UN environment

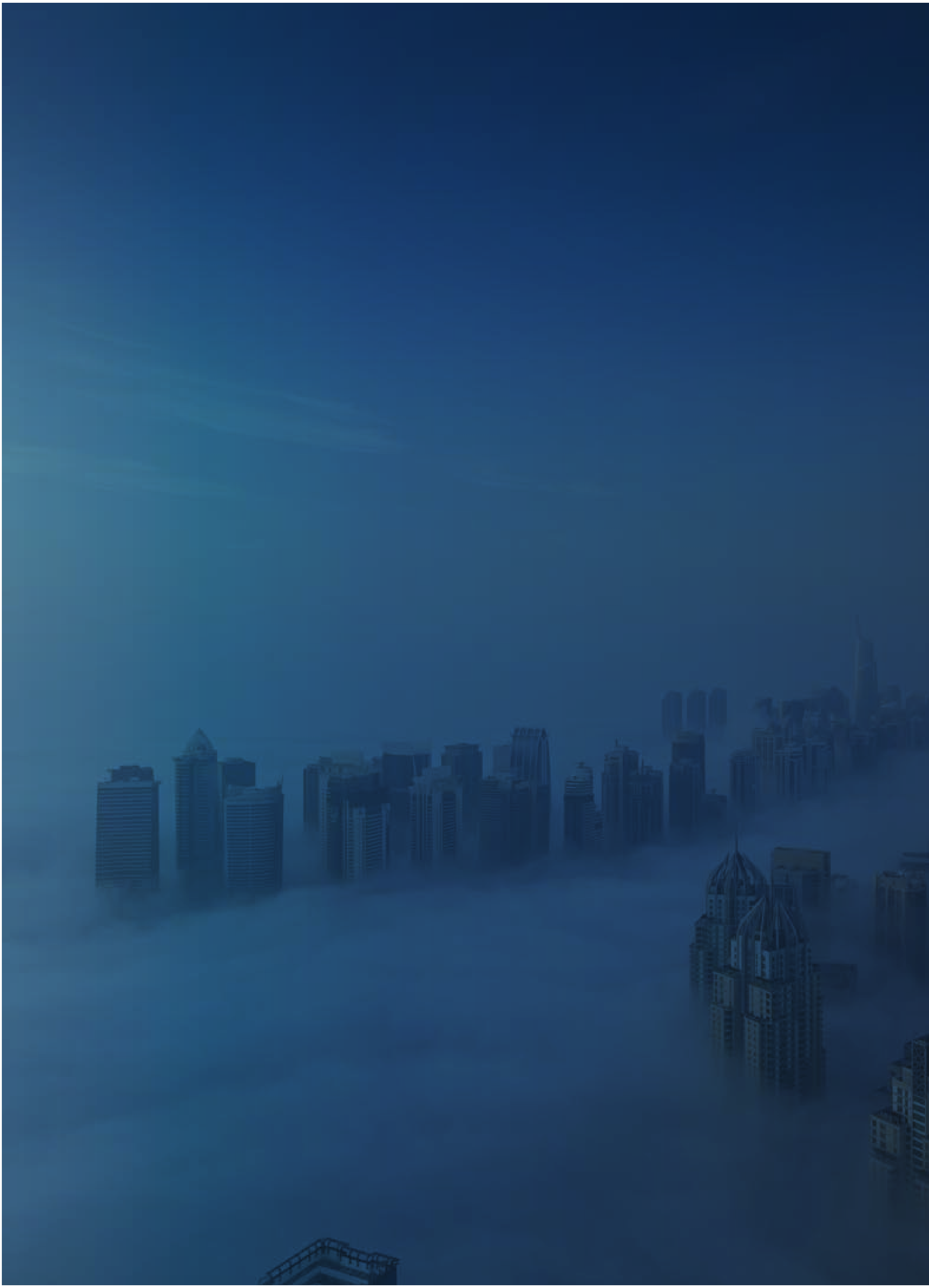
GLOBAL ROADMAP

TOWARDS LOW-GHG AND RESILIENT BUILDINGS

“This Roadmap aims to describe, when possible, the main overarching goals, steps and agenda that the Building sector as a whole could share, creating the framework of a common vision for low GHG and resilient global real estate pathways”

Global Alliance for Buildings and Construction

November 2016



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» INTRODUCTION

Energy use in buildings represents roughly one-third of global final energy consumption and accounts for nearly 20%[1] of the greenhouse gases (GHG) emissions worldwide[2]. Growing population, as well as rapid growth in purchasing power in emerging economies and many developing countries, means that energy demand in buildings could increase by 50% by 2050 (IEA, 2016). Construction of new buildings will also drive energy demand and buildings-related emissions, with global floor area in buildings expected to double to more than 415 billion square metres (m^2) by 2050 (IEA).

The responsibility of the building sector

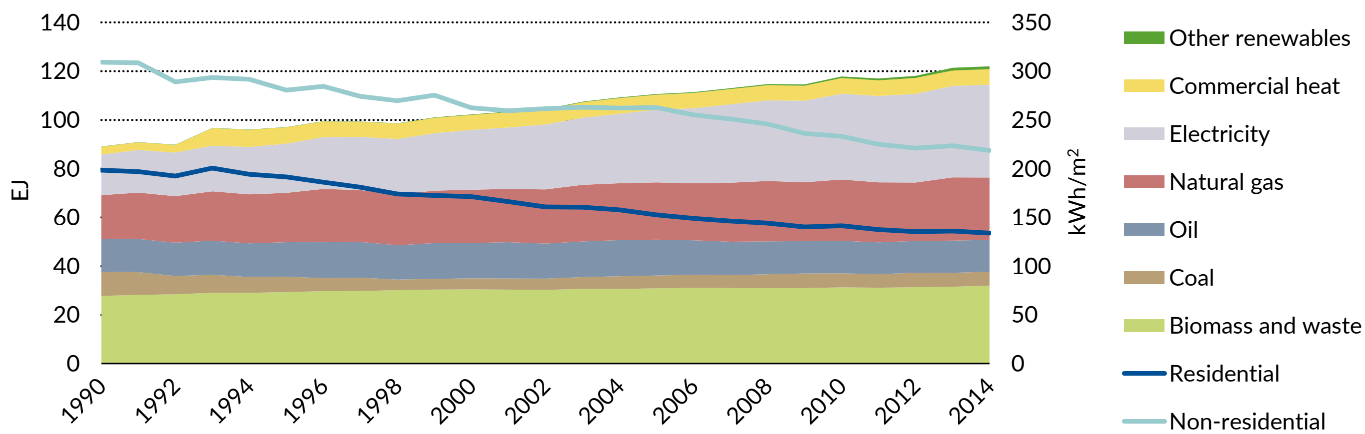
Nearly 20%

of global GHG emissions are buildings-related (Scope 1,2,3).

1 *This figure is a proxy: 33% (building contribution to energy consumption) of 56% (CO_2 energy part into GHG global emissions).*

2 *This data covers more than building-related energy (which is defined in Scope 1, 2 and 3). This concept will be further explained in the Roadmap (see page 6).*

Figure 1 **Global building sector energy consumption and intensity by sub-sector, 1990-2014**



Note: *building sector energy consumption and intensities represent final energy consumption.*

Source: *IEA, calculations derived from IEA World Energy Statistics and Balances 2016, www.iea.org/statistics.*

Buildings will also be particularly affected by the effects of climate change: storms, flooding and seepages, reduced durability of some building materials and increased risk of structure damage or collapse (e.g. from severe storms) could all decrease building lifetime, while increasing health-related risks such as deteriorating indoor climate.

2015 was a pivotal year in addressing climate change, with the adoption of the Sendai Framework for Disaster Risk Reduction[3], the 2030 Agenda for Sustainable Development[4] and the Paris Agreement at COP21. Now, in order for countries to successfully implement these agendas and reach their goals, it is crucial that important changes are made in the buildings and construction sector.

The Paris Agreement sets milestones for decarbonizing our society. It aims at "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels" (Art. 2 para 1a). It sets a long- term target on mitigation, by stating that "Parties aim to reach global peaking of GHG emissions as soon as possible" and to be carbon neutral in the second half of this century (Art. 4, para 1). Moreover, it decides that in 2018 Parties will take stock of the progress made towards this long-term goal, will undertake the first global stock take in 2023 and every five years thereafter (Art. 14 para 2), and will communicate a nationally determined contribution (NDC) every five years (Art. 4 para 9).

The Paris Agreement also recognises that "climate change represents an urgent and potentially irreversible threat to human societies and the planet and thus requires the widest possible cooperation by all countries, and their participation in an effective and appropriate international response, with a view to accelerating the reduction of global greenhouse gas emissions".

In this context, the purpose of this Roadmap is to set up a collective framework for the building and construction sector to match the climate related objectives set out in the Paris Agreement, i.e. for the world to stay well below 2°C and to be carbon neutral in the second half of this century.

It is by no means a prescriptive roadmap for countries. This document at a global level can help policy makers when designing their national building and climate strategies, as well as organisations in designing their long-term and medium-term policies and determining their investments allocations. It is aiming at identifying global goals and milestone and therefore does not replace a much more detailed Building and Construction Roadmap that would have to take into account the different circumstances of the countries and be flexible as far as its detailed implementation is concerned.

This Roadmap is developed by the Global Alliance for Buildings and Construction (GABC)*[5], which is a coalition of over 90 states and non-states actors, aiming to work towards a low carbon and resilient building sector.

The roadmap is a "LIVING document"

which will allow adaptation over time and stick as close as possible to regional and local needs and trends in the buildings and construction sectors.

3 *Under the UNISDR, the Sendai Framework is a 15-year, voluntary, non-binding agreement which recognises that the State has the primary role to reduce disaster risk (including climate risk) but that responsibility should be shared with other stakeholders including local government, the private sector and others. It has seven targets and four priorities for action. For more information: http://www.unisdr.org/we/coordinate/sendai-framework.*

4 *Following the Millennium Development Goals (2000-2015), the 2030 Agenda for Sustainable Development sets 17 Sustainable Development Goals. The 7th goal concerns access to affordable and clean energy for all and sets the objective of doubling the global rate of improvement in energy efficiency by 2030.*

5 *Every time there is the "*" sign, it means that the concept is further explained in the glossary.*

AN INDUSTRY IN FOCUS

The building sector is a both traditional and innovative industry: it accounts for between 5 and 10 % of the national GDP of each and every state in the world. Buildings are also assets that represent 50% of global wealth. Hence, a policy on building investment has a major impact on our economy; the financial dimension and business models for the sector will be further developed in a future, second version of this Roadmap.

