Book Review: Climate Change 2022

Mitigation of Climate Change: Buildings
The Sixth Assessment Report of the Intergovernmental Panel on Climate Change
2042pp.

Reviewed by
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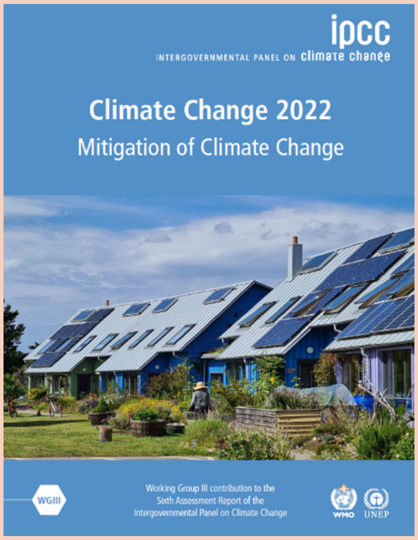

In climate change mitigation, the building sector is assessed by the Intergovernmental Panel on Climate Change's (IPCC). The Sixth Assessment Report (AR6) is a comprehensive assessment of the current state of knowledge on climate change, including the physical science basis, impacts, adaptation, and mitigation. The IPCC-AR6 emphasizes that the building sector is critical during 2020-2030 to avoid lock-in CO_2 emissions. However, readily available, and highly cost-effective actions that can be undertaken now to reduce CO_2 emissions in the building sector are identified. The sufficiency, efficiency, and renewable (SER) measures must be really designed and effectively implemented to decarbonize the building sector before 2050. The IPCC affirms that we can still secure a safe and livable future if actions are taken now.

Summary

The Intergovernmental Panel on Climate Change's (IPCC) Sixth Assessment Report (AR6) assesses literature on the scientific, technological, environmental, economic, and social aspects of mitigation of climate change. It reflects, among other factors: developments in the UN Framework Convention on Climate Change (UNFCCC) process, including the Kyoto Protocol and the Paris Agreement, and the UN 2030 Agenda for Sustainable Development including the Sustainable Development Goals (SDGs). This paper reviews the assessment in the building sector and its pathways in transition to the net zero emissions under the Paris Agreement. It is found that global decarbonization of buildings is constrained by barriers and obstacles as well as limited finance. The lack of institutional capacity and appropriate governance structures slow down the decarbonization of the building stock. The well-designed and effectively implemented mitigation actions have significant potential for achieving the net zero emissions and the UN SDGs.

Keywords: Climate change, IPCC, net zero emissions, sufficiency efficiency & renewable, buildings

New Developments in CO_2 Emission Trends and Drivers

Over the period 1990–2019, global CO_2 emissions from the building sector increased by 50%, its final energy demand grew by 38% and its final electricity demand increased by 161%. In 2019, global final energy demand in the building sector reached 128.8 EJ, accounting for 31% of global final energy demand while global electricity demand in the building sector was slightly above 43 EJ and accounted for 18% of global electricity demand. Residential buildings consumed 70% of global final energy demand from buildings. In the same year, global greenhouse gas (GHG) emissions from buildings were estimated at 12 $GtCO_{2\text{-eq}}$, equivalent to 21% of global GHG emissions, out of which 57% were indirect emissions from offsite generation of electricity and heat, 24% direct emissions produced onsite and 18% were embodied emissions from the use of cement and steel. More than 95% of GHG emissions from buildings were CO_2 emissions. The share of CO_2 emissions from buildings in global emissions would increase from 21% in 2019 to 31% in 2050.

In the Intergovernmental Panel on Climate Change's Sixth Assessment Report (IPCC-AR6), drivers of GHG emissions in buildings were assessed using the SER (Sufficiency, Efficiency, Renewables) framework. (see Figure 1) Sufficiency measures deal with avoiding energy demand and materials needed over the buildings' lifecycle to reduce energy consumption and GHG emissions. Then, the emissions are decomposed into four driving factors: population (*Pop*), Sufficiency (*Suff*), Efficiency (*Eff*) and Renewables (*Ren*). (see Equation 1)

$$CO2^{k}_{total} = Pop \times \frac{m^2}{Pop} \times \frac{EJ}{m^2} \times \frac{Mt_{CO2}}{EJ} = Pop \times Suff \times Eff \times Ren \qquad \text{Eq.(1)}$$

