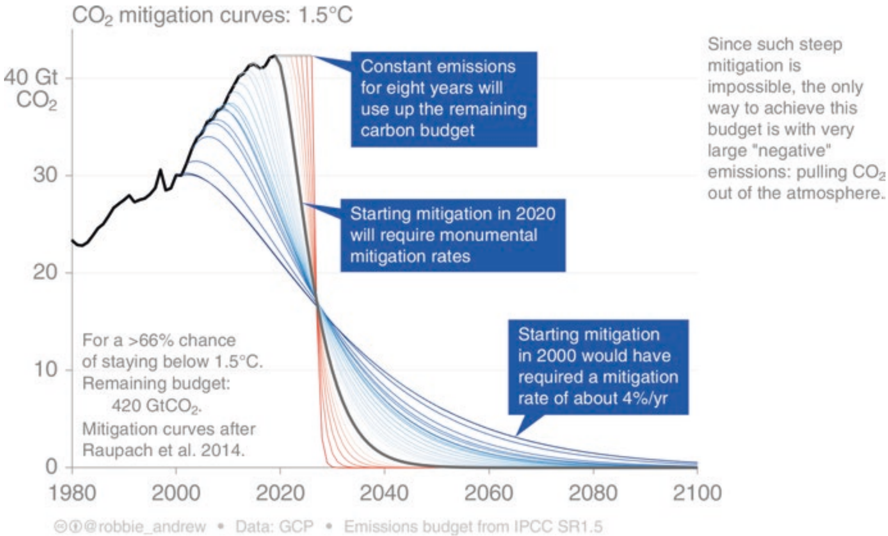


Fig. 1 CO_2 mitigation curves:1.5 °C [12]

Today, the burning of fossil fuels such as coal, oil or gas is the cause of about three quarters of global greenhouse gas emissions. They are also the largest source of air pollution [14].

If we suppose a scenario in which mitigation starts in 2020, monumental mitigation rates will be required. Since such steep mitigation is impossible, the only way to achieve this budget is with very large ‘negative’ emissions. That is, pulling CO_2 out of the atmosphere. Frankhauser et al. [1] state that carbon dioxide removal will probably be constrained by cost considerations and geopolitical factors, as well as by biological, geological, technological and institutional limitations on our ability to remove carbon from the atmosphere and store it durably and safely.

Moreover, Dyke et al. [15] emphasise that there are also concerns about moral hazard risks arising from an over-reliance on carbon removal strategies, which may enable business as usual rather than the drastic scaling back of fossil fuel use.

Figures 1 and 2 present historical emissions to 2017 from CDIAC/Global Carbon Project, projection to 2018 from Global Carbon Project [13].

In Fig. 2 are shown mitigation curves assuming a 2 °C increment in temperatures by 2100. In this scenario, constant emissions for 10 years lead to a required mitigation rate of 10%/year. If we suppose mitigation has started in 2020, the required mitigation rate is about 6%/year. And if mitigation would have started in 2000, it would have required mitigation rates of about 2%/year.

This second temporal scenario presents better chances of achievement, but also depending on the models used to estimate global greenhouse gas emissions, there are even greater risks if the increase in global warming reaches or exceeds 2 °C. Heat waves, which already affect agricultural systems and human health, are projected to become more intense and prolonged. Some regions will suffer an increased risk of

