International Center for Climate Governance

# Energy-efficient buildings for low-carbon cities

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**Abstract**

Buildings represent a key area for climate change mitigation. They account for approximately 30% of global energy consumption, and in turn generate around 20% of all energy-related greenhouse gas (GHG) emissions. Current trends in population growth and urbanization will lead to a significant need for new buildings in the near future. Such growth will bring with it a rise in energy consumption and associated GHG emissions – and not just from residential buildings but also the commercial and industrial developments that accompany them. Considerable opportunities exist to realize significant gains in energy efficiency and implement low-carbon strategies in urban areas.

## The building sector, cities, and climate change

Around one-third of global greenhouse gas (GHG) emissions are the product of buildings; a value that is anticipated to double by 2050 if no action is taken (UNEP, 2015). As cities house the majority of the world's population and building stock, and are responsible for approximately two-thirds of global energy use and over 75% of energy related GHG emissions (UNEP, 2014), they are inherently part of the discussion. Buildings account for more than 40% of global energy use, and approximately 30% of energy-related GHG emissions (Lucon et al. 2014; UNEP, 2014), however, energy use and emissions from buildings have the potential to decrease significantly if the existing best practices and technologies are widely diffused, simultaneously supporting the transition to low-carbon cities.

The importance of buildings in the international climate change discourse was recently highlighted at the United Nations Framework Convention's 21st Conference of the Parties (COP21), where an entire day was dedicated to drawing attention to the building sector's potential to assist in limiting global warming to below 2°C. The Global Alliance for Buildings and Construction (UNFCCC, 2015) was launched by 20 countries and over 60 organizations with the goal of reducing emissions and building resilience by encouraging the widespread adoption of the best existing policies and most efficient building materials, technologies, and designs around the world.

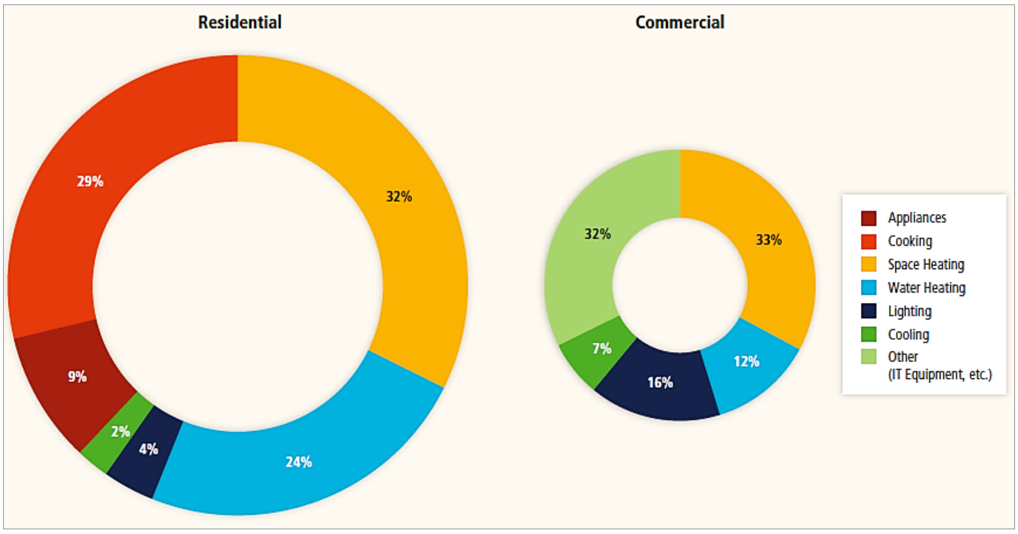
Beyond decreasing consumption, energy efficiency technologies are furthermore cost-effective, typically paying back well within the building lifetime (Lucon et al., 2014), providing the benefits of both savings and sustainability. In fact, implementing energy efficiency measures can reduce the global cost of limiting warming to 2°C by up to $2.8 trillion by 2030 compared to pursuing a more energy intensive pathway (Fraunhofer ISI, 2015). A February 2016 report on Sustainable Real Estate Investment (UNEP FI 2016) carries forth this idea of engaging financing institutions promoted by the Alliance at COP21, noting that global real estate asset managers, representing around $50 trillion, are an important decision making group to include in the discourse on climate change, as they are responsible for the implementation of climate friendly and greener properties. The integration of climate and social considerations into real estate strategies presents business opportunities and serves to "future-proof" the value of investments. The Alliance aims to support the mainstreaming of actions that have the potential to avoid about 3.2 $GtCO_2$ by 2050, noting that financial returns could reach 124% with a 50% increase on investment in energy efficient buildings.

