Foreword

Many of the buildings in 2050 are the ones that exist today; so refurbishment is vitally important to understand how they can continually adapt to change and retain an effective sustainability profile. The focus here is on energy performance and the steps necessary to ensure the actual energy performance is as designed for.

The book explains how to tackle the challenges of building refurbishment towards nearly zero energy. A central theme throughout is the importance of taking a multi-disciplinary approach not only across disciplines but the need for consultants, contractors and facilities managers to share a unified view. Energy covers a wide range of considerations during various phases of a project whether it be design, management or operation.

Choice of materials as well as systems determine the energy profile for the building in respect of embodied and operational energy. However, a low carbon building has to also satisfy the human needs because if it does not, the whole resource is wasted. Sustainability drivers are aimed to improve the quality of life in terms of health and well-being with minimum resources.

Poor facilities management and occupancy behaviour can make any low energy design ineffective. So it is important that the users understand how the building works. Controls need to be user friendly. Facilities managers need to carry out post-occupancy evaluations continually to diagnose weaknesses. Feedback can be used with self-adapting algorithms to ensure a continual good performance.

Experience from research, the Energy Performance of Buildings Directive as well as case studies provide the evidence for successful energy retrofitting and argued thoroughly by a distinguished team of international authors.

In the next few years, all buildings have to follow the regulatory pressures and become low carbon or net zero energy. This book is welcome at this time and sets the scene for professionals whether practitioners or researchers to learn more about how we can make whether old or new buildings more efficient and effective in terms of energy performance.

Derek Clements-Croome University of Reading
Introduction

Fernando Pacheco Torgal

Abstract This chapter starts with an overview on CO₂ emissions and climate change addressing key investigations and important related events. The situation of the European Union concerning energy efficiency is described. A short analysis of the nearly zero-energy building (NZEB) concept is presented. A book outline is also presented.

1 CO₂ Emissions and Climate Change

Four decades ago several investigators used a computer model based on the fixed-stock paradigm to study the interactions between population, food production, industrial production, pollution and the consumption of non-renewable resources. As a result, they predicted that during the twenty-first century the Earth’s capacity would be exhausted resulting in the collapse of human civilization as we know it (Meadows et al. 1972).

Two decades after that an update of this study was published showing that some limits had already been crossed (Meadows et al. 1992).

Climate change is one of the most important environmental problems faced by the Planet Earth (IPCC 2007; Schellnhuber 2008).

This is due to the increase of carbon dioxide (CO₂eq) in the atmosphere for which the built environment is a significant contributor. In the early eighteenth century, the concentration level of atmospheric CO₂eq was 280 parts per million (ppm); at present, it is already 450 ppm (Fig. 1).

Keeping the current level of emissions (which is unlikely given the high economic growth of less developed countries with consequent increases in emission rates)
will imply a dramatic increase in $\text{CO}_2\text{eq}$ concentration to as much as 731 ppm in the year 2130 leading to a 3.7 °C global warming above pre-industrial temperatures (Valero et al. 2011).

Global warming will lead to a rise in the sea level caused by thermal expansion of the water. When the sea level rises above 0.40 m, it will submerge 11 % of the area of Bangladesh, and as a result, this fact will lead to almost 10 million homeless (IPCC 2007).

Another consequence of global warming is the occurrence of increasingly extreme atmospheric events. Global warming may also be responsible for the thawing of the permafrost (permanently frozen ground), where approximately $1 \times 10^6$ million tons (1,000 GtCO$_2$eq) is still retained. This astonishing figure is equivalent to the current worldwide production (34 GtCO$_2$eq) during 30 years.

It is important to mention the probable meltdown of the world economy associated with climate change. According to Stern (2007) if we act now, the cost of all the services and products to tackle climate change will be 1 % of the GDP; otherwise, an economic depression of about 20 % GDP may take place.

Increasing atmospheric carbon dioxide levels is also responsible for ocean acidification (Hofmann and Schellnhuber 2010; Harrould-Kholieb and Herr 2012). This will lead to severe negative consequences in coral reefs putting habitats of high economic value at risk.

The coral reefs habitats represent fish resources that feed more than 1,000 million people and have an economic value estimated at 20,000 million euro (Bourne 2008; Anthony et al. 2008).

In this context is important also to bear in mind the value of services provided free of charge by Nature that reaches almost 33 billion ($10^{12}$) dollars/year (Constanza et al. 1998). As a comparison, the global GDP in the same period was of 18 billion ($10^{12}$) dollars per year, roughly half the value of the services and products provided by Nature.
Even if all the greenhouse gas emissions suddenly ceased, the inertia associated with climatic systems would mean that the rise in the sea level, ocean acidification and extreme atmospheric events will continue at least in the next one hundred years.