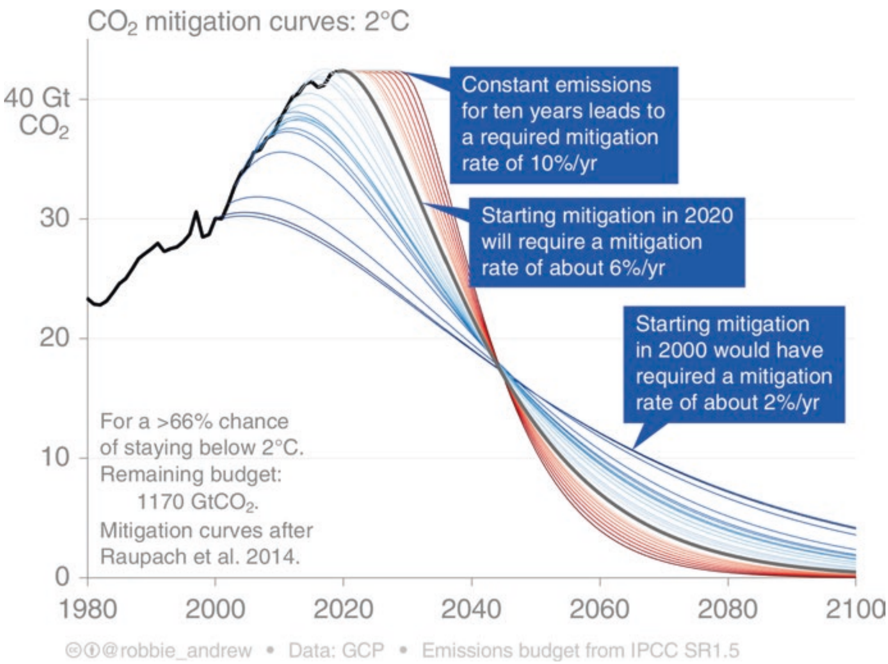


Fig. 2 CO_2 mitigation curves: 2 °C [12]

drought, while others will be severely affected by severe flooding due to increased rainfall intensity, frequency and volume.

In order to slow the advance of climate change and thus preserve people's health, it is essential to aim for a reduction in energy consumption and a transition to renewable energy sources. It is vital to implement measures in the short term, given that under current consumption patterns, global energy consumption is expected to increase by 27% by 2040.

Among other aspects, a range of possibilities associated to the building industry should be considered: the integration into the architectural envelope of small-scale renewable energy producing systems (photovoltaic and solar thermal) and passive conditioning strategies (thermal insulating materials, materials with thermal inertia, absorptive, reflective and selective materials, thermo-economic balances, use of thermal energy in industry, etc.).

Therefore, the identification and application of methodologies to decrease the energy demands of buildings is very important given the global energy challenges as well as the imminent consequences of climate change. Technologies that are applied for efficient energy use in buildings with payback periods for the consumer of less than 5 years have the economic potential to reduce carbon emissions by 25% by 2020 and up to 40% by 2050.

In the face of the global challenge scenarios related to climate change and future climates, the first measures should be the adjustment of bioclimatic strategies for buildings based on in situ measurements and computational simulations and the quantification of the impact towards climate change and future climates of new and retrofitted buildings, using IPCC climate models.

The Technical Challenge: Net Zero in the Building Industry

The construction sector is one of the main causes of pollution, due to the excessive emissions released into the environment as a result of the processes of heating and cooling systems in buildings. Therefore, a turnaround is required, entrusted to the design of new buildings with a reduced annual energy requirement, supported by the inclusion of systems powered by renewable energy sources (RES) [16].

According to the International Energy Agency [17], the energy intensity per square metre of the building sector needs to improve by 30% by 2030 to meet the climate targets of the Paris Agreement. This will require almost doubling the current energy performance of buildings and means that nearly zero energy buildings (nZEB) need to become the global standard in the next decade. At the same time, there is a clear need to invest in the energy renovation of existing buildings.

Most contemporary authors agree that the building stock is inexorably aging, composed of 75% buildings built before 1990, and the replacement of existing building stock by new (environmentally sound) construction is in the order of 1.2% per year [18–22].

This situation leads to the assumption that, in the case that the current regulations consider adequate standards for new building, the negative impacts due to energy consumption and polluting emissions in cities due to the permanence of a large amount of existing building stock would be little reduced. It is important to keep in mind that in a decades-long perspective, the remaining buildings of the twentieth century will cause most of the environmental impacts in cities.

For this reason, improvements to the existing building stock will be the only way in which the benefits of energy efficiency will be made available to the majority of the population, and absolute reductions in domestic energy use and carbon emissions can be achieved. Increasing energy efficiency is the fastest and least costly way to meet the challenges of energy security, the environment and the economy. This fact leaves the main responsibility to the refurbishment of existing buildings, and this is a very complex task.

Another difficulty to overcome is related to passive design as we know it. As a response to the last century energy crisis, passive strategies have been an interesting approach. With the aim of displacing fossil fuels for space conditioning and lighting, the design of construction and shape of the building itself play major roles in capturing, storing and distributing wind and solar energy.