The benefits of improving the use of energy in buildings for the climate, society, and economy are clear. Which technologies to use and the means of encouraging uptake require some further exploration. Since buildings are concentrated in cities, along with more than 50% of the current global population and a projected 2.5 billion more urban dwellers by 2050, consideration should be given to the types of energy efficiency improvements to focus on and the use of urban planning and energy policy design in implementing them.

## Energy consumption in buildings

The building sector is characterized by a variety of building types (e.g. public, residential, commercial, and industrial, etc.) that utilize a large number of technologies for heating, cooling, and lighting, and a wide range of building materials and building techniques. Figure 1 shows the final energy consumption by end-use for both residential and commercial buildings in 2010. The services demanded of buildings – lighting, warming in the winter, cooling in the summer, water heating, electronic entertainment, computing, refrigeration, and cooking – require significant energy use.

**Figure 1. Global final energy consumption by end-use for buildings in 2010 (Lucon et al. 2014)**




Energy consumption in buildings has grown in aggregate over time, and energy use and associated GHG emissions will continue to grow without action supported by effective policy design. In the building sector alone, this could mean a doubling of energy use and emissions by 2050 (Lucon et al. 2014). The sector's global final energy consumption has already doubled between 1971 and 2010 to reach 2,794 Mtoe, driven by population increase and economic growth (IEA et al. 2013). Likewise, GHG emissions from the building sector have more than doubled since 1970 to reach 9.18 Gt$CO_2$eq in 2010; most of these GHG emissions (6.02 Gt) are indirect $CO_2$ emissions from electricity use in buildings (Lucon et al. 2014). However, technologies and skills needed to break from this "business as usual" scenario and to make concrete reductions in energy use and emissions already exist. These include the policies and technologies capable of making new buildings 50% to 90% more energy efficient than current prevailing practice, and improving the performance of existing buildings (USGBC, 2009).

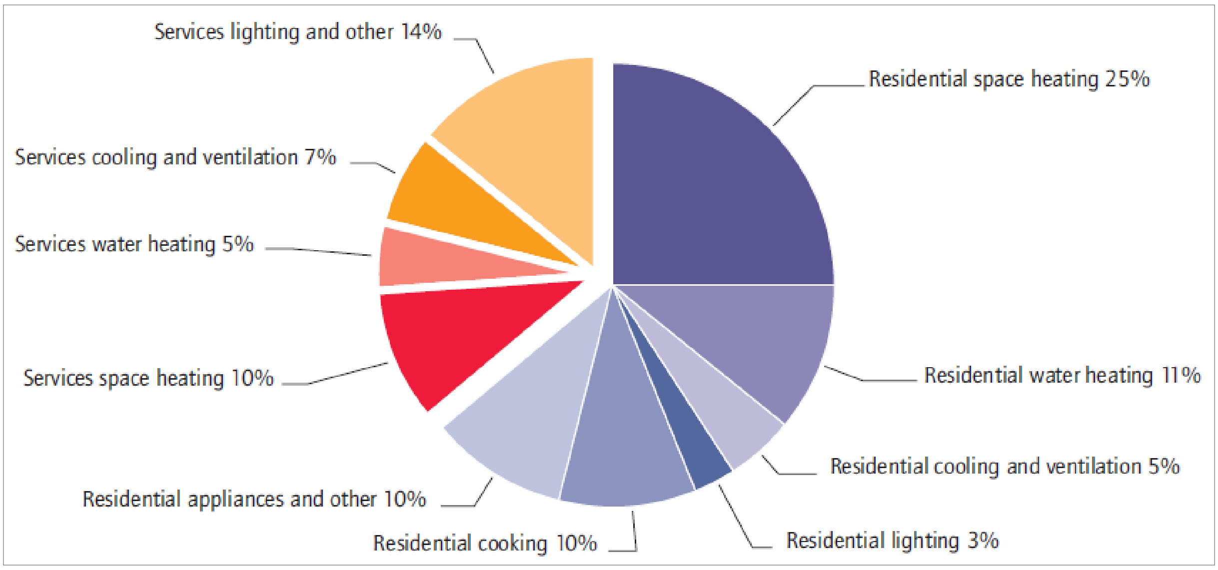
Methods to decrease energy consumption and to reduce and ultimately phase out the $CO_2$ emissions produced by the building sector include transforming the ways that buildings are designed, built, and operated. Reductions in building-related GHG emissions can be achieved in several different ways: by increasing the amount of electricity generated from low- and zero-carbon technologies, by retrofitting existing buildings to reduce energy consumption and improve energy efficiency, and by constructing new buildings to be low- or zero-energy buildings.