Policies on buildings and construction have a social impact. Indeed, the building and construction sector is a major employer with 10% of the employment of the workforce, and has a multiplying effect (1 job in construction generates 2 jobs in other sectors, FIEC): it requires a large spectrum of qualifications and in some countries it plays a social role for the integration of migrants into the host society.

Moreover, the activity of the building sector is a highly "local" and the sector is a "low concentrated" industry, with no large businesses having control of the value chain, and it has low entry barriers facilitating the fragmentation of the value chain. Dissemination of innovation is also slow, largely due to this fragmented structure, even though the building sector answers to complex situations by prototype solutions. For this reason, there is a lack of a common and international vision from the different actors in the buildings sector. Thus, it is crucial to facilitate a common language and vision, foster transparency, inclusion and cooperation among these stakeholders, implementing a strong long-term policy and instruments and integrating emerging and innovative technologies into every-day practices.

Investing in buildings and infrastructure provides an opportunity to tackling the central challenges facing the global community: reigniting growth, creating and maintaining jobs, delivering on the Sustainable Development Goals and reducing climate risk in line with the Paris Agreement.

6 Global Construction Perspectives and Oxford Economics. 2013. "Global Construction 2025: A Global Forecast for the Construction Industry to 2025."

I. METHODOLOGY AND PRINCIPLES

1 Building-related GHG emissions

1.1 *Definition of "building-related emissions"*

The building sector accounts for nearly one-third of global energy consumption and half of global electricity consumption. Moreover, around 20% of global GHG emissions are building-related (Scope 1,2,3). To define what is meant by "building-related emissions", we refer to the 3 scopes defined by the ISO 14064 methodology[7].

Building GHG emissions are generated by all the following emission sources:

- **Scope 1 - direct emission sources from buildings:** they are all the GHG sources located physically in the building, mainly fossil-fuel consuming equipment (e.g. boilers, oil lamps...), as well as heating and cooling systems using Fluorinated F-Gas[8], and marginally insulation material. Cooking with gas or fuel also accounts as a major source of GHG emissions[9].
- **Scope 2 - indirect emissions sources from building energy consumption:** mainly building electricity use, plus commercial heat[10] from district heating and cooling. The electrical demand in buildings induces GHG emissions in the power sector. Electrical uses include notably: the consumption by electrical equipment that are incorporated in the building (e.g. heating and cooling systems, electric lighting, elevators, pumps) and consumption of electrical goods (e.g. household appliances) and other related service equipment (e.g. IT goods).
- **Scope 3 – Buildings' indirect emissions from other sources:** Scope 3' borders are not clearly defined: it mainly concerns embedded emissions from building materials and the GHG emissions generated by urban planning decisions (e.g. unnecessary travel or traffic induced by building location).

7 *The ISO 14064 standard (published in 2006) is a three-part international standard for GHG management activities, including the development of entity emission inventories.*

8 *F-Gas have an impact on the ozone depletion and a strong global warming potential (GWP).*

9 *UNFCCC Common Reporting Framework does not take CO_2 emissions of biomass combustion into consideration, because variations of the biomass stock are reported under LULUCF inventory.*

10 *In statistics, heating and cooling are considered "heat".*

Table 1 **Emissions of GHG from real estate**

	Emissions sources & fields covered by the Alliance (building-related)	*Not Covered by the Alliance (energy consumption in buildings which are not building-related)*
Scope 1	***Direct emissions (from consumption of natural gas, fuel…and F-gas fugitive emissions)***	
	• space and water heating (gas, fuel,..boilers) • heating and cooling systems (F-Gas) • insulation materials (F-Gas)	• cooking (gas and fuel cooking) • fuel use (e.g. kerosene) for lighting (notably in developing countries)
Scope 2	***Indirect emissions from energy consumption (electricity and heat district)***	
	• electric heating and cooling systems (including hot water) • district heating/cooling demand (including hot water) • artificial lighting demand • other building services (elevators, pumps and mechanical ventilation systems use)	• cooking (electric cooking) • lamp performance • IT systems and products • domestic appliances and other electrical goods (see note below)
Scope 3	***Buildings' indirect emissions from other sources***	
	• embodied GHG and energy in materials (concrete, glass, steel, wood...)	• traffic induced by building users
	Link with other sectors	
	• decarbonisation of energy supply • urban planning minimising heat islands and optimising solarisation etc.	• coastal sand • urban planning minimising the use of transportation

Note on appliances: Scope 2 in the Roadmap focuses only on electricity demand from equipment incorporated in the buildings. The part of appliances and IT products in buildings represents 14% of the energy consumed in buildings. This part should grow as buildings become more energy efficient. For social purposes, incentives to choose energy efficient appliances, such as energy labelling and eco-design, could be coupled to some building developments.

1.2 *Links with other sectors (energy supply, transport and coastal sand extraction)*

Deep decarbonisation of our societies needs a systemic approach. As stated above, Scope 3's limits are not clearly defined, yet, the building sector has an influence on three other main sectors having an impact on climate change:

1. Energy: buildings professionals are the main responsible for the level of energy demand of buildings (i.e. the building envelope* determines the energy demand that has to be satisfied by building equipment, such as boilers for heat and fans for air flow). Yet, as far energy supply is concerned, their responsibility depends on the local availability of de-carbonised energy (either directly on-site or through the local energy grid). In the majority of cases, building-related decarbonisation will also necessitate upstream decisions by the energy industry (i.e. decarbonizing the power sector).

2. Transport: travel and traffic induced by building users has a large impact on global GHG emissions, which can be as important (or even more important) than building energy consumption depending on the type of building and its location (e.g. office building complexes outside city centres). Some building actors (e.g. developers and urban planning authorities) are directly concerned and are partially responsible for these emissions, as they select the location of buildings, taking into consideration land use and construction permits.

3. Coastal sand extraction: to build with concrete, there is a need to extract each year 30 billion tons of sand (UN Environment, 2014), equivalent to nearly 4 tonnes per person. The majority of this sand is extracted in river and coastal areas, which increases the vulnerabilities of coastlines, where an important part of human settlements is located.

The decarbonisation of energy supply is strictly linked to "building-related GHG emissions", and will be addressed in the Roadmap. Other factors such as urban planning that minimise the use of transportation and coastal sand and gravel extraction are considered without detailed targets attached (See Table 1).

Every time there is the "" sign, it means that the concept is further explained in the glossary.*

2 Relevance of emissions covered by the Roadmap: 20% of total GHG worldwide

A first evaluation of the emissions covered by the Roadmap can be based on the following proxies:

1. As for Table 1, energy includes: heating (56%, 11.8 petawatt-hours [PWh]), hot water (23%, 5 PWh), lighting (12%, 2.6 PWh) and cooling (9%, 1.8 PWh), which represent around 22% of global final energy consumption and around 13% of total GHG emissions[11] (IEA, 2016; IPCC, 2015, own calculation).

2. F-Gas: emissions of F-Gas are estimated around [1,5[12]] Gteq CO_2, or [3%] GHG emissions. F-Gas monitoring is assured under the Montreal Protocol* and the UN Framework Convention on Climate Change.

3. Materials: Even if embodies GHG in building materials do represent 15-20% of the total lifecycle GHG emissions of a building, the production of construction materials represents a significant proportion of total GHG emissions (figures range between 8-15% of total GHG emissions for concrete, steel and bricks, whose cement represents 3%).

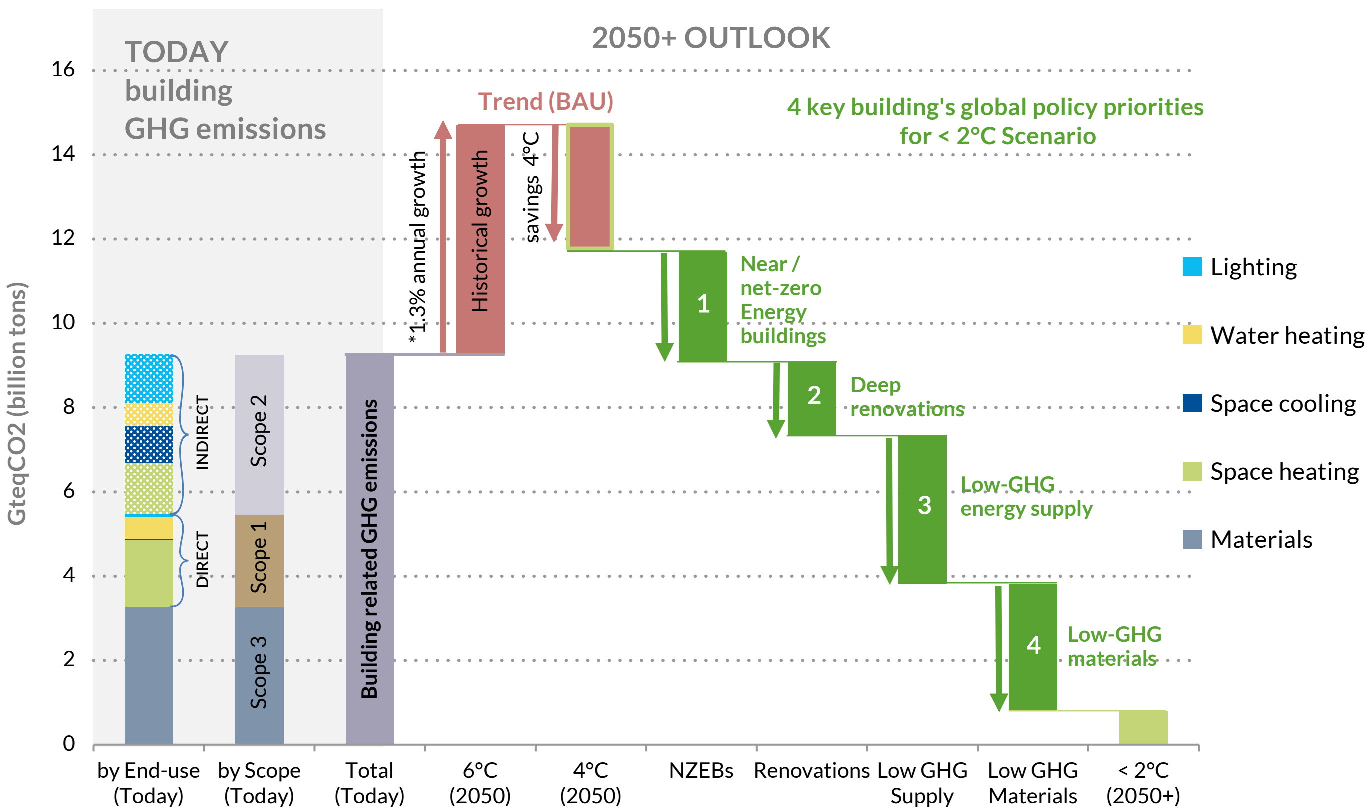
Every time there is the "" sign, it means that the concept is further explained in the glossary.*

11 *Energy data from the IEA Energy Technology Perspectives 2016 publication; Buildings-related GHG emissions estimated from the IPCC 4th report, in Final energy, 1 Pwh = 1 million of Gwh or 1 000 Twh and represents for example more than twice the annual electrical consumption of France.*

12 *This figure is illustrative. It is necessary to identify the emissions of F-Gas coming exclusively from fixed installations and not from industrial processes.*

All together these three sources of emissions account for nearly 20% of total GHG emissions worldwide.