The superscript k stands for the case, defined by the period and scenario of the emissions used by the International Energy Agency (IEA). The zero carbon buildings could be achieved when the remaining global carbon budget, and its target for distributional equity, sets the upper limit, while requirements for living standards define the minimum level of sufficiency. The concept of sufficiency introduced to buildings includes the optimization of building operation, repurposing unused buildings, prioritizing multi-family homes over single-family buildings, and adjusting the size of residential buildings by downsizing dwellings. (see Figure 2)
The crucial benefit of sufficiency is described by providing an opportunity to avoid lock-in emissions. In general, building services include shelter, nutrition, sanitation, thermal, visual, and acoustic comfort, communications, illumination etc. When designing building services, density, compacity, building typologies, bioclimatic design, multi-function space, circular materials, thermal mass, shared space, are the sufficiency actions worldwide employed in leading cities.

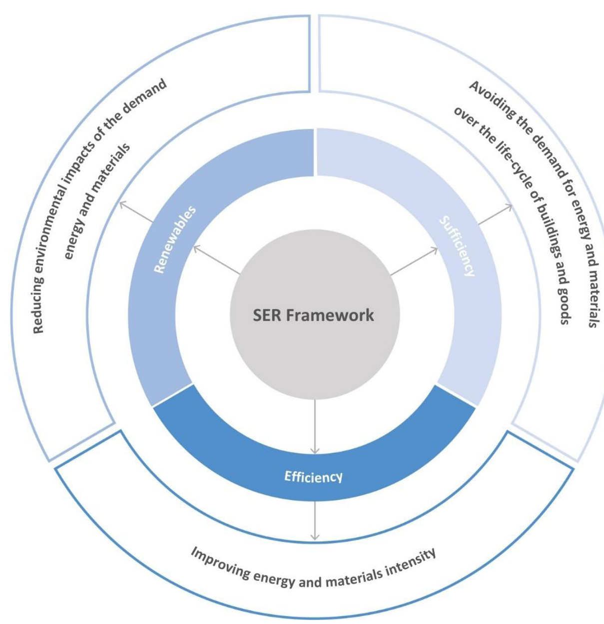

Figure 1 SER framework adopted in the building sector.

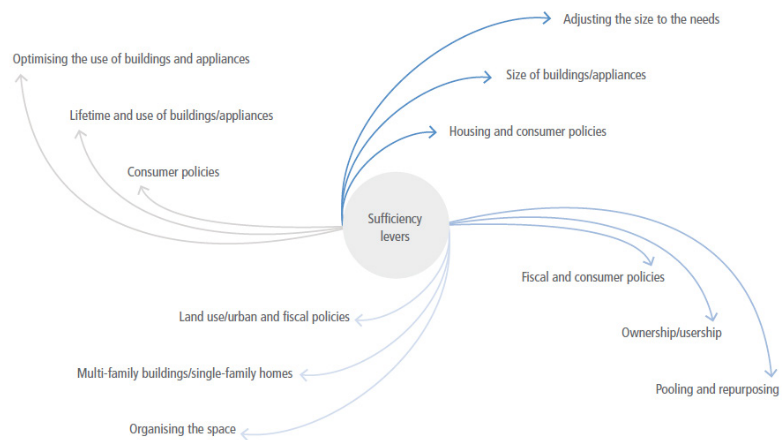

Figure 2 Sufficiency interventions and policies in the building sector.