But there are limits to passive design today, and these limits will be greater constrains to the maintenance of interior temperatures within acceptable parameters in the future's more extreme climatic conditions, even with the complementary use of auxiliary energy. A key question is whether a particular energy-optimised design under the present climate and use conditions would remain energy optimised in the future emission scenarios.

Extreme hot climates will become even hotter, and the possibilities of using passive strategies will be further reduced. The use of renewable energy as a primary response to extreme weather conditions will be a constant in many regions of the world, and passive design criteria in these cases will be an accompanying factor in reducing energy demand.

However, there will be nuances, and in complex climates with significant daily and seasonal temperature variations, passive design still presents itself as a viable alternative in the future. However, consideration of dynamic forward projections will allow for flexibility and adaptation to future changes, as opposed to the static simplification of current passive design recommendations.

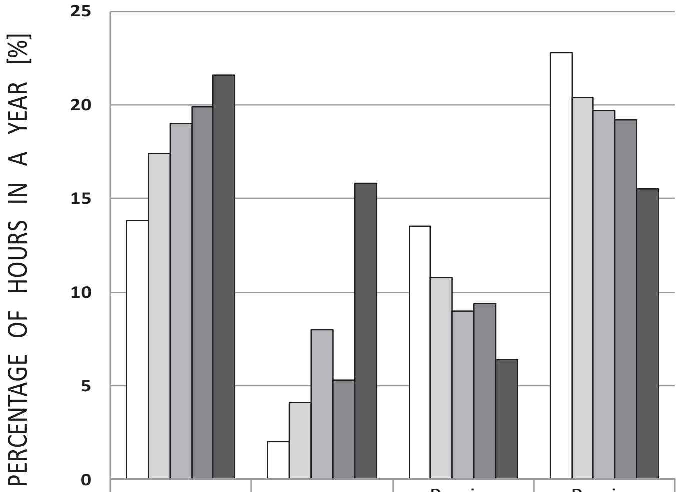
In the case of temperate continental climates, throughout the twentieth century and specifically since the energy crisis of the 1970s, research into passive or low-energy strategies that contribute to the thermal conditioning of buildings in winter has been a priority. Well into the twenty-first century, the urban heat island is a well-known and sufficiently studied phenomenon, which, together with the prospective climate scenarios proposed by the IPCC for the next 50–80 years, redirects the disciplinary field to give priority to research on the thermal and energy situation of buildings in summer.

These changes not only imply a sustained increase in temperature values but also a change in the relationship between daily maximum and minimum temperatures, which were the methodological basis for the application of passive cooling strategies such as night-time ventilation. In other words, an effective and massive assessment of the current condition of existing buildings and their likely future behaviour is necessary in order to reorient energy efficiency and passive cooling strategies. Only in this way will it be possible to make accurate recommendations from academia to decision-making bodies for the implementation of public policies that will ensure the resilience of our cities throughout the twenty-first century (coinciding with the estimated useful life of buildings).

As an example, it is presented a study performed for the city of Mendoza, Argentina (south latitude −33°9′, west longitude 69°15′, elevation 1.950 m above sea level), a continental temperate cold desert climate (Bwk, according to Koeppen) [24] in which is shown how the different climate change projected scenarios could impact on passive strategies effectiveness.

Notice in Fig. 3 that, in a sun, shading of windows and cooling with dehumidification will be crucial in a years' perspective in summer. And in winter passive strategies such as passive solar direct gain will lose importance as climate will be warmer [23].

Based on the obtained results for the Metropolitan Area of Mendoza, the impact of climate change on urban microclimate and expected changes in energy consumption of buildings during the next century will present new challenges. The heat waves with respect to the present will be more extensive and are estimated to be incremented in 115 more days by 2050 [25].