## Designing low-energy buildings

It is critical to incorporate energy efficiency measures in buildings in order to reduce energy demand. Improving the energy efficiency and comfort conditions of buildings in a cost effective manner requires careful consideration of many issues at the design stage. Priority should be given to compactness of design, orientation, thermal insulation and air change management on the basis that they should not entail significant additional capital costs if addressed properly at the design stage, should not require active management by the householder, and should continue to deliver cost and comfort benefits throughout the life of the building. Other issues include consideration of the life expectancy of energy technologies relative to the building as a whole, the need for regular maintenance to preserve optimum performance, and embodied energy requirements of proposed materials or components. High insulation values as well as tightening building envelopes can reduce energy demand significantly.

Passive design strategies also decrease energy needs with the use of solar orientation. For example, interrelationships between the building site, site features, the path of the sun, and the location and orientation of the building and elements such as windows and external shading devices have a significant impact on the quality and effectiveness of natural daylighting. These elements also affect direct solar loads and overall energy performance for the life of the building. Buildings that take advantage of the low angle of the sun in winter, while also providing solar shading during the summertime reduce heating and cooling needs. Without considering these issues early in the design process, the design is not fully optimized and the result is likely to be an inefficient building. Figure 2 shows the potential buildings sector energy saving by type and end-use[1].

**Figure 2. Potential energy savings in buildings (IEA et al. 2011)**




Because energy-efficient and low-carbon heating and cooling systems and building shell improvements account for 63% of the potential energy savings (IEA et al. 2011), it is important to know which measures can play a central role in reducing $CO_2$ emissions and increasing energy security. These solutions support the regenerative process of restoring a site and its surrounding environment.

Constructing an energy-efficient building is not just a matter of assembling a collection of the latest green technologies. Rather, it is a process in which every element of the design is first optimized, and then the impact and interrelationship of various different elements and systems within the building and site are re-evaluated, integrated, and optimized as part of a whole building solution. This approach iteratively enhances building performance through a process that involves all design team members from the beginning. The conventional process of designing and constructing a building and its systems, on the other hand, is linear, where all design elements and system components are specified, built, and installed without consideration of optimization opportunities in the following design and building phases, thus losing key opportunities for the optimization of whole buildings as systems.