Figure 2 **Split of global building-related emissions and emissions reduction potential**



Source: IEA Energy Technology Perspectives 2016

3 Guiding principles of the Roadmap

Building-related emissions, accounting for roughly 20% of global GHG emissions, will play a critical role in achieving the goal stated by the Paris Agreement to remain well below 2°C, especially given the long service life of buildings and the speed of global decarbonisation of the power sector.

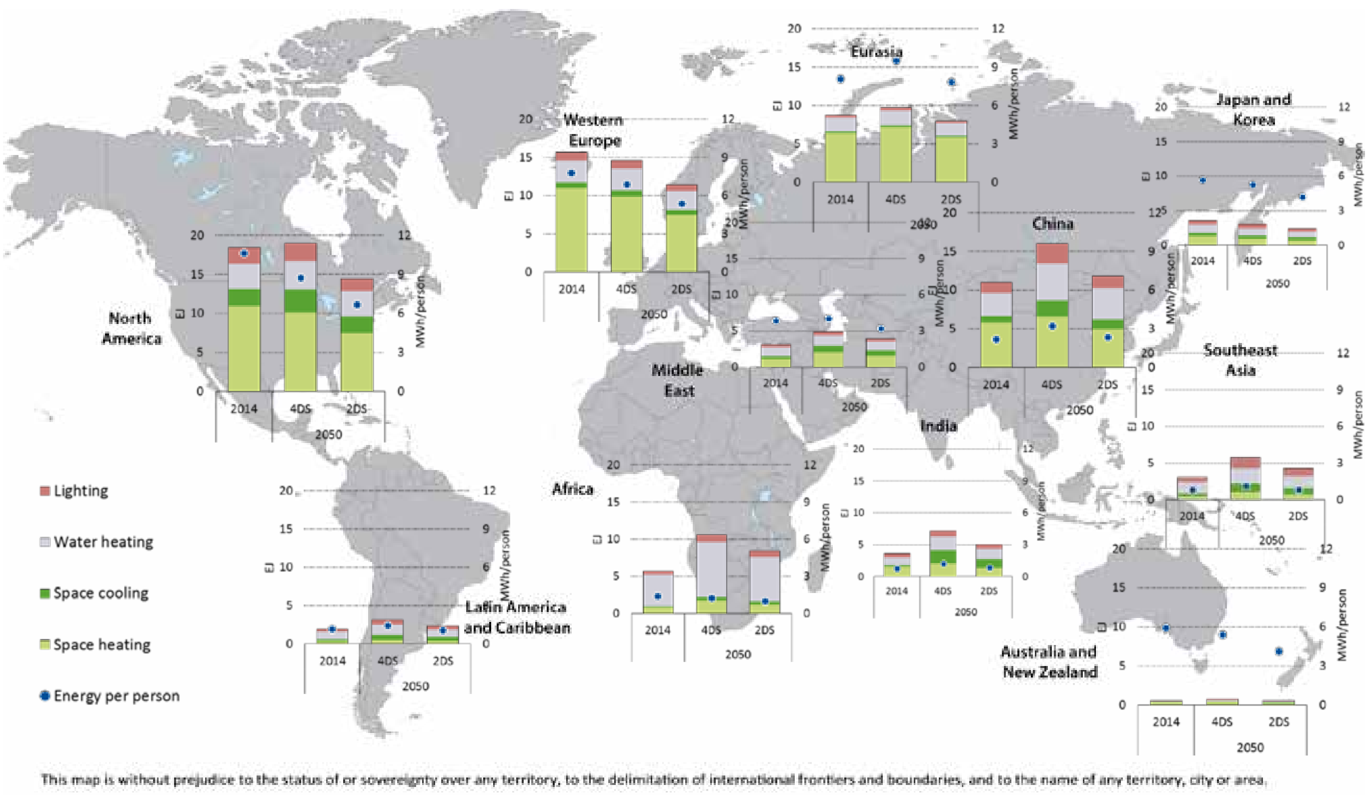
In defining a global roadmap to decarbonise the sector before the end of the century, it will be critical to take into account 5 major issues:

1. Energy efficiency first: reduce the energy demand from the building sector to its minimal level

Measures on energy saving are the most economically efficient mitigation actions, as they often come at a negative cost. Yet, they are not systematically implemented as they face many non-economic barriers (e.g. households' debt capacity…). As new buildings will mostly be in developing countries in the coming decades, building nearly zero emission buildings becomes a priority.

In industrialised countries the priority is to reduce drastically and as soon as possible before 2050 the energy consumption of their building stock, as new buildings are a very small part of all buildings.

Figure 3 **Buildings sector final energy demand in 2050**



Note: Final energy demand here represents energy consumption for space heating, water heating, space cooling and lighting in buildings. It does not include cooking, appliances or other building energy services. The 4-degree Celsius scenario (4DS) represents a global energy and emissions trajectory that takes into account recent pledges by countries to limit emissions and improve energy efficiency, which help to limit average global temperature rise to 4°C. The 2°C scenario (2DS) lays out an energy systems deployment pathway and emissions trajectory that is consistent with a 50% change of limiting average global temperature increase to 2°C.

Source: IEA Energy Technology Perspectives 2016

Energy efficiency to increase access to energy: Improving the energy efficiency of buildings has many co-benefits. One of them is a reduction in total energy demand, often an important factor in countries where energy access is still a priority. There is an obvious link between an efficient building sector in these countries and energy for all. Indeed, SDG 7 sets the goal of doubling the energy efficiency trend to be in line with the climate goals but also to enable an equitable development of every country.

Energy efficiency to increase comfort: To satisfy occupant needs and comfort in **buildings, energy services** (e.g. providing temperature and humidity control and lighting adapted to end uses) are required. Energy (e.g. gas and electricity) is the carrier through which those energy services are provided.

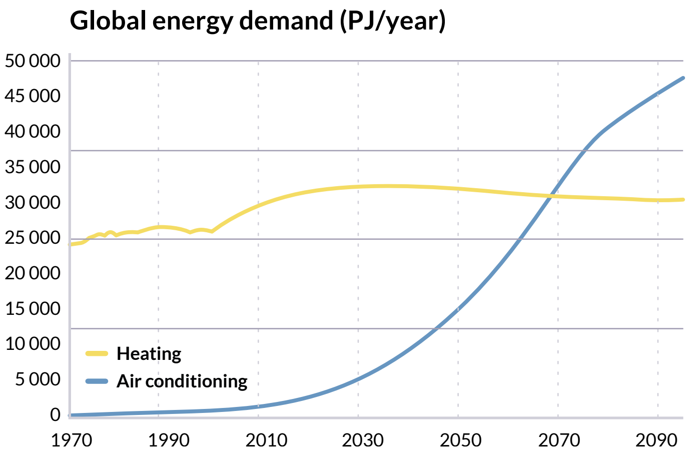
Many cost-effective, market-available solutions already exist to provide the energy services that satisfy occupant needs, both through passive design approaches (i.e. architecture, building envelope, solarisation) or through appropriate equipment specifications (i.e. sizing, appropriate dimensioning, technology choice and energy efficiency of building equipment and products). For a 2°C trajectory, or below, both energy-efficiency and low-GHG design and equipment will be necessary.

Energy efficiency at a negative cost but facing implementation barriers: Typically, the immediate potential benefit of energy-efficient solutions is the financial gain achieved through energy saving, even though there can be potential “rebound effects” from reduced cost of the energy service. Yet, the financial gain alone is not always enough to drive investments in building energy efficiency. Decisions for significant works on buildings are often motivated by numerous factors, including patrimonial value, adaptation to change of uses and improvement in comfort. Upfront investment costs, despite long-term cost savings, can also be a major barrier to energy efficiency improvements in buildings. Consequently, it is crucial to embed energy efficiency in every major step of a building’s life-cycle and

Increase of cooling issues

As developing countries and emerging economies continue to grow, one major change expected in the global built environment is a shift in heating and cooling demand. Whereas there are important challenges and barriers to improving building heat demand in most developed economies, space cooling demand will rise steadily across nearly all regions, and in particular in rapidly emerging economies with warmer climates.

Figure 4 **Projected global energy demand for heating vs cooling**



Large spectrum of action: Building professionals can act to improve the energy efficiency of building envelopes and equipment during the design, construction and management phases, even if this applies differently:

- **for new** and **existing** buildings,
- in **hot** and **cold** climates[13]
- **for the different real-estate segments, including:**
  - single-family houses and attached housing,
  - multi-storey housing buildings,
  - social housing,
  - private service buildings (e.g. offices and commercial space),
  - public buildings (e.g. schools, hospitals and public forums), and
  - informal settlements.

Residential housing, representing roughly 3/4 of global building floor space (IEA, 2016), is the main segment at stake, although it can also be more difficult to address as it is a fragmented segment (i.e. various owner, rental and occupant arrangements) that is typically built, renovated or maintained by an equally fragmented mix of individuals, small enterprises and buildings-related institutes or organisations (e.g. public housing agencies and housing associations).