	Sun Shading of Windows	Cooling & Deshumidification	Passive Solar Direct Gain low Mass	Passive Solar Direct Gain Higt Mass
Today	13.8	2	13.5	22.8
RCP 4.5 - 2050	17.4	4.1	10.8	20.4
RCP 4.5 - 2100	19	8	9	19.7
RCP 8.5 - 2050	19.9	5.3	9.4	19.2
RCP 8.5 - 2100	21.6	15.8	6.4	15.5

Fig. 3 Percentage of hours in a year where the different passive strategies are recommended for the city of Mendoza in RCP 4.5 and RCP 8.5 (2050 and 2100) [23]

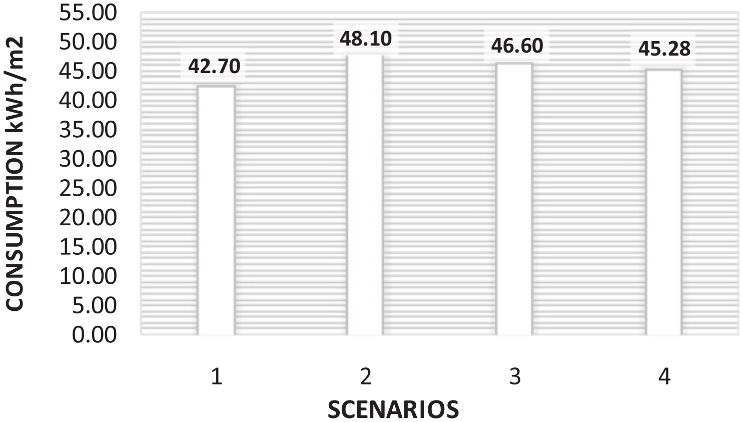


Fig. 4 Total energy consumption results for each scenario [23]

The previous analyses on passive strategies show a clear tendency to the increment of cooling loads and a reduction of the heating requirement. Moreover, when heating and cooling needs are added in a single figure, it is interesting to analyse the whole energy consumption trends. In the case under study, as well as similar constructions, total energy consumption presents maximum variation of less than 10% when compared with the worst-case scenario 4: CRP 8.5 (2100). See Fig. 4.

It is important to take into account that even though consumptions seem similar and variations are perceived as low between scenarios, the main aspect to discuss is in the use of the energy required. In the current situation prevails energy consumption for heating with 57.5% of the total, mainly covered by using natural gas as auxiliary energy. While in the worst scenario, predominates energy consumption for cooling with 77.8% of the total, mainly covered by using electricity.

A third aspect to consider is that the application of energy savings measures in related directly with the people that manage them, and how the risks related to climate change are underestimated. There is a tendency to be unduly optimistic about the likelihood of adverse events occurring, and 'follow the herd', such that our choices are often influenced by other people's behaviour, especially under conditions of uncertainty. It is important to take responsibility for the impact associated with our way of living; this involves a commitment to reduce the negative effects that our actions can cause in the future.

The Social Challenge: Net Zero Perception and Commitment

Change – including climate change – is inherent to planet Earth, which, over its billions of years of history, has undergone much more intense changes [26]. However, there are two characteristics of current climate change that make the associated global biophysical and social impacts unique in the history of the planet: the speed and intensity with which this change is taking place, in such a short space of time for the evolution of the planet as decades, and human activity as a driver of all these changes.

It is almost a self-evident fact to remember that societies are constantly changing, although sometimes more evolutionary (slow) and sometimes more revolutionary (fast). The speed of change in societies is a key factor for the analysis of social impact, especially in terms of its interrelation with the biogeophysical environment, since a large part of the problem of so-called climate change is being produced by the high speed of social change in contemporary societies (e.g., the increase in the demand for energy and basic resources), which produces pressures on the biogeophysical environment, whose possibilities for renewal of resources and, above all, for 'integration' of toxic and hazardous waste require a much longer time and a slower speed of pressure.

The social impact or consequences of global change is ultimately what will result from the interactions between changes in the biophysical environment and changes in the specific social environment. However, these interactions are almost never direct, as they are also – and mainly – mediated by the various spheres of social activity, including social organisation (economy, social relations, norms, values, etc.) and technology.

Human activities on earth impact globally in such a way that a virus initially spread in the city of Wuhan in China in December 2019 caused the death of 4,962,000 people worldwide by September 2021. In March 2020, the WHO declared a COVID-19 pandemic, with 437,923,303 people infected with the virus worldwide. Governments in all countries immediately took steps to contain the spread of the virus by implementing collective actions that would drastically change the way we relate to each other. The closure of schools and public buildings, the cancellation of flights, the wearing of face masks, and the closing of restaurants and entertainment venues, among many others.