Essential steps in the design of low-energy buildings are (Lucon et al. 2014):

1) building orientation, thermal mass, and shape;
2) high-performance envelope specification;
3) maximization of passive features (daylighting, heating, cooling, and ventilation);
4) efficient systems meeting remaining loads;

[1] These results come from the IEA *Energy Technology Perspectives 2010* (ETP) *BLUE Map Scenario*, which describes the role of energy technologies in transforming the buildings sector by 2050 in line with an overall goal of reducing global annual energy-related $CO_2$ emissions to half that of 2007 levels. The model uses cost optimization to identify least-cost mixes of energy technologies and fuels to meet energy demand, given constraints such as the availability of natural resources and technology progress. To achieve this scenario, strong policies will be needed from governments around the world in terms of energy efficiency in the buildings sector. In this scenario, global building-sector energy consumption is reduced by 1,509 Mtoe in 2050, while $CO_2$ emissions are 83% lower than in the baseline scenario.

5) highest possible efficiencies and adequate sizing of individual energy-using devices; and
6) accurate commissioning of systems and devices.

Many firms are now working to transform these principles into reality. For example, the BIQ (*Bio Intelligent Quotient*) house in Hamburg represents the world's first pilot project for the implementation of a bio-reactive façade in residential buildings. The bio-reactive façade, called *SolarLeaf*, generates renewable energy from algal biomass and solar thermal heat. The BIQ house has 200 $m^2$ of algae filled bio-reactive panels, which supply the building with all of the energy it needs while reducing $CO_2$ emissions by 6 tons per year. However, sustainable buildings should not be an exception, but must become mainstream, state-of-the-art, contemporary architecture.

Today, many buildings aim to promote good practices of design and construction through the achievement of sustainable building certification programs. These can be exemplified by LEED (Leadership in Energy and Environmental Design) born in 2000 by the United States Green Building Council, or PassivHaus, which began in Germany in 1991 and aims to achieve buildings with a power consumption of about a liter (10 kWh/$m^2$) of gas per year. Uptake of programs such as these further support and encourage the implementation and recognition of sustainable building.

## Urban planning and energy policy design

The built environment has a profound impact on our natural environment, economy, health, and productivity. However, advances in building science, technology, and operations are now available to designers, builders, operators, and owners who want to build green and maximize both economic and environmental performance. This offers great potential for energy savings in building low-carbon and sustainable cities. Hence, cities can become focal points of creativity and experimentation where innovative ideas on implementing low-carbon economic growth can be developed.

The world has been seriously affected by unsustainable development and extensive consumption. Indeed, society now must rethink urban areas through evolving resource efficiency in cities with an increased focus on planning and making socially and economically attractive places, well-functioning spatial structures, and energy efficient systems. How cities are planned, built, and managed now will determine the result of our efforts to achieve sustainable and harmonious development tomorrow. In this context of well-planned cities, buildings play a central role in contributing to energy efficiency and lower energy use. Well-designed policies and regulations are essential to achieve market changes.

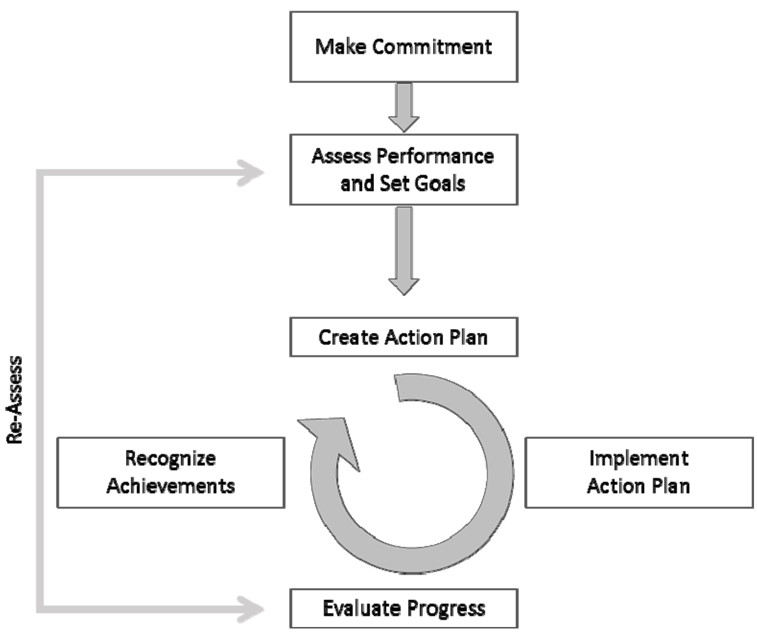
Governments should concentrate on the most efficient and cost-effective approaches. Research for the UNEP Sustainable Buildings and Construction Initiative (UNEP SBCI, 2007) found that the most effective instruments achieve net savings for society, and that packages of measures combining different elements are desirable. The study identified policies that were both successful in reducing emissions and cost-effective. Table 1 shows the most successful instruments to achieve this aim in buildings and, hence, in urban areas.