13 *According to the Köppen climate classification system, hot climates cover group A, B and part of C, and cold climates cover group D, E and part of group C.*

Consequently, it is often easier to:

- start energy efficiency with more concentrated building segments such as social housing, public buildings and large private service buildings;
- focus first on buildings with large potential energy efficiency gain and emissions reduction;
- consider a large-scale effort, in order to create appropriate market scales for cost-effective material and equipment;
- collaborate with manufacturers and retail networks, as they play an important role in fostering and accelerating technology diffusion of high-efficiency material and certified equipment;
- ensure that continuous training is available to all key actors in the industry.

2. **The need to take immediate action, given the investment cycles in buildings.** The investment cycles related to the various sources of emissions in buildings have different life spans: some investments or actions will have short-term results (e.g. improved energy efficiency and reduced operating emissions), while others will only show results in the longer term (e.g. life-cycle emissions from new construction of low-carbon, energy-efficient buildings). The lifetimes of those investments represent different challenges and opportunities. By 2050, for example, boilers will have had 2 to 3 cycles of investment, while roofs and building facades are likely to only have had 1 to 2 cycles of renovation. Thus, renovation works would need to be coordinated strategically over time, to avoid lock-in of carbon-intensive investments. This coordination should also extend to the energy performance and GHG intensity of building equipment, to ensure that the most efficient, cost-effective and least carbon-intensive investments are made over the coming decades. It is hence crucial to seize all opportunities at every investment stage to improve building energy performance while ensuring that those investments are aligned with long-term energy and emissions ambitions.

3. **The links with upstream energy and emissions, as electricity and heat have to be taken into account.** The supply sector (e.g. for district heating and cooling) is of fundamental importance to the buildings sector, where electricity and commercial heat account for nearly [40%] of global final energy consumption in buildings (IEA, 2016) including appliances. Conversely, a major demand on the supply sector comes from buildings: half of global electricity consumption is used in buildings, and the buildings sector is the first consumer of natural gas in many countries. Dramatic reductions of building energy demand will have a strong impact on the overall energy sector, while decarbonising energy supply will contribute to a decarbonised buildings sector.

4. **The diversity of national circumstances has to be taken into account in setting global policies and technical goals for the built environment.** Every country has different norms to follow and different objectives according to its own national priorities. For instance, the demolition and reconstruction rhythms, the demand for new housing, and the perceived comfort for heating and cooling needs vary greatly across countries due to climate, socio-demographic influences and cultural and behavioural norms. Hence, a flexible technology policy approach is crucial to meet challenging performance goals across the global buildings sector.

5. **Effective integration of all levels of government remains a key component to unlocking cohesive policies, strategies and plans in the building and construction sector,** to advance Nationally Appropriate Mitigation Actions (NAMAs) and NDCs.

Local and subnational governments often have the mandate to adopt and implement building efficiency codes and standards, certifications and performance information and energy efficiency improvement targets.

In addition to regulation, local and subnational governments can incentivize and finance smart, compact, low-carbon development, serving as hubs to spur growth and connect a wide range of stakeholders - from builders, technology developers, manufacturers and utilities to business and household consumers.

National governments have the power to set enabling framework conditions for visionary roadmaps, policies and plans, to accelerated low-carbon urban development for enhanced action at all levels of government.

II. TOWARDS ENERGY-EFFICIENT, ZERO GHG EMISSIONS AND RESILIENT BUILDINGS WELL BEFORE THE END OF THE CENTURY

Unlike other sectors, the building sector varies substantially from country to country, which means that the needs and measures required to decarbonise it are different according to locations. This **Roadmap identifies the following key steps** to enable the transition towards an energy-efficient, low-GHG and resilient real estate that can be implemented in different ways through different mixes of measures, whilst still converging towards the same end.

The Roadmap is not composed of sequential steps, but it presents a logical order or priorities. It can also be considered as a frame to present and report policies and measures for the transition to a low-GHG real estate.

1 Implement urban planning policies for energy efficiency

The form and compactness of buildings, as well as mutual shading, have a great influence on energy demand in buildings and solar power capacity. They are framed by rules set in urban planning policies. Their impact on energy consumption and local energy production should be taken into consideration when defining urban planning policies and urban development projects (e.g. new urban districts).

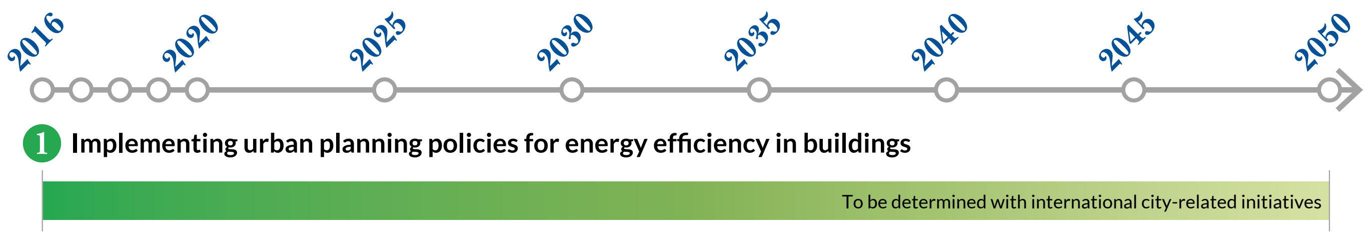
a A global target could be that all countries have urban planning policies in place that take into account the long term goal of decarbonising the building sector.

b It may include reinforced targets for new district development, as a systemic approach integrating energy demand and supply at district level delivers more efficient solutions. District heating and cooling systems have to be integrated in planning policies as well: a related target could be set up that include the number of buildings connected[14].

Furthermore, urban planning plays an important role in the prevention of climate risks exposition (e.g. avoid critical equipment in the lower floors...).

14 This aspect is included in II.5 „Decarbonized energy".

Graph1 **Timeframe for urban planning for energy efficiency**



2 Accelerate the improvement of existing buildings' performance

Considering the fact that in many countries the existing building stock (= not recently completed buildings) today will represent the large majority (i.e. 2/3 or more) of the overall building stock (floor area) and building-related emissions in 2050, the performance of today's existing buildings has to be improved to be close to zero emissions at least by 2070[15] through an increase of the renovation rate*[16] as well as an upgraded level of energy efficiency performance required. In addition to deep renovation (see footnote 16), maintenance and replacement works on existing buildings can benefit from the integration of energy efficiency measures as a no-regret solution.

In any case, increasing renovation rates needs a better access to finance.

15 *2 degrees' scenarios (2DS) targets require us to go to zero emissions absolute by 2100 (Paris Agreement). Other scenarios well-below 2 °C suggest to go to zero emissions closer to 2050-60. 2070 is a temporary proposal to be discussed by scientific experts.*

16 *Standalone works concerning equipment and building components (e.g. boilers, windows...) decided in the context of maintenance and replacement are not considered as refurbishments and are not counted in the renovation rate. Renovation rate concerns only deep renovation, meaning a coordinated package of works that significantly reduce the energy consumption. In the IEA Technology Roadmap on Energy Efficient Building Envelopes (2013), deep renovation is considered to mean refurbishment that reduces energy consumption by 75% and limits energy consumption for heating, cooling, ventilation, hot water and lighting to 60k Wh/m²/yr (GBPN, 2013).*

2.1 *Significant increase of renovation operations including energy efficiency.*

Renovation rates for deep energy-efficient refurbishments have to be increased so that the global building stock is fully renewed by 2070:

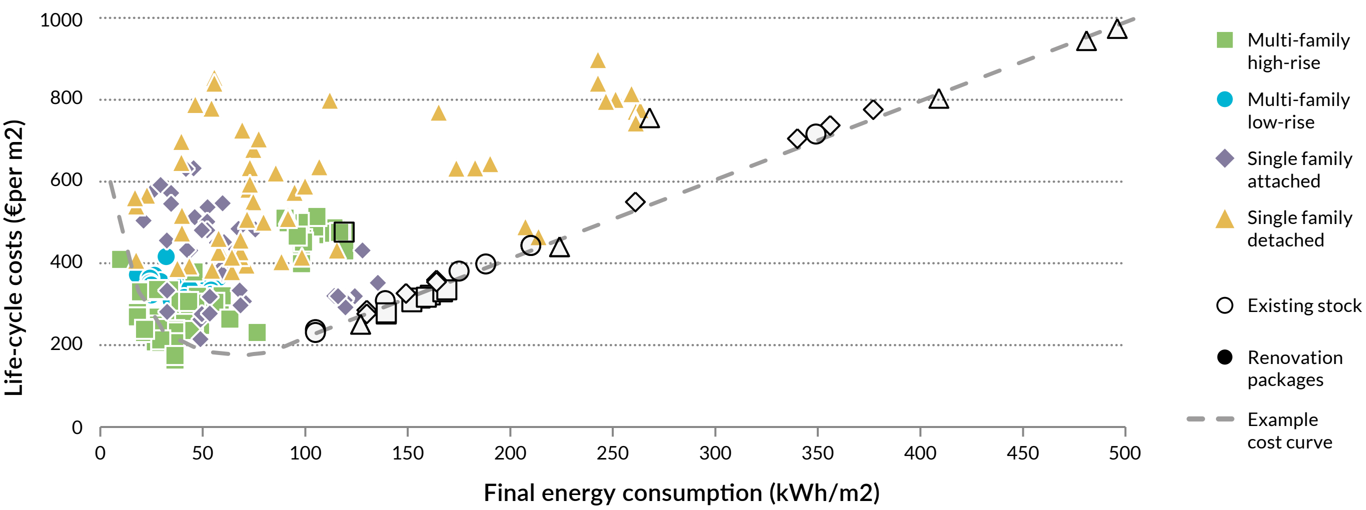
a Renovation rates in industrialised countries to reach 2% on average of the existing stock by 2025 and 3% by 2040.

Today's renovation rates generally amount to 1% or less of the existing stock each year, typically with energy efficiency improvements in the order of 10% to 15%. These improvement rates are not in line with global energy and emissions targets to limit average temperature rise to 2°C or less. Moreover, numerous studies have demonstrated that these levels of renovation investments are often not at the cost-effective technical potential of building energy-efficiency measures.

b Renovation rates reaching 1.5% by 2025 and 2% by 2040 in developing countries.

c Quick-win solutions: a key element should be to pursue policies that will ensure that this area is improved for all buildings but especially for government assets as an initial initiative.