What has happened shows that global challenges can be met with massive behavioural responses by governments and citizens, especially if they are implemented immediately. At the same time, there is an opportunity for people to recognise that our individual actions cause global impacts, both positive and negative.

Numerous studies now draw parallels between the pandemic and another global externality, climate change. Similarities have been found between the two issues, mainly in the negative effects on developing countries. Both the impacts of the current pandemic and many consequences of climate change, such as more frequent and intense natural disasters, can be characterised as low probability-high consequences (LP-HC) risks. Recent studies [27] show that people underestimate LP-HC risks, such as climate change and COVID-19, until they experience the consequences themselves or see the life of a close friend or family member affected. People are likely to make decisions focusing on the low probability of a disaster happening to them or its possible consequences, rather than making a rational assessment of the overall risk. Many climate change-related risks, such as natural disasters, have a low probability that individuals simplify to being zero or falling below their threshold level of concern. The same case occurs with pandemics.

However, there are striking similarities between the climate and COVID-19 crises; they also differ in many fundamental ways, including the speed at which they develop [28]. The COVID-19 crisis can both occur and be controlled rapidly, in comparison to the more slowly looming climate crisis, whose impacts may be even greater. There are no safe climate change vaccines or potential treatments to be developed that could 'solve' the climate crisis, and any activities aiming for the reversal of climate change would likely take decades or more before coming to fruition. The COVID-19 crisis shows us the importance of prevention and early action, and this may be even more important in averting the worst outcomes of climate crisis.

Even though it is important to take immediate action on the occurrence of an event that involves an imminent risk, it is even more important to be prepared before the effects are devastating. Many factors lead to delay response, related to emotional reactions and cognitive biases such as the failure of the human mind to grasp the concept of exponential growth and the misperception of risk [29]. Several other biases lead people to ignore the potential consequences of a looming event. The 'simplification bias' implies that individuals view the likelihood of LP-HC events as falling below their threshold level of concern and fail to take risk reduction measures, unless they experience the impacts of a disaster according to the 'availability bias'.

As with COVID-19, it will be important for political leaders at the national, state and local levels in every country in the entire world to recognise cognitive biases and turn to experts for advice on how to deal with the impacts of climate change. Addressing the 'simplification and availability biases' necessitates the development of communication strategies that stress the consequences of risks associated with climate change and COVID-19 to ensure that individuals start paying attention. The need to accelerate climate action can be managed by linking policies and measures that are currently adopted to limit the risks from pandemics to actions that also reduce the risks from climate change.

In an image that has now gone viral (Fig. 5), cartoonist Graeme Mackay reflects how society takes action in the face of imminent risks, currently the pandemic, paying less attention to those they consider less urgent, such as climate change. The associated impacts would also be devastating for human life and ecosystems. However, many of the actions that can be implemented in the future to prevent a new pandemic can also help combat climate change and vice versa.