**Table 1. Energy-efficient policy design for both emission reduction and relative cost effectiveness**

| | EFFECTIVENESS FOR EMISSION REDUCTION | COST EFFECTIVENESS |
|---|---|---|
| **CONTROL AND REGULATORY INSTRUMENTS** | | |
| Appliance standards | HIGH | HIGH |
| Mandatory labelling and certification programs | HIGH | HIGH |
| Energy efficiency obligations and quotas | HIGH | HIGH |
| Utility demand-side management programs | HIGH | HIGH |
| **ECONOMIC AND MARKET-BASED INSTRUMENTS** | | |
| Energy performance contracting | HIGH | MEDIUM-HIGH |
| **FISCAL INSTRUMENTS AND INCENTIVES** | | |
| Tax exemptions and reductions | HIGH | HIGH |
| **SUPPORT, INFORMATION AND VOLUNTARY ACTION** | | |
| Voluntary certification and labelling | MEDIUM-HIGH | HIGH |
| Public leadership | MEDIUM-HIGH | MEDIUM-HIGH |
| Education and information programs | MEDIUM | MEDIUM-HIGH |

The U.S. Environmental Protection Agency's Energy Star Program (EPA, 2011) serves as a good example for local governments seeking a systematic approach for achieving energy management in the building sector. This approach, summarized in the *Guidelines for Energy Management* and in Figure 3, involves seven steps. The first is to make a commitment by establishing an energy team and instituting an energy policy. Second, assess performance by collecting and managing data, establishing baselines and benchmarks, analyzing data, and conducting technical assessments and audits. Third, set goals by estimating potential for improvement and establishing goals. Fourth, create an Action Plan by defining technical measures, defining targets for each type of building, and determining roles and resources. Fifth, implement an Action Plan by creating a communication Plan, raising awareness and building capacity, and tracking and monitoring progress. Sixth, evaluate progress by measuring results and reviewing the Action Plan, and finally, recognize achievements.

**Figure 3. Roadmap for improving energy efficiency in buildings (EPA, 2011)**



**Conclusion: sustainable buildings for a sustainable urban future**

Existing and future buildings will determine a large proportion of global energy demand and GHG emissions. Current trends in growth and consumption indicate the potential for massive increases in energy demand and associated emissions; however existing energy-efficiency technologies and building design techniques offer a potential solution.

As the world becomes increasingly urban, questions regarding the shape, size, density and distribution of cities will become ever more complex. This urban emergence, whilst presenting many problems, also offers a unique opportunity for more sustainable development patterns through recalibration of the relationship between economic prosperity, social justice, resource efficiency, and environmental protection. Here the role of the building sector is particularly relevant due to the high consumption of energy resources and production of GHG emissions. Moving forward, the building sector offers a great opportunity to respond to the challenge of climate change through increased energy efficiency and decreased energy consumption, in turn leading to fewer GHG emissions.

Ultimately, the most effective way to reduce energy consumption in buildings is to adopt a systematic approach for improving energy efficiency in each type of building, to incorporate energy efficiency into the design of new and renovated buildings, and to utilize urban policies to support this process. Realizing these opportunities requires aggressive and sustained policies and action to address every aspect of the design, construction, and operation of buildings and their equipment around the world. In this way, through the implementation of good practices for future building development, local governments, together with citizens, can promote a low-carbon urban future and shape better cities in which to live and work.

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