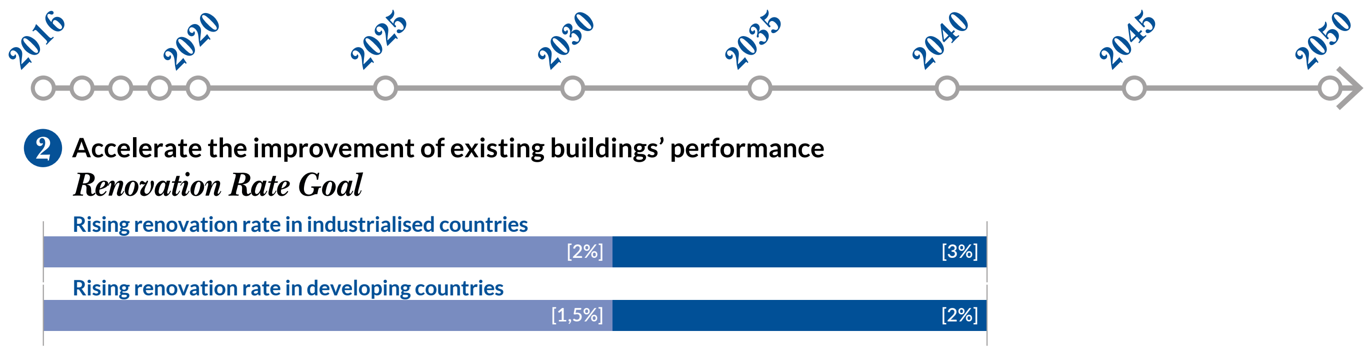
Figure 5 **Example of existing versus potential building envelope renovation packages in Turin, Italy, relative to life-cycle costs**



Note: This figure shows an optimum of renovation cost around 50/60 KWh/m²

Source: IEA Energy Technology Perspectives 2016 with Torino Polytechnic University (IEA, 2016)

Graph2.1 **Timeframe for Energy Renovation activity**



2.2 *Upgrade of the level of energy efficiency of each operation, in line with long-term standards:*

a Set up global progress performance goals for heating and cooling demand after deep renovation [wh/m²/HDD* or CDD* + sustainability criteria according to cold as well as hot climate].

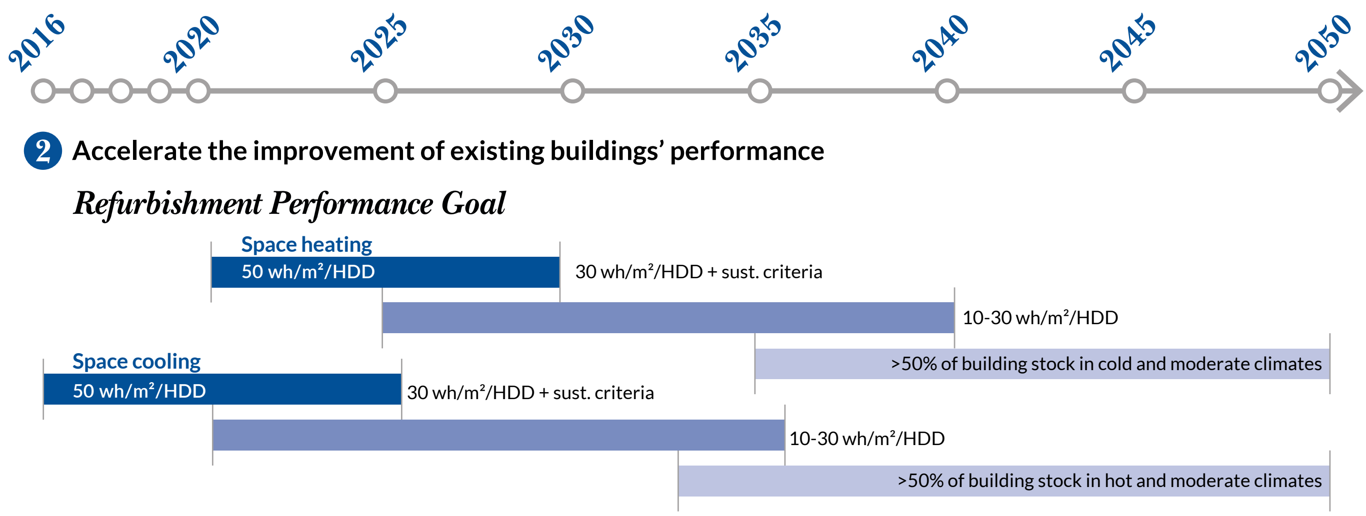
b For maintenance and replacement works, partial improvements can be achieved as a step leading to deep renovation (see renovation booklets or passports 1.3) for roofs, windows...

In both cases, a mix of policy instruments that take into account different interests of tenants and landlords can be used to upgrade the level of energy efficiency. Recommendations in that regard include:

- Promotion of energy-efficient refurbishment of the building envelope (e.g.: R* min or U* max or Gain or max heating and cooling demand); including air sealing, highly isolated windows.
- Replacement of inefficient heating and cooling systems (e.g.: COP*<1,5 for heating and COP<2,5 for cooling before 2025).
- Improved efficiency of boilers and especially hot water heaters. Encouraging the up-take of performant heat pump and solar system for space and water heating.
- Optimizing the energy use of technical buildings systems by appropriate dimensioning, system adjustments and control[17] (e.g. effective controls for generation, distribution, and emission at full and partial demand loads to match energy use to building and occupant needs.
- Integration of renewable energy systems.
- Reinforced targets for renovation of clusters of buildings or districts.
- Introduction of tools (such as building passports) to allow for step by step (staged) deep renovations.

17 *Depending on the building type, roughly system losses can represent 50% of heat consumption.*

Graph2.2 **Timeframe for Energy Renovation performance**



3 All new buildings achieve nearly net zero operating emission performances

In the current context of worldwide population growth (2,5 billion increase by 2050), the global stock of buildings is estimated to grow in m² by over 90% by 2050 (IPEEC), which means an increase of around 200 billion m². Hence, the priority should be given to policies, regulation and guidance that promote energy efficiency and functionality and that facilitate passive solar design by site design, layout and fenestration, taking into account a life cycle approach when data are available. There is increasing evidence that well-designed energy-efficient buildings often promote occupant productivity and health (Fourth Assessment Report of the IPCC, 2007). In many dense areas, net-zero operating emissions goals will be considered at the system level: campus, community or district level with decarbonised electrical or heat grids.

3.1 *Achieving a large uptake of nearly Net-Zero Operating Emissions from new buildings*[18] before 2025 in cold climates[19] (where all new buildings can be at least passive).*

3.2 *Achieving a large uptake of nearly Net-Zero Operating Emissions from new buildings by 2030 in hot climates[20] where the temperature challenges require different responses.*

Feasibility and cost-effectiveness must be considered in the aim of increasing the number of Net-Zero Operating Emissions Buildings.

At the conception and construction stage, this can be done through:

- **Ambitious thermal regulations or incentives for new constructions** that include:

  a. very low energy demand for heating and cooling
  b. ambitious primary energy performance targets to be defined
  c. targets for using renewable energy sources to cover the largest possible share of the remaining energy demand of the building

- **Development of mixed usage buildings** (alternate housing and office floors in the same building) to smooth peaks of energy demand and raise the overall energy performance of the building.

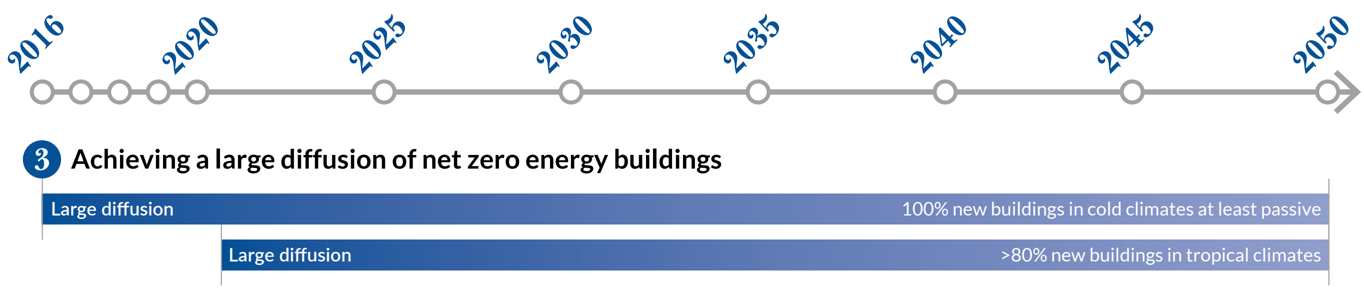
This requires major changes and the mobilisation of the entire value chain

of particular importance will be the consideration by architects and policy makers of:

- Place and envelope
- Bioclimatic architecture that minimises air conditioning demand in all climate zones
- Local and traditional knowledge and materials
- Technology transfer

During the life cycle of buildings, it will be essential *to keep the remaining energy demand as low as possible (see next session on improving the management of buildings).*

Graph3 **Achieving a large diffusion of net zero operating emissions buildings**



Every time there is the "*" sign, it means that the concept is further explained in the glossary.

18 It is recognised that total life-cycle GHG emissions are the most relevant impacts on the environment, but given the difficulty of calculating embodied emissions, operating emissions are considered to be an adequate measure for this first cycle of the Global Roadmap.

19 See footnote n. 13. This also includes intermediate climates.

20 See footnote n.13. This also includes tropical climates.

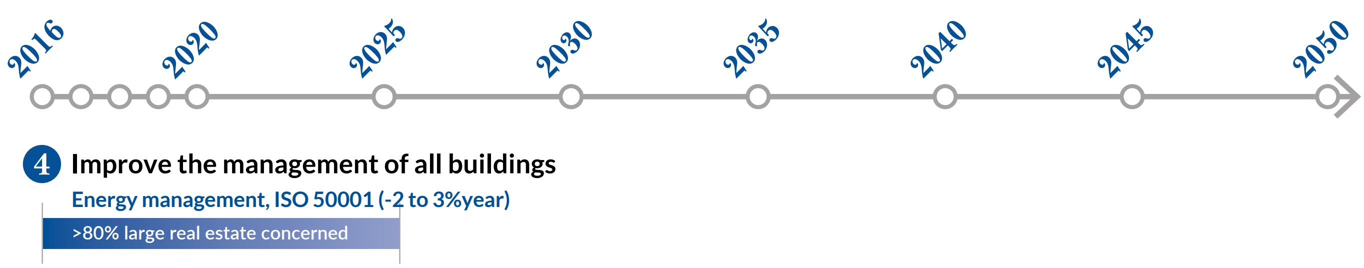
4 Improve the management of all buildings

The delivery of highly energy-efficient new or renovated performant buildings is essential. Yet, it is equally important to maintain this performance over time. It is crucial to optimize not just technologies, but behavioural and operational aspects of energy and GHG performance. To do this, design and management tools must integrate the issue of energy management. Objective-based building management policies like ISO 50001, or renovation booklets, are good examples of such tools.