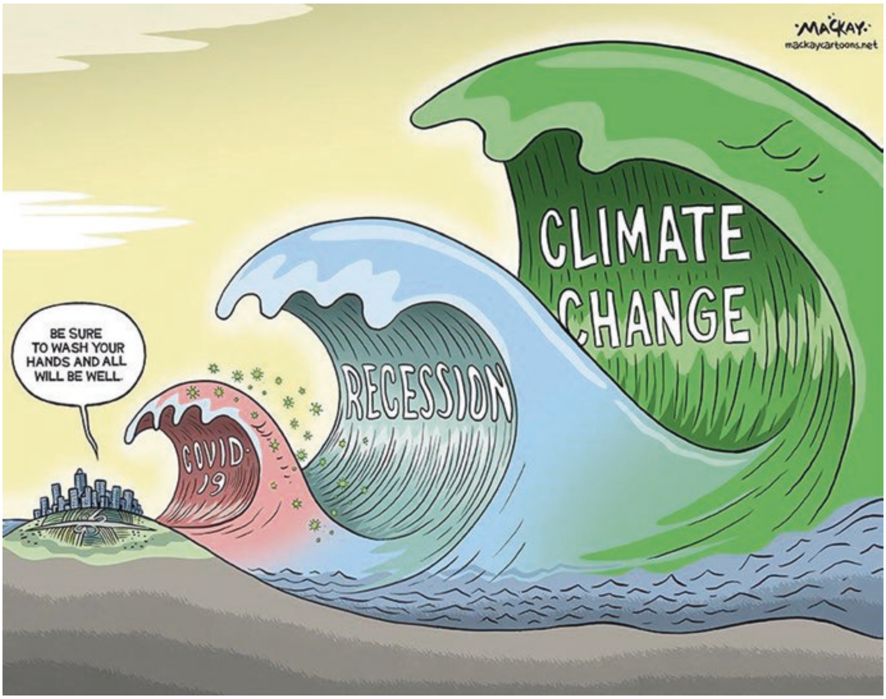


Fig. 5 Viral cartoon of Graeme Mackay with the message: "Be sure you wash your hands and all will be well" [30]

Society's response to the COVID-19 pandemic crisis has demonstrated convincingly that people can adapt quickly and change habits and incorporate new ones if there is an imminent threat. It is therefore possible to believe that achieving behavioural changes in people that aim to mitigate climate change is a feasible reality.

The Future Challenge: From the Building Itself to a Low-Carbon Community – Energy-Positive Buildings

Our remaining carbon budget to keep warming under 1.5 °C is tiny. Modelling shows the 'best' way to achieve this is by actively removing CO_2 from the atmosphere: 'negative emissions'. Doing this allows more room for actual, positive emissions. Various technologies are being explored, as well as good, old-fashioned tree planting, but all have significant limits. It is partly this hope in future technologies – technological optimism – that delays action [12].

Figure 6 presents projections based in the functional form from Raupach et al. [31] for positive emissions, adding residual, hard-to-mitigate emissions of 5% of the current level, and negative emissions using the ramp of a cosine function. Σ indicates the cumulative emissions in 2019–2100. Global cumulative CO_2 emissions budgets are from the IPCC Special Report on 1.5 °C: 420 GtCO2 for a 66% of 1.5 °C and 1170 GtCO2 for a 66% of 2 °C [32].

If this was actually possible, and the positive and negative emissions on Fig. 6 in 2100 were to continue beyond 2100, we would begin to pull the global temperature increase back under 1.5 °C.

Mitigation curves describe approximately exponential decay pathways such that the quota is never exceeded [31]. But note that these are not exponential pathways:

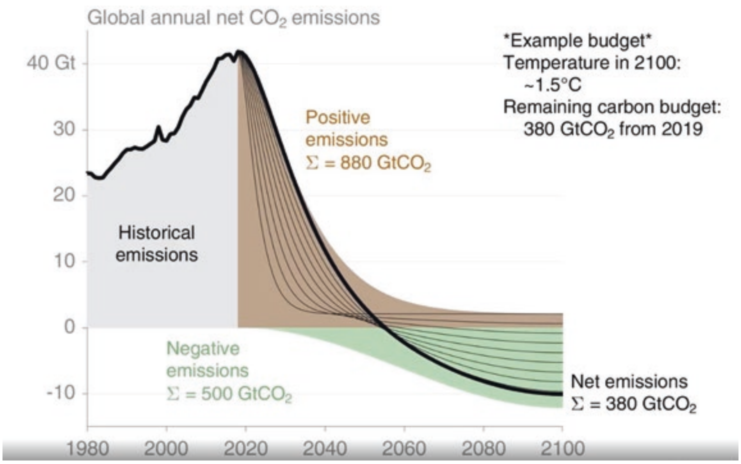


Fig. 6 Projections based in the functional form from for positive emissions [31]

the rate of mitigation is not the same every year. This comes from a recognition that an oil tanker cannot turn on a dime: we have enormous infrastructure (social, political, physical) that cannot be changed overnight. So these curves allow for some inertia in the early years of mitigation.

A further step is represented by the possibility of connecting the individual NZEBs to an intelligent energy distribution network, also called smart grids. Positive energy buildings (PEBs) could be a new target, through their contribution to the energy support of other buildings connected to them, producing more energy than necessary to their needs. A system of units connected together at the neighbourhood level, aiming of achieving neutrality or, in extreme cases, energy positivity is the next challenge. The buildings will thus become collectors and energy storage structures [16].