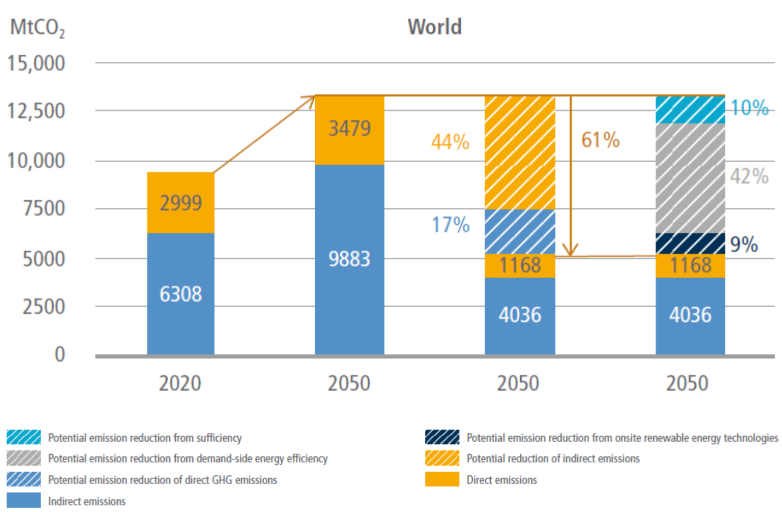

Figure 3 Global estimates of GHG emissions in the building sector in 2020 and 2050.

Efficiency is the short-term marginal technological improvements in operation of buildings. Historical improvements in efficiency have been matched by growth in floor area per capita, particularly in developed countries, reduces the dependence of climate mitigation on technological solutions.

The IPCC-AR6 concludes that the main drivers of emissions in the building sector in the future at the global level include (i) population growth, (ii) increase in per capita floor area, (iii) the inefficiency of the newly constructed buildings, and the low renovation rates and ambition level, (iv) the increase in use, number and size of appliances and equipment, especially information and communication technology (ICT) and cooling, driven by the growing welfare/income, and (v) the continued reliance on fossil fuel-based electricity generation and slow decarbonization of primary energy supply in countries.

GHG Emissions and Mitigation Potentials in the Building Sector

The IPCC-AR6 reviews worldwide bottom-up studies in the building sector. Results show a mitigation potential up to 85% in Europe and North America and up to 45% in Australia, Japan, and New Zealand, compared to the baselines by 2050. In developing countries, bottom-up studies estimate the potential of up to 40–80% in 2050, as compared to sharply growing baselines. The aggregated energy demand from all bottom-up studies translates into a global mitigation potential by 2050 of at least 8.2 $GtCO_2$, which is equivalent to 61% of the baseline scenario. (see Figure 3).

Figure 4a shows scenarios of global energy demand by end-use types and Figure 4b shows scenarios of regional energy demand by end-use types under the two international energy agency (IEA) scenarios (sustainable development, and net zero emissions), Integrated Model to Assess the Global Environment (IMAGE) Lifestyle-Renewable scenario and Resource