Policy instruments to improve energy management in buildings include:

- Developing energy management practices with a target of energy reduction of 2% to 3% per year or 20% to 30% by 2025], with the aim to cover 80% of large real estate by 2025.
- Deploying individual cost-effective room temperature control and energy metering especially for residential, and digitalisation of controls for service buildings with a target of 100% by 2030. Better knowledge of energy consumption thanks to energy metering allows for a reduction of energy bills of a few percent. The introduction of energy metering and energy control in service buildings can achieve from 10% up to 30% energy savings of the controlled energy (mainly lighting, heating and cooling) and is a quick win solution.
- Promoting information (for individuals and companies) to ease behaviour change and investment decisions for energy efficiency and renewable energies.
- Define metrics for occupancy rates of buildings to evaluate useless energy consumption or energy amortisation of embedded energy in materials and increase occupancy rates when socially acceptable. Thus, in management rules it is essential that multiusers for the same space are allowed.
- Developing individual building renovation booklets or passports with ambitious energy efficiency targets to be able to coordinate works over time, which are in line with the long-term strategy of decarbonizing the building stock. Each building will thus have a long-term strategy which is adapted to its own circumstances.

Graph4 **Timeframe for Energy management goal**



5 Decarbonised energy: decarbonise the energy and power supply for buildings load

As previously stated, buildings are not standalone energy objects but are deeply connected to energy grids, especially heat district grids. The remaining energy demand for heating and cooling, as well as lighting, should be covered by decarbonised energy, preferably by renewable energy (including heat pump technologies). On-site produced renewables should be preferably taken into account. Moreover, new energy services can be provided by buildings, such as energy storage (i.e. smart grid services and thermal storage).

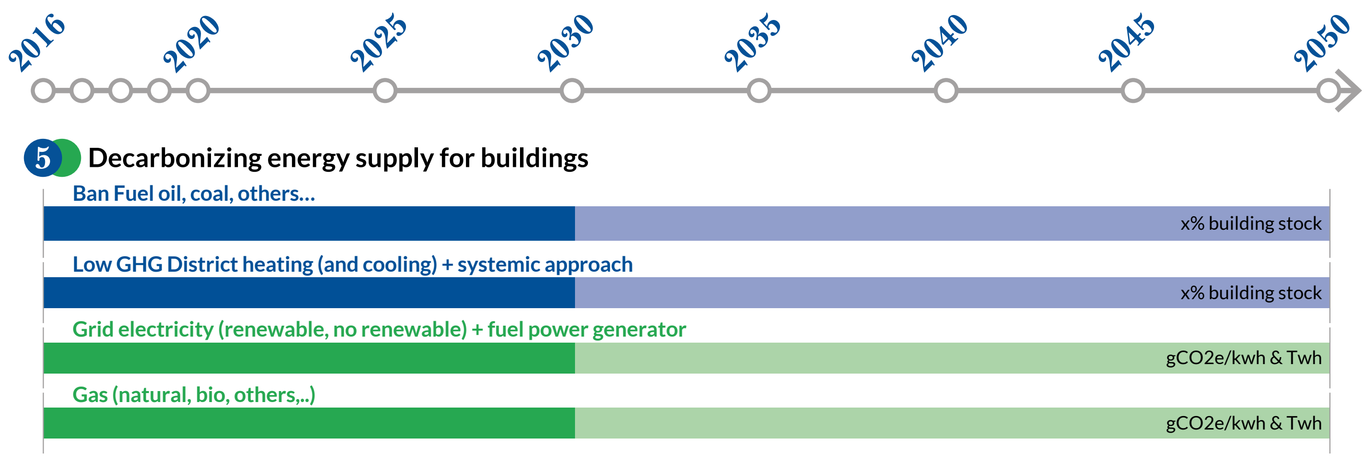
Thus, the building sector has a major influence on lowering the demand of high GHG content energy supply, mainly through the following actions:

- **a** Integrating on-site renewable energy if possible and economically more advantageous (as in Net-Zero Energy Buildings for instance).
- **b** Reducing drastically the installation of boilers using high GHG fossil fuels like coal and fuel oil.
- **c** Increasing the number of buildings connected to low-GHG heating and cooling district supply.
- **d** Developing energy services based on the valorisation of the thermal mass effects (i.e. inertia, phase change).

Still, it is important to recall the decarbonization targets of energy supply to ensure consistency. Energy policy has to have a dedicated chapter on decarbonisation of energy supply to buildings (see the IRENA* and IEA* Energy Roadmap) such as electricity, gas and heat.

- **a** Decarbonizing electricity, which is the base of all deep decarbonisation pathways.
- **b** Reducing the GHG content of gas supply. In many countries a gas network has been deployed, for which the buildings are the first clients. These networks can be used to inject low-GHG biogas and synthetic gas.
- **c** Using only biomass with no negative impact on LULUCF*. Biomass use for heating has a very low GHG footprint under the condition that it does not contribute to deforestation.

Graph5 **Timeframe for decarbonizing energy supply for buildings**[22]



Every time there is the "" sign, it means that the concept is further explained in the glossary.*

22 *Colour code of the graphs: green recalls goals addressed by actors/sectors/communities other than the building's sector ones. In this case, they are addressed by the energy supply sector.*

6 Reduced embodied energy and GHG emissions: reduce environmental impacts (life cycle approach) of materials and equipment: manufacture (extraction included), transport, maintenance, use and end-of-life

Construction activity in the building sector is generating a major flow of materials in every country, evaluated at 24%[23] of global raw materials removed from the earth with a large impact on climate change: GHG emissions or energy consumption are linked to every phase of the life cycle[24] of materials, from extraction or harvesting to manufacture, transport, construction, use and demolition. For instance, steel, bricks, cement (3% of GHG emissions), non-certified wood (deforestation issue), or heating and cooling systems using F-Gas (3% of GHG emissions), are some of the major building products or equipment and emitters of GHG. Technical solutions do exist. Furthermore, recycling construction materials represents a large benefit in GHG reduction.

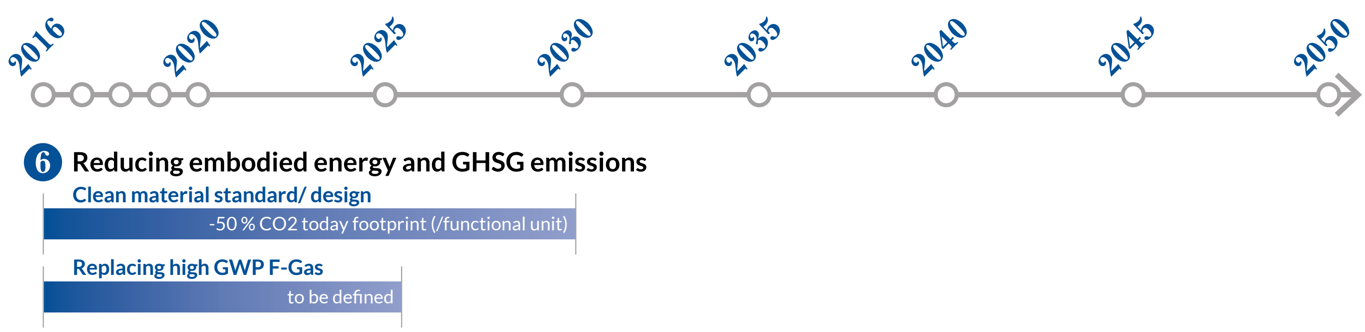
To sum up, scope 3 generally represents between 10 and 20% of buildings' carbon footprint. For Near/Net-Zero Buildings, this can reach 50%[25]. Thus, from now on, it is important to minimise embodied energy and GHG emissions of construction materials and technical systems, firstly for new buildings, and on a longer run for renovation of existing buildings.

Reduce the energy and GHG footprint of the major (in quantity) building materials; average -50% (functional unit) by 2030[26] and replace high global warming potential F-gas in heating and cooling system.

THIS CAN BE ACHIEVED BY:

- **a** Developing (cradle to grave, and when possible cradle to cradle) life-cycle approach in the building sector, so that a systemic, material-neutral and performance-based approach is guaranteed (positive global assessment).
- **a** Promoting wide knowledge and the adoption of low-carbon materials and technologies (e.g. wood and earth constructions, innovative concrete[27]) amongst professionals involved in the design and building process.
- **a** Acknowledging vernacular solutions as an alternative for low-carbon construction methods and bioclimatic performance.

Graph6 **Timeframe for reducing embodied energy and GHG emissions**



23 EU LoRe-LCA project (FP7)

24 The norm EN15804 describes a methodology of the CO_2 footprint assessment of any building products.

25 These figures are based on carbon-footprint calculations of real estate projects (mainly in France).

26 This point has to be clarified. Functional unit allows fair comparison of GHG performance.

27 Carbon footprint reduced by up to 70%.

7 Reduce energy demand from appliances

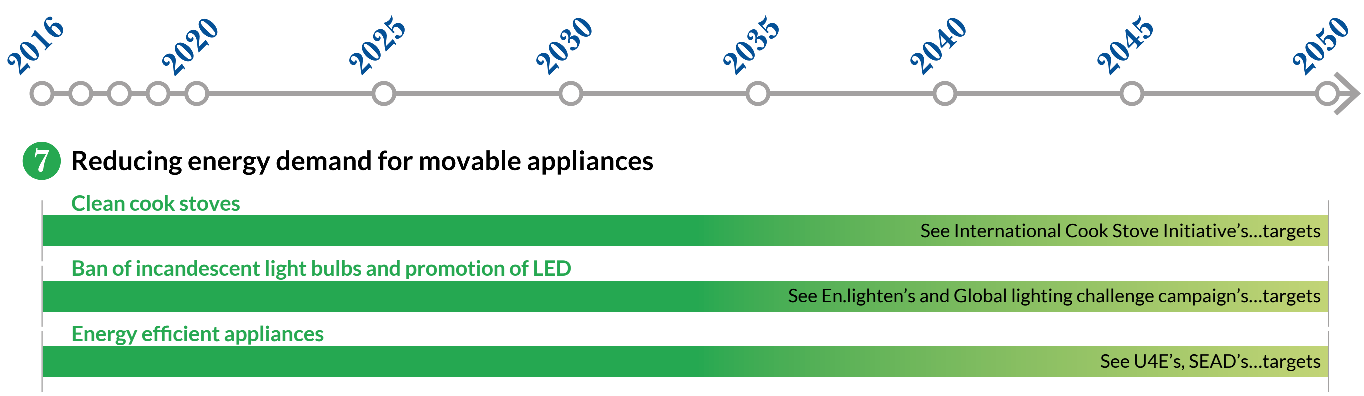
Emissions induced by the energy consumption coming from the use of movable indoor appliances (refrigerator, washing machine, IT equipment, lamp, hair dryer…) are growing. The individual gain in energy efficiency of each type of equipment does not compensate the larger use of this equipment by households or enterprises. The electric and electronic appliances' community is the most concerned.