According to Carlisle et al. [33], the net zero energy community (NZEC) is to be considered by four following perspectives:

- The central energy system should consist of renewable energy sources and will accommodate the energy for the whole community.
- The percentage of energy loss should be kept in mind to deliver the energy.
- The financial aspects of the community should be considered.
- The environmental impacts including GHGs emissions are to be considered.

Ulla et al. [34] reviewed 23 case studies of net zero energy communities around the globe revealing that they mainly focus on the onsite energy generation. Solar energy is the widely used renewable energy resources for NZEC, as 22 settlements have considered utilising it. Beside the solar energy, wind energy is the second most popular renewable energy source, while geothermal energy, biogas plants and other sources are not considered significantly.

NZEC components are highlighted in the Fig. 7. It is also clear that energy storage, management, and control systems are also the vital parts of the NZES to increase the self-consumption and reduce the cost and size of energy generation and supply systems [35].

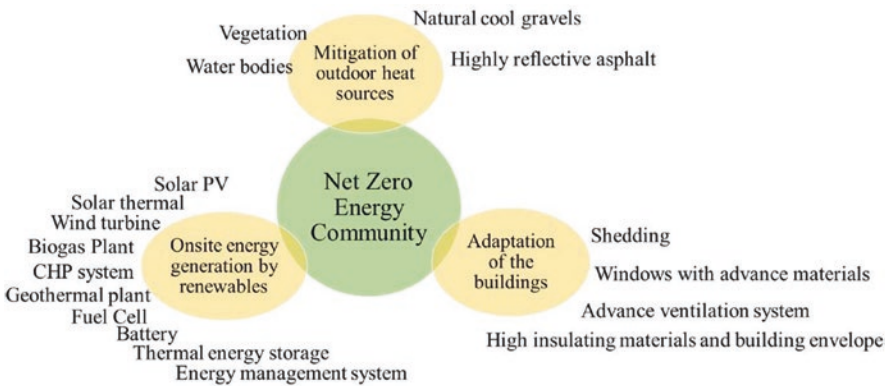


Fig. 7 The various components of a NZEC. Ulla et al. [34]

The impacts of climate zones and building types have influenced the selection methods of these building adaptation tools and techniques along with the renewable. Among them, 17 settlements additionally consider various adaptation techniques that have significantly lessened the energy demand of the buildings. However, some case studies did not thoroughly consider the adaptation tools and new technologies for the adaptation of buildings. A few studies (four settlements only) incorporate some mitigation strategies to mitigate the outdoor heat sources that enable to lower the ambient temperature along with diminishing the GHGs emissions as well as minimising the energy demand of the community.

Therefore, to establish the NZEC, further efforts can be given to the following areas:

– Mitigation strategies to reduce the ambient temperature, especially for the settlements at hot climate zones, such as vegetation, water bodies, natural cool graves and highly reflective asphalt.
– Adaptation of the buildings with high-performance materials would be a promising option to reduce the energy demand and improve the indoor air quality as well as control the indoor temperature of the buildings.
– Diversified use of renewables: The solar energy (PV and thermal collector) and wind energy are mainly considered as renewable energy resources.

Discussion: Our Role in the Transition to Net Zero: We Must Be There as Soon as Possible

Despite being a widely used term, sustainability is a concept that acquires different connotations according to its interpretation. In its most basic meaning it is understood as 'maintaining the status quo and not disappearing' [36]. Maintaining the status quo, however, translates into a notion that avoids or mitigates change [37]. Thinking of sustainability as 'longevity' is another way of approaching the concept, meaning 'the longer the system can be maintained, the more sustainable it is' [38, 39].

Leach et al. [40] define sustainability as the "capacity to maintain over an indefinite period of time specific qualities of well-being, social equity and environmental integrity" and argue that, while the concept of sustainability focuses on reducing negative impacts on the environment to avoid change, the concept of resilience is about adapting to change.

Holling [41] introduced the term resilience as a measure of the persistence of a system and the ability to absorb change and still maintain the same relationships between variables. The twenty-first century requires buildings to be not only sustainable but also resilient, that is, not contributing to the deterioration of the environment but also flexible to change as here are changes in climate that will be inevitable in the future.