The majority of CO₂ emissions come from burning fossil fuels for energy production. Oil accounts for 32.8 %, coal for 27.2 % and natural gas for 20.9 % (Hook and Tang 2013).

In 2009, China became the largest energy consumer (IEA 2010), and Chinese coal plants are responsible for 80 % of electricity generation (Shealy and Dorian 2009). Still is fair to say that although China is the responsible for the major CO₂ emissions in the world (9,700 million tonnes), it has just a 7.2 tonnes per capita. While for instance Canada, the USA and Australia have, respectively, 16.2, 17.3 and 19 tonnes per capita (ICR 2012).

The 2009 Copenhagen Summit recognized the scientific view “that the increase in global temperature should be below 2 degrees Celsius” despite growing views that this might be too high. However, a comprehensive agreement that could have a significant impact on reducing carbon emissions was not reached (Dimitrov 2010; New et al. 2011).

Instead different countries decide to adopt different targets. The European Union agreed to reduce its overall emissions by 20 % in the year 2020 in the reference to the year 1990. The USA agreed to reduce its overall emissions by 17 % in 2010, in the reference to the year 2005. China and India did not accept a reduction in their total emissions, but rather a reduction in their carbon intensity (carbon/unit of GDP) relative to 2005 levels until 2020, between 40 and 45 % for China and between 20 and 25 % for India.

Goldenberg and Prado (2010) reviewed the above-cited goals and reported that they simply follow the standard “business as usual” for the period 1990–2007, which is clearly insufficient to achieve significant reductions by the year 2020. This view is confirmed by other authors (Peterson et al. 2011).

The World Business Council for Sustainable Development estimates that by 2050 a fourfold–tenfold increase in efficiency will be needed (COM 2011c 571). According to the World Energy Outlook 2012, energy-efficiency improvements show the greatest potential of any single strategy to abate global GHG emissions from the energy sector (IEA 2012). However, worldwide investment in energy-efficiency projects is very scarce. A recent report shows that energy efficiency amounts to a very small portion of the US$343–385 billion flowing into climate finance each year (Ryan et al. 2012).

## 2 European Union Situation

Europe has the world’s highest net imports of resources per person, and its open economy relies heavily on imported raw materials and energy.

The building sector is the largest energy user responsible for about 40 % of the EU’s total final energy consumption (Lechtenbohmer and Schuring 2011).
Energy-related emissions account for almost 80% of the EU’s total greenhouse gas emissions (COM (2010) 639).

To address smart, sustainable and inclusive growth until 2020 and beyond the European Union has been on the lead of seven paramount flagship initiatives. One of such “A resource-efficient Europe—Flagship initiative under the Europe 2020 Strategy” highlights the importance of increasing resource efficiency as key to bring major economic opportunities, improve productivity, drive down costs and boost competitiveness.

To tackle climate change, EU has agreed that by 2020 greenhouse gas emissions have to be reduce by 20% compared with the 1990 emissions level as well as to increase by 20% the energy consumption from renewable resources (COM (2008) 30).

Between 2010 and 2020, energy investments in the order of € 1 trillion will be needed, both to diversify existing resources and replace equipment and to cater for challenging and changing energy requirements (COM (2010) 639).

According to the Energy Road Map 2050 (COM (2011a) 885/2), higher energy efficiency in new and existing buildings is key for the transformation of the EU’s energy system.

Of the several areas related to the built environment energy efficiency and renewable energies are the only ones that will be funded under the HORIZON 2020 EU Framework Program (COM (2011b) 808 final).

Energy efficiency is the most cost-effective way to reduce emissions, improve competitiveness, as well as create employment (COM (2010) 639).

According to Lund and Hvelplund (2012), the implementation of a district heating and individual heat pump scenario in Denmark over a period of 10 years will create 7-8000 jobs.

A recent report shows that the global market for energy-efficient building will go from 68 billion dollars in 2011 surpassing 100 billion dollars by 2017 (Pike Research 2011).

Unfortunately, as the same EU Communication recognizes that “The quality of National Energy Efficiency Action Plans, developed by Member States since 2008, is disappointing, leaving vast potential untapped”. This means that technologies and methods to improve energy efficiency (Clements-Croome 2011) are therefore required.

Another important aspect related to energy efficiency concerns indoor