This Roadmap does not set a specific target related to appliances, as other initiatives are directly targeting this issue, which is less under the direct responsibility of building professionals and more that of the consumers and appliance producers.

Many initiatives are also actively attempting to reduce the GHG emissions related to appliances, for instance (non-exhaustive list):

- **Cooking:** the International Cook Stove Initiative supports clean alternatives to wood-cook stoves. In that regard, IEA recommendation is to mandate minimum energy performance to achieve clean and sustainable cooking systems
- **Lamps:** UN Environment en.lighten calls for the ban of incandescent light bulbs and promotes LED deployment; the Global lighting challenge campaign's call for the deployment of 10 Billion High-Efficiency Bulbs initiated by the Clean Energy Ministerial. IEA recommendation, over this ban, is to set after 2025 a minimum performance of 100 lumens/watt for lighting
- **Appliances:** United for Efficiency (U4E) UN Environment-GEF partnership aims at deploying highly efficient air conditioners, refrigerators, fans, electric motors and distribution transformers; Super-Efficient Equipment and Appliance Deployment (SEAD) from the CEM. IEA recommendation is to mandate minimum energy performance for appliances and after 2025 for all electrical plug-loads

Graph7 **Timeframe for reducing energy demand for appliances**



8 Reduced climate change-related risks for buildings: upgrade adaptation

In the context of the Sendai Framework for Disaster Risk Reduction, countries are engaged in taking measures to reduce disaster risks.

Climate and climate change affects construction in three ways: they have a relevant influence on construction delays and thus costs; as climate changes, buildings' and building materials' design standards will have to change in order to withstand the new weather conditions; as the pattern of natural disasters changes, a change in the demand for rebuilding and repair is implied[28].

Upgrading building durability and resilience of all buildings by gradually addressing the building stock. To reach this goal, the upgrade of the most critical infrastructures (e.g. having a social and economic relevance, like hospitals, emergency centers, schools, power plants, production and storage of hazardous products etc.) at first offers the best social value.

THE PROPOSED STEPS ARE FOR INSTANCE:

- **a** 100% of the existing and new critical infrastructures are better conceived by 2030;
- **b** 80% of the existing and new buildings have integrated risk and adaptation in their conception and maintenance by 2050.

QUICK WINS:

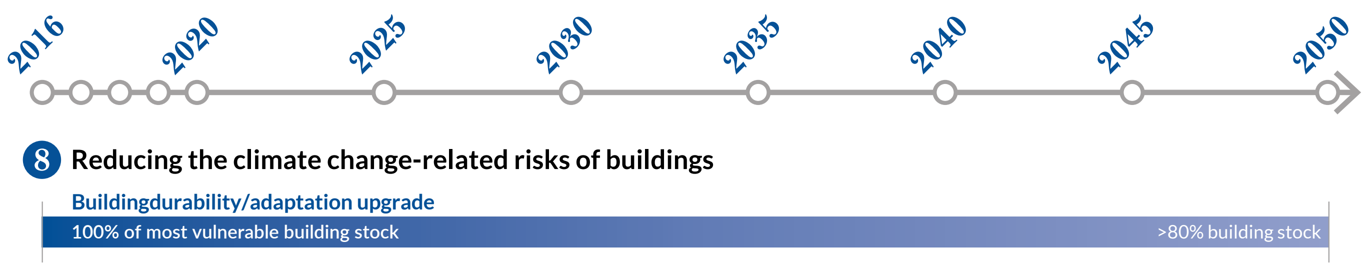
e.g. develop green and cool roofs. For instance, to prepare for more intense storms, some cities are using green infrastructure to capture rainwater before it can flood the combined sewer system, implementing green roofs, and elevating boilers and other equipment above ground[29].

In the case of new buildings, the implementation of urban planning rules integrating a risk approach (risk zoning) can prevent or lower the exposure to major climate risks.

28 *IPCC AR 5 Chapter 10 on Key Economic Sectors and Services: 10.5.2.2. Construction and Housing*

29 *Interalia [8.3.3, 26.3.3, 26.8.4] IPCC AR5 Technical summary*

Graph8 **Timeframe for reducing the climate change-related risks of buildings**



III. MEASUREMENT OF PROGRESS AND IMPACT

Once these steps with their sub measures are implemented (once again this approach is not prescriptive for countries, but a collective framework that can have different implementation strategies according to the needs and realities of each country), it is pivotal to the achievement of effective climate mitigation, to monitor, and report progress of measures and impact on building-related GHG emissions at all levels of government.

1 Measurement of progress

The Roadmap is based on 13 objectives using 15 indicators (see Annex 2), which will allow for progress to be tracked and for policy implementation to be monitored. Most of these indicators already exist in many countries, especially in the OECD. It is crucial that every country builds the capacity to improve available data and indicators.

Data availability: There is a growing need to monitor and report on energy efficiency due to the increasing level of energy efficiency policies and measures that are in place. The building sector is estimated to be the first sector to define and follow an international sectoral system of reporting. Many experiences of good practices and methodologies in reporting at national and international levels already exist (IEA, NEEAP in EU, UN-ECLAC).

2 Measurement of impact

Under the UNFCCC Climate Convention, states have to report their GHG emissions regularly according to the UNFCCC Common Reporting Framework (CRF).

Data availability: Most data needed to evaluate emissions from buildings (Scope 1, 2, 3) can be found in the UNFCCC inventories (CRF tables). Annex I Parties to the Convention have to report their national GHG inventories on an annual base, whereas Non-annex I Parties report them every 2 years (in their Biannual Update Reports and in their National Communications). Yet, these reports are not always available for every country. UNFCCC ensures that data are comparable between countries (via the use of IPCC guidelines) and reliable: Annex I Parties' inventories are subject to an annual technical review process, Non-annex I Parties' reports are addressed through the process of international consultation and analysis (ICA).

At local and sub-national level several methods exist. The Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) proposes a standardized GHG emissions inventory framework employed in the carbonn Climate Registry for enhanced horizontal aggregation and vertical integration.

Proposal for UNFCCC CRF: As far as buildings are concerned, the GHG inventory only names emissions from buildings under the sections UNFCCC CRF 1.A 4 a and b, which are only buildings' direct emissions (Scope 1). To limit direct emissions to heating, hot water, cooling and lighting, detailed end-uses are needed, and indirect emissions need to assess the share of electricity and district heat for buildings

It will thus probably be necessary to reframe the UNFCCC CRF so that the data concerning the Scopes 2 and 3 are clearly identified, extracted and gathered together. Moreover, as the number of Near/Net-Zero buildings has to increase, a "Scope 0" might need to be added to the 3 Scopes framework, which will cover the self-made energy production that is consumed by the building itself.

GABC PROPOSAL FOR BUILDING-RELATED GHG EMISSIONS' INVENTORIES

Scope 0: self-energy production with no emissions

- on site electricity: photovoltaics, micro-wind turbine...
- on site heat: solar panels, heat pump, geothermal, biomass (impact on LULUCF)

Scope 1: direct emissions of the building sector (UNFCCC CRF 1. A 4 a and b)

- gas (fossil, bio, other)
- other fossil: fuel oil, coal
- F-Gas of heating and cooling system (Gas Montreal and Climate Convention)

Scope 2: indirect emissions of buildings in the energy sector (part of UNFCCC CRF 1. A 1 a)

- grid electricity (renewable and non-renewable)
- heat district (heating and cooling)

Scope 3: indirect emissions generated by [life cycle of] construction materials

- GHG emissions from major building materials manufactures sector (part of UNFCCC CRF 1 A 2 f energy + 2 A 1 process)
- LULUCF from wood consumption for buildings

IV. NEXT STEPS

This document presents the first draft of the Buildings and Construction Roadmap. It was prepared through input and discussions of the GABC in October 2016, distributed to all GABC members, and presented during the GABC Partner meeting on 09 November 2016 and at the Building Action Day at COP22 in Marrakech on 10 November 2016. The Roadmap will be periodically reviewed and updated by the GABC.

The Global Roadmap is accessible on the GABC website (www.globalabc.org)

V. GLOSSARY

Building envelope: the physical parts of a building that form the primary thermal barrier between interior and exterior (roof, ceilings, windows, exterior doors and walls).

Building-related energy: energy for heating, cooling, hot water, lighting and ventilation.

CDD: cooling degree day. Evaluation of annual cooling need.

COP (in energy): coefficient of performance

Energy in buildings: building-related energy + cooking, IT, domestic electrical goods.

Energy intensity: it is calculated by the ratio between energy consumption and GDP.

Global Alliance for Buildings and Construction (GABC): launched on the 3rd of December 2015 during the Building Day at COP21 in Paris, Le Bourget, by France and UN Environment*, GABC gathers together 23 countries and 70 partner organisations. The Alliance aims at supporting and accelerating the implementation of the NDCs, and thus facilitate the implementation of the Paris Agreement for the buildings and construction sector in terms of energy efficiency gains, growth of renewable energy and GHG emissions reduction. Moreover, the Alliance aims at dramatically reducing the GHG emissions of the global building stock by increasing the share of eco-friendly buildings, whether new or renovated.

HDD: heating degree day. Evaluation of annual heating need.

IEA: International Energy Agency.

IRENA: International Renewable Energy Agency.

ISO: International Standard Organisation.