Even if emissions of carbon dioxide and other pollutants were to be drastically reduced, these climate scenarios would not change much until 2040 because gas concentrations remain in the atmosphere for a long time and thermal adjustment is slow. In other words, over the next 30 years the outlook is inexorable, and we must prepare to adapt finding means to achieve net zero in the building industry.

Therefore, net zero commitments are not an alternative to urgent and comprehensive emissions cuts. Indeed, net zero demands greater focus on eliminating difficult emissions sources than has so far been the case. The 'net' in net zero is essential, but the need for social and environmental integrity imposes firm constraints on the scope, timing and governance of both carbon dioxide removal and carbon offsets. It is possible to align net zero with sustainable development objectives, allow for different stages of development and secure zero-carbon prosperity [1].

From an economic perspective, while NZEBs require higher investment costs, there are much greater long-term benefits, both in micro- and macro-perspectives. For NZEBs generating power on site, the speed of reaching the payback period may be influenced by the local feed-in tariff structure.

Preferential government policies, such as tax subsidies, will help make NZEBs more economically attractive. Financing opportunities can be found in various investment schemes, such as green bonds and green investments. Making these more accessible to the general population can help accelerate the adoption of the NZEB concept in each country.

Also, different net zero configurations imply different system and lifestyle changes and strongly depend on people supporting and adopting these changes. Behaviour change by individuals, commercial entities, and policy makers is critical to achieving net zero in all domains [42]. People's knowledge of which behaviours generate the most greenhouse gases is generally poor. It is important to develop new communication strategies to ensure that individuals start paying attention.

While legislative mechanisms, geographical and climatic conditions are essential factors, it is the technological applications and innovations that are at the heart of

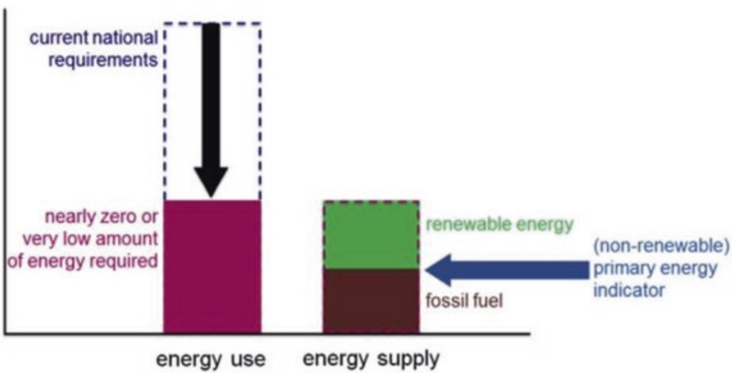


Fig. 8 The NZEB model according to EPBD indications [16]

the design of an NZEB. These apply to both the energy generation and energy saving characteristics of a building [43, 44].

The introduction of the NZEB target in the building design will encourage a decrease in the amount of energy required, thus abandoning fossil fuels [45]. A graphical interpretation of the NZEB energy balance is indicated in the scheme of Fig. 8. With fairly limited options for on-site renewable energy generation systems, it is crucial that NZEBs diversify in design and energy efficiency technologies.

It is important to take into account that no single technology alone, negative emission technologies included, can reduce global warming to 1.5 °C. There is agreement among climate scientists that reducing overall energy demand, using energy more efficiently and shifting to cleaner energy sources and technologies, is critical for reducing global carbon emissions. Changes in everyday energy behaviours of individuals and households, in particular, behaviours related to mobility, housing and food, have a substantial potential to reduce carbon emissions.

Real progress is frozen until a solution is found that works for (almost) everyone at (almost) the same time. Our role in the transition to net zero is that energy-positive buildings and low-carbon communities will become the new normal, and at the same time, we will grow more connected on a human scale.

Acknowledgments Authors would like to thank the National Research Council of Argentina (CONICET) and the Fund for Scientific and Technological Research of Argentina (FONCYT) for funding this research.

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A. Sayigh (ed.), *Towards Net Zero Carbon Emissions in the Building Industry*, Innovative Renewable Energy, https://doi.org/10.1007/978-3-031-15218-4

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