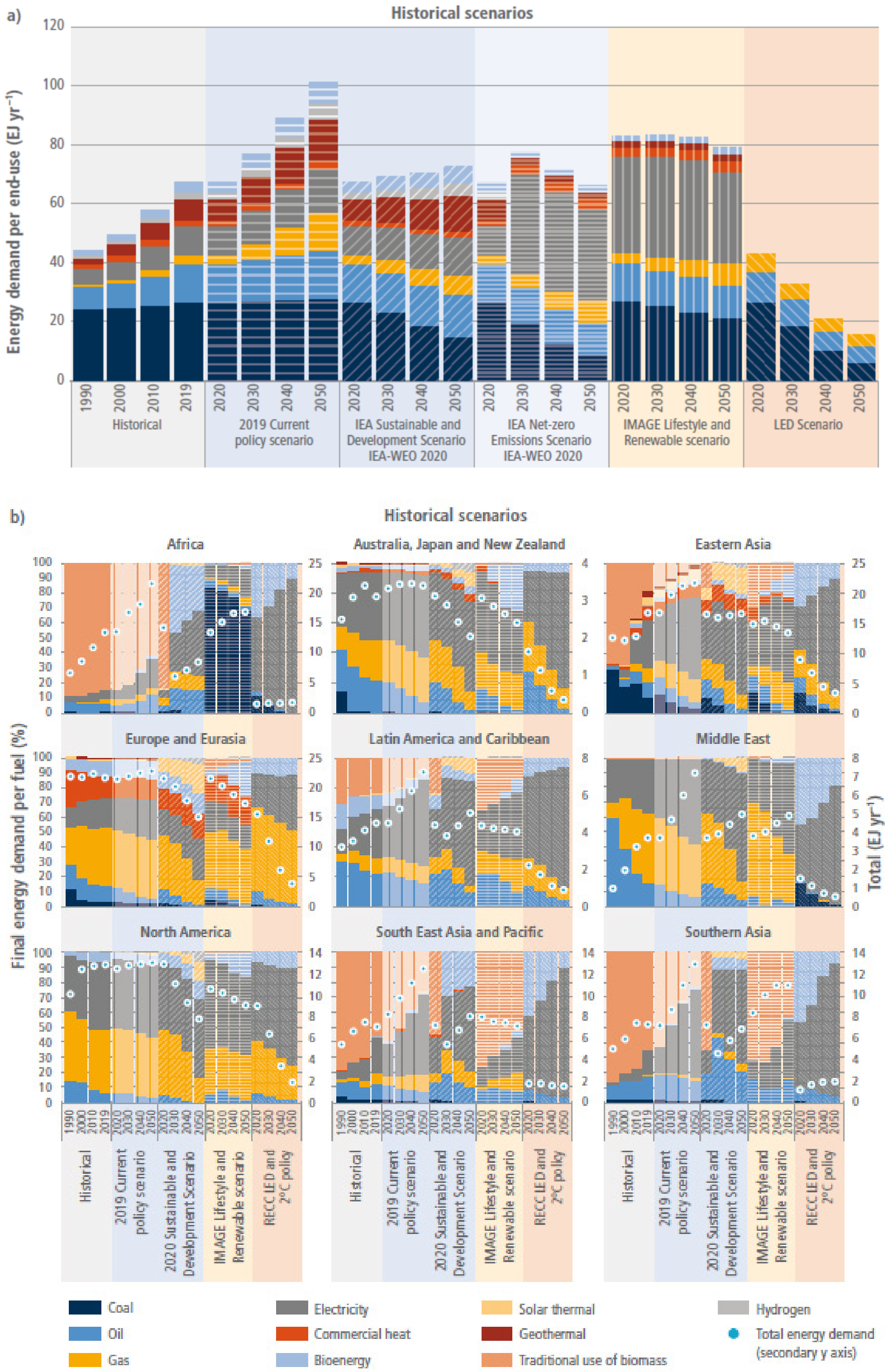

Figure 4 End-use energy demand: historical based on IEA data and future emissions based on two IEA scenarios (sustainable development, and net zero emissions), IMAGE Lifestyle-Renewable scenario and Resource Efficiency and Climate Change-Low Energy Demand scenario (RECC-LED).

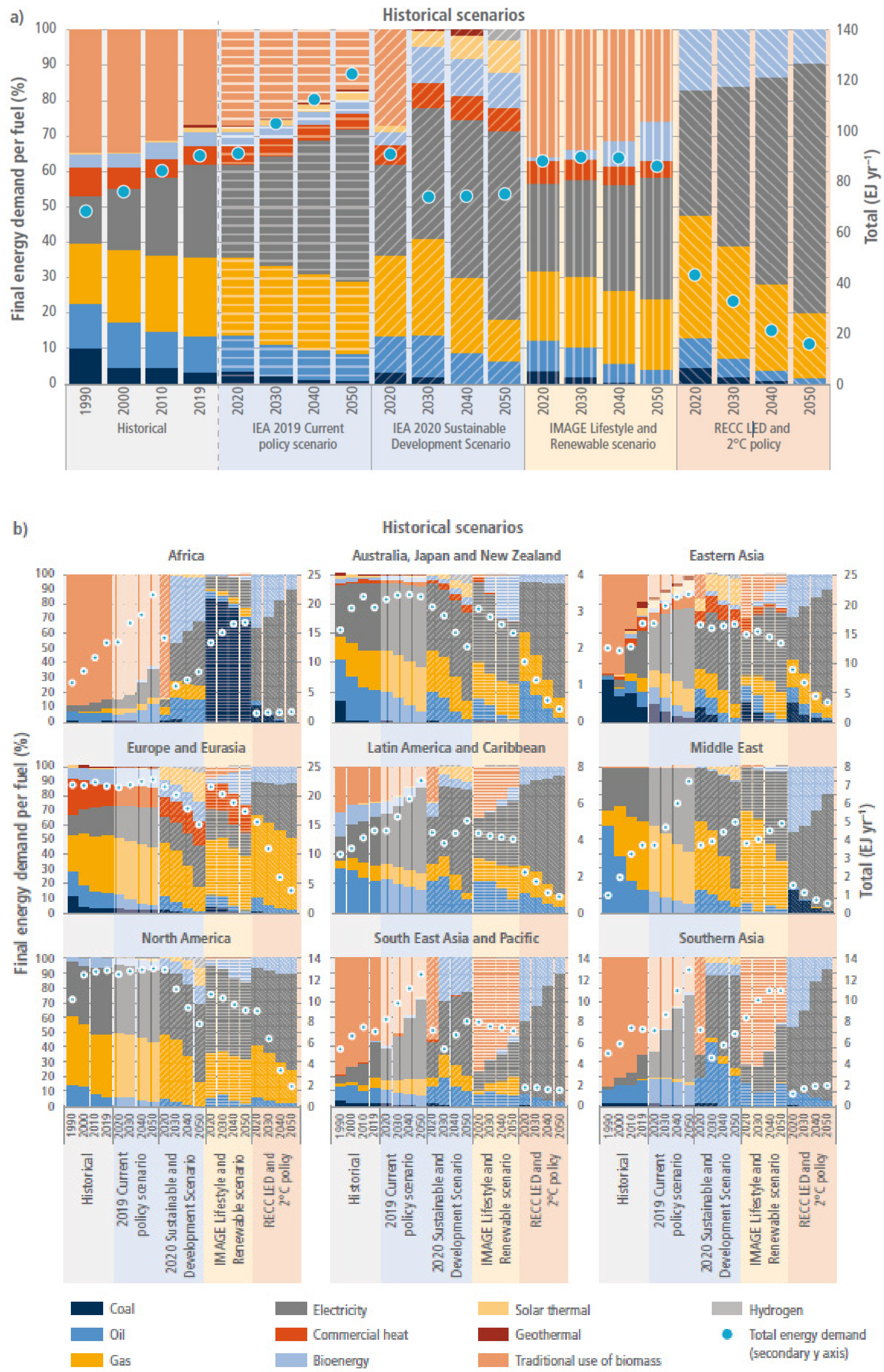

Figure 5 Shares of final energy demand by fuel types: historical based on IEA data and future emissions based on two IEA scenarios (sustainable development, and net zero emissions), IMAGE Lifestyle-Renewable scenario and Resource Efficiency and Climate Change-Low Energy Demand scenario (RECC-LED).

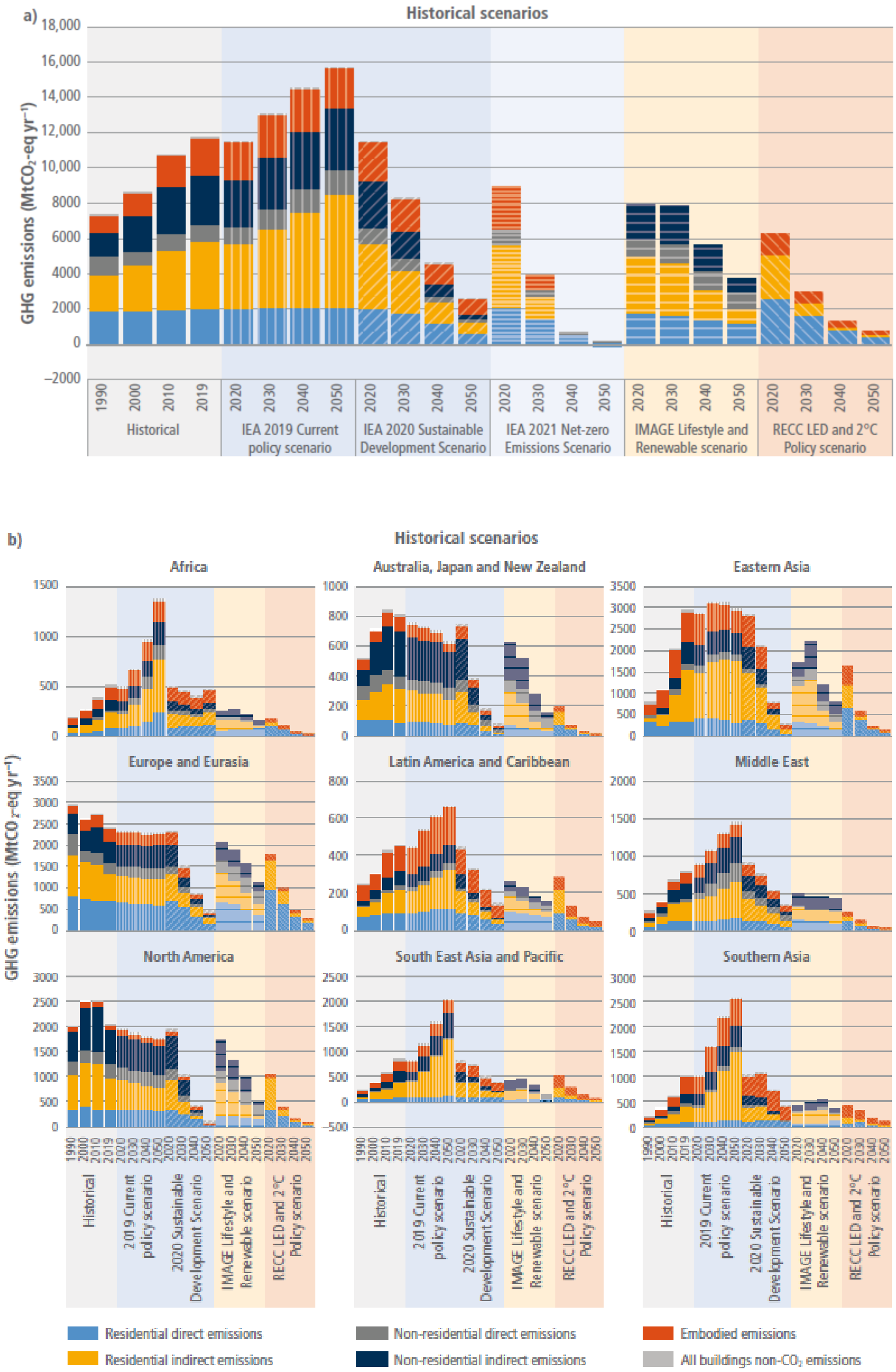

Figure 6 Global and regional building GHG emissions: historical based on IEA data and future emissions based on two IEA scenarios (sustainable development, and net zero emissions), IMAGE Lifestyle-Renewable scenario and Resource Efficiency and Climate Change-Low Energy Demand scenario (RECC-LED).

Efficiency and Climate Change-Low Energy Demand scenario (RECC-LED). The end-use devices are classified by activities. They are space heating, water heating, space cooling, cooking, lighting, small appliances, cleaning appliances, and refrigeration. Different end-use devices need different fuels such as coal, oil, gas, electricity, bioenergy, and solar etc. The assessment of end-use activities results in final energy demand by fuel types. Figure 5a shows scenarios of shares of global final energy demand by fuel types and Figure 5b shows scenarios of regional shares of final energy demand by fuel types.

Figure 6a shows global GHG emissions from buildings and Figure 6b shows regional GHG emissions from buildings under the two IEA scenarios, IMAGE Lifestyle-Renewable scenario and RECC-LED scenario. In addition to the four decarbonization scenarios, the 2019 current policy scenario is also assessed and presented. (see Figures 4, 5, and 6)

These bottom-up studies reveal that zero carbon buildings are possible under implementation of policy packages in sufficiency, efficiency and renewable (SER) framework. It is noted that these mitigation potentials are based on actions taken during 2020-2030. Any delays in the implementation of measures in the building sector result in lock-in emissions in the midcentury.

Mitigation Costs in the Building Sector

The IPCC-AR6 reveals the mitigation costs in the building sector. By 2050, the construction of high-performance buildings will become a business-as-usual (BAU) technology with costs below USD20 per tCO_2 in developed countries and below USD100 per tCO_2 in developing countries. The building sector is critical between 2020 and 2030 in accelerating the learning of knowledge and skills to reduce the costs and remove constraints for achieving high efficiency buildings. The deep decarbonization of the building sector is constrained by multiple barriers and obstacles as well as limited flow of finance. Global investment in the decarbonization of buildings was estimated at USD164 billion in 2020, which is not enough to close the investment gap.

CO_2 Mitigation Options and Strategies Towards Zero Carbon Buildings

The strategies to achieve zero carbon buildings are highlighted. Policy packages based on the SER (Sufficiency, Efficiency, Renewables) framework is suggested to grasp the full mitigation potential of the global building stock. (see Figure 7) It concludes that low ambitious policies will lock buildings in carbon for decades. Building Energy Codes (BECs) measure is the key regulatory instrument to reduce emissions from both new and existing buildings. The advanced measures that contribute to fostering decarbonized buildings include market-based instruments such as carbon taxes with recycling of the revenues and personal or building carbon allowances.

It also highlights embodied energy and embodied emissions. Buildings are recognized as built following five building frames: concrete, wood, masonry, steel, and composite frames. The embodied carbon can be calculated using the lifecycle assessment (LCA) methodology with different boundaries. (see Figure 8) Steel represents the materials with higher embodied energy, and higher embodied carbon. However, due to different boundaries and assumptions used in LCA such embodied emissions from different studies could not be directly compared and concluded.

The IPCC-AR6 concludes that in the bottom-up studies, nearly zero energy (NZE) buildings or low-energy buildings are possible in the relevant climate zones, in Europe and north America (See Figure 9). NZE buildings are possible for new and retrofitted buildings, but different envelope design and advanced technologies need to be employed on the site specifically, depending on the climate and the building shape and orientation.

Links to Adaptation and Sustainable Development

Finally, mitigation of climate change in the building sector shows links to adaptation and sustainable development goals. Actions are needed to adapt buildings to future climate. The expected heatwaves will inevitably increase cooling needs to limit the health impacts of climate change. Global warming above 1.5 degrees Celsius drastically impacts not only cooling and heating needs but also the performance, durability, and safety of buildings. Adaptation measures in the building sector to cope with climate change may increase the energy demand and low carbon materials leading to increasing GHG emissions. Sufficiency measures such as bioclimatic design of buildings, which consider the expected future climate, and includes natural ventilation, white walls, and nature-based solutions such as green roofs will decrease the demand for cooling. Shared cooled spaces with highly efficient cooling solutions are among the mitigation strategies which can limit the effect of the expected heatwaves on people’s health. It is concluded that sufficiency, efficiency, and renewable energy (SER) can be designed to reduce buildings’ vulnerability to climate change impacts.

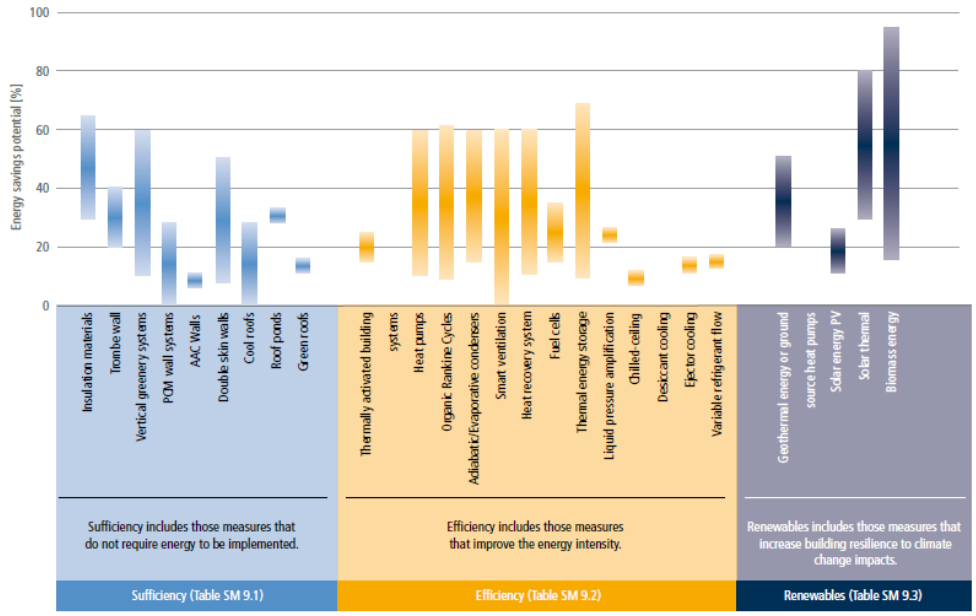

Figure 7 Energy savings potential of technology strategies for climate change mitigation in buildings.

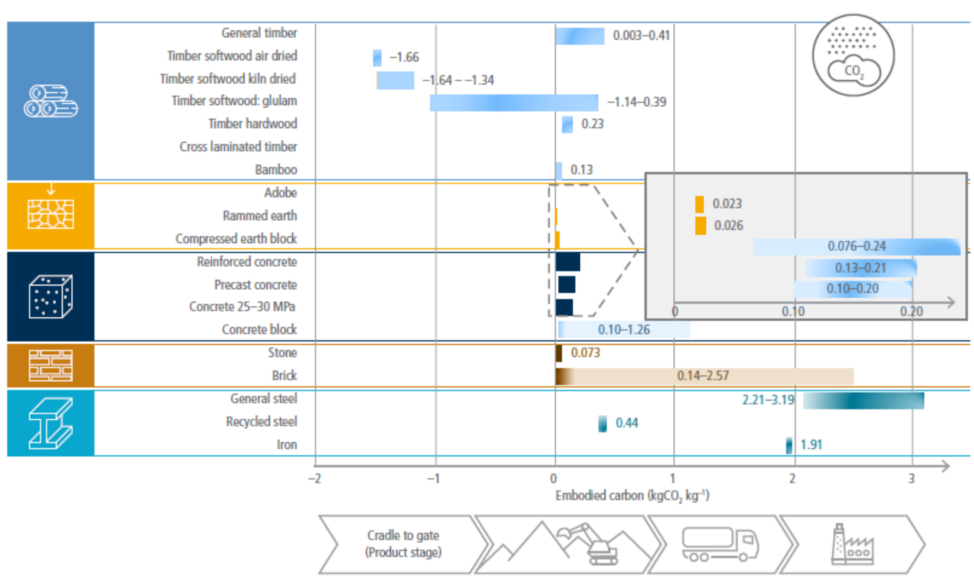

Figure 8 Embodied carbon in building materials

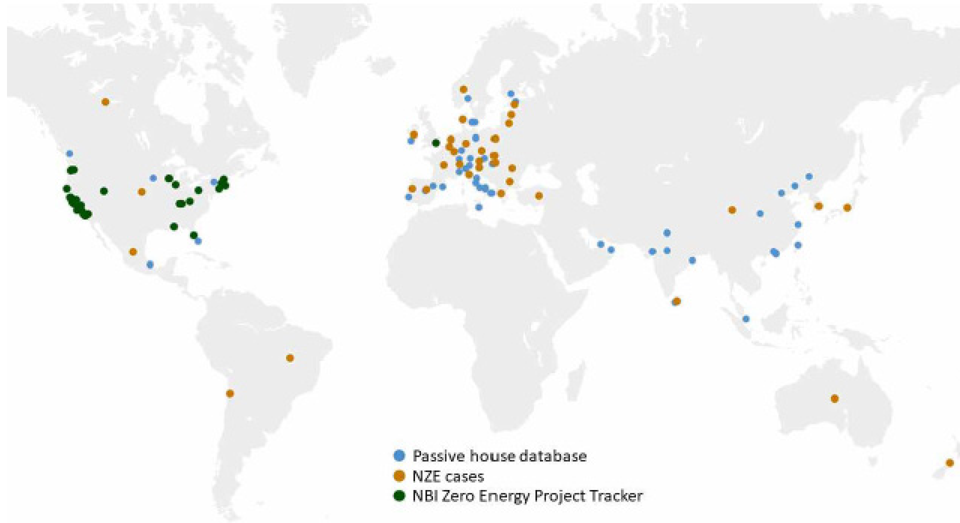

Figure 9 Regional distribution of documented low-energy buildings

These well-designed and effectively implemented mitigation actions in the buildings sector have significant potential for achieving the United Nations Sustainable Development Goals.

Conclusions

Low ambitious policies will lock-in carbon emissions from the built environment for decades. Existing buildings, if retrofitted, and buildings yet to be built, are projected to approach net zero emissions in 2050 if sufficiency, efficiency, and renewable (SER) measures are effectively implemented and barriers to decarbonization are removed.

The 2020-2030 decade is critical for accelerating knowledge, building the technical and institutional capacity, setting the appropriate governance structures, ensuring the flow of finance, and developing the skills needed to fully capture the mitigation potential of buildings. In addition to SER, several studies show that demand-side measures can reduce global GHG emissions in end-use sectors by 40-70% by 2050 compared to baseline scenarios.

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