ISO 14064: norms on GHG accounting and verification, published on the 1st of March 2006 by the International Standard Organisation.

LULUCF: Land Use, Land-Use Change and Forestry.

Montreal Protocol on Substances that Deplete the Ozone Layer (a protocol to the Vienna Convention for the Protection of the Ozone Layer): an international treaty designed to protect the ozone layer by phasing out the production of numerous substances that are responsible for ozone depletion. It was agreed on 26 August 1987, and entered into force on 26 August 1989.

NEEAP: National Energy Efficiency Action Plans are an obligation for EU countries under the Energy Efficiency Directive. EU countries must draw up these plans every three years and on this base they publish an annual report on their implementation.

Net-Zero Operating Emissions Building: a highly energy efficient residential or service building that produces on-site, or procures, enough carbon-free renewable energy to meet building operations energy consumption annually.

R (thermal resistance): evaluates the insulation factor of surfaces. Its unit is (m^2.delta temperature)/W .

Rebound effects as first described by William Stanley Jevons in 1865: economic gain coming from energy saving that triggers a new behaviour generating new energy consumption (e.g. better thermal insulation can lead to a raise of indoor comfort temperature level).

Renovation rate: renovated building surface divided by total not renovated building stock surface (in m^2 or equivalent residential unit).

U (thermal transmittance co-efficient): the opposite of R. It measures the flow of energy passing through a structure (expressed in W/(m^2.delta temperature). It can evaluate the global needs of the building envelope.

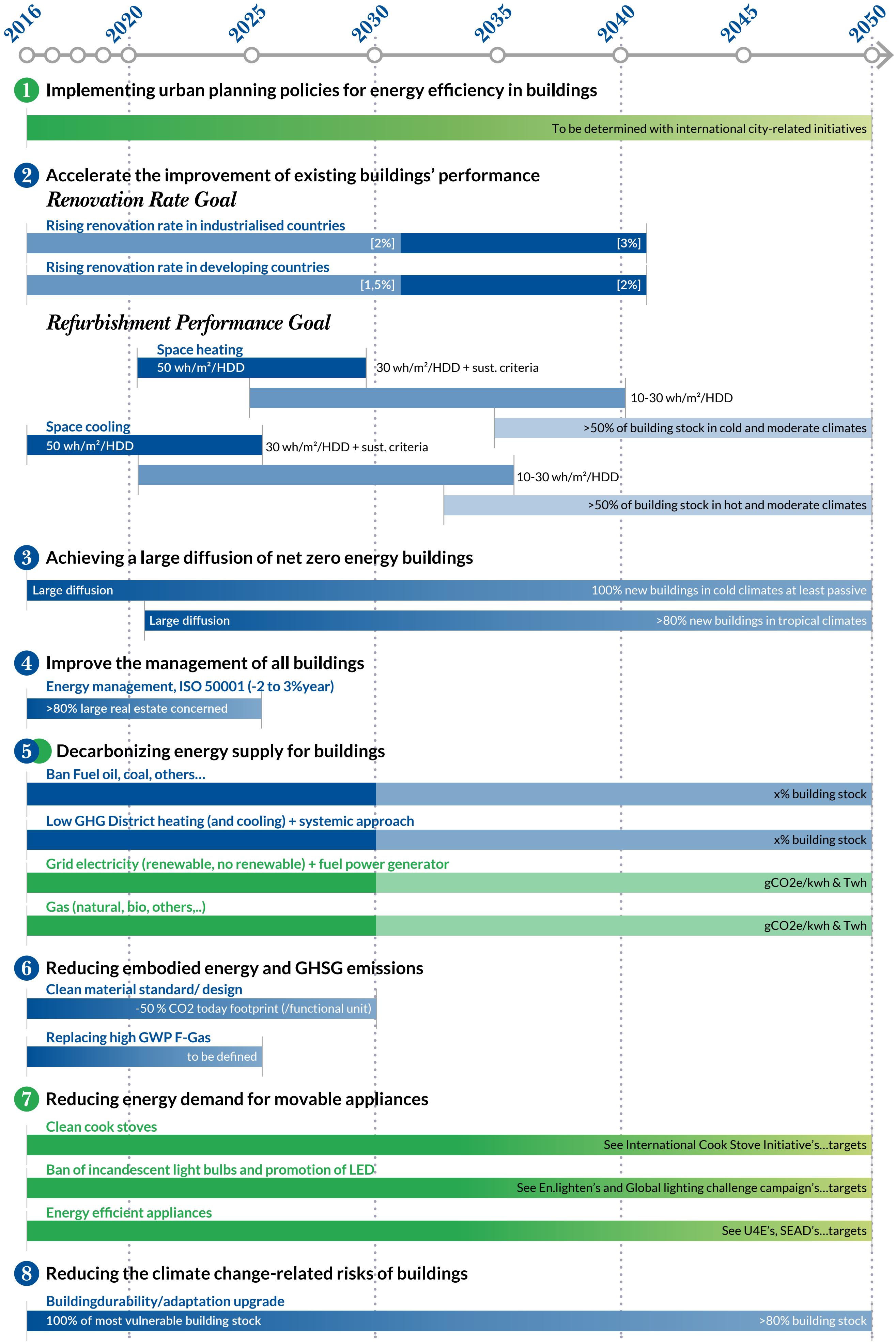
UN-ECLAC: United Nations Economic Commission for Latin American and the Caribbean.

UNFCCC: United Nations Framework Convention on Climate Change.

ANNEX 1 – TIMEFRAME OF THE GLOBAL ROADMAP'S STEPS

Colour code of the graphs:

- *GOALS OF THE ROADMAP*
- *REMINDER OF GOALS ADDRESSED BY OTHER SECTORS/COMMUNITIES*


2016
2020
2025
2030
2035
2040
2045
2050
1 Implementing urban planning policies for energy efficiency in buildings
To be determined with international city-related initiatives
2 Accelerate the improvement of existing buildings' performance
Renovation Rate Goal
Rising renovation rate in industrialised countries
[2%]
[3%]
Rising renovation rate in developing countries
[1,5%]
[2%]
Refurbishment Performance Goal
Space heating
50 wh/m²/HDD
30 wh/m²/HDD + sust. criteria
10-30 wh/m²/HDD
>50% of building stock in cold and moderate climates
Space cooling
50 wh/m²/HDD
30 wh/m²/HDD + sust. criteria
10-30 wh/m²/HDD
>50% of building stock in hot and moderate climates
3 Achieving a large diffusion of net zero energy buildings
Large diffusion
100% new buildings in cold climates at least passive
Large diffusion
>80% new buildings in tropical climates
4 Improve the management of all buildings
Energy management, ISO 50001 (-2 to 3%year)
>80% large real estate concerned
5 Decarbonizing energy supply for buildings
Ban Fuel oil, coal, others...
x% building stock
Low GHG District heating (and cooling) + systemic approach
x% building stock
Grid electricity (renewable, no renewable) + fuel power generator
gCO2e/kwh & Twh
Gas (natural, bio, others,..)
gCO2e/kwh & Twh
6 Reducing embodied energy and GHSG emissions
Clean material standard/ design
-50 % CO2 today footprint (/functional unit)
Replacing high GWP F-Gas
to be defined
7 Reducing energy demand for movable appliances
Clean cook stoves
See International Cook Stove Initiative's...targets
Ban of incandescent light bulbs and promotion of LED
See En.lighten's and Global lighting challenge campaign's...targets
Energy efficient appliances
See U4E's, SEAD's...targets
8 Reducing the climate change-related risks of buildings
Buildingdurability/adaptation upgrade
100% of most vulnerable building stock
>80% building stock

ANNEX 2 – SUMMARY OF OBJECTIVES AND INDICATORS

Goals	*Suggested Targets & Dates*	*Accounting Units*
	Based on Existing Data or Indicators	
Improvement of existing buildings' performance	Close to zero emissions from today's existing buildings at least by 2070	Petajoules
Renovation rate goal for industrialized countries	2% on average of the existing stock by 2025 and 3% by 2040	% of renovation of stock, but what is called renovation (in meter square? Only deep and total renovation?)
Achieving a large uptake of net-zero energy buildings before 2025 in cold and intermediate climates	100% new buildings in cold climates at least passive by 2025	Operating emissions, in %
Decarbonizing energy supply for buildings	% of building stock with high GHG fuels; % of building stock with low GHG district heating/cooling; CO_2 content and total consumption of electricity and gas	% building stock & gCO_2e/kwh&Twh
	Reachable Indicators	
Renovation rate goal for developing countries	1,5% on average of the existing stock by 2025 and 2% by 2040	%
Performance goal for space heating after refurbishment	From 50 wh/m^2/HDD in 2020 to 30 wh/m^2/HDD + sust. Criteria in 2030, to 10-30 wh/m^2/HDD in 2040	wh/m^2/HDD* or CDD* + sustainability criteria according to cold/hot climate
Performance goal for space cooling after refurbishment	From 50 wh/m^2/HDD today to 30 wh/m^2/HDD + sust. Criteria in 2025, to 10 wh/m^2/HDD in 2035	idem
Achieving a large uptake of net-zero energy buildings before 2030 in hot and intermediate climates	>80% new buildings in tropical climates by 2030	Operating emissions, in %
Energy management goal	Energy reduction of 2% to 3% per year or 20% to 30% by 2025, with the aim to cover 80% of large real estate by 2025	% energy consumption
Energy management goal	Achieving 100% energy metering of delivery point or energy control in service building by 2030, achieving 30% energy savings of the new controlled energy	% energy delivery point, % service building
Replacing high GWP F-Gas	tbd	
Reducing the climate-change- related risks of buildings	100% of most critical building infrastructure by 2030, >80% of building stock upgraded in terms of building durability/adaptation by 2050	% of most critical building infrastructure, % of the building stock
	More Difficult Indicators if not Limited to Main Products	
Reducing embodied energy and GHG emissions	-50% CO_2 today footprint	tbd

ANNEX 3

Kaya identity: an equation relating factors that determine the level of human impact on climate, in the form of emissions of the CO_2. If we adapt the Kaya identity to the building sector, we would have as follows:

CO_2 = population x (social needs/population) x (energy/social needs) x (CO_2/Energy)

When the population and the social needs increase, the first step to stabilise and decrease GHG emissions is to dramatically reduce the energy used to cover these needs by investing in energy efficiency. This will trigger the reduction of the investments needed to provide energy as well as the annual energy costs for the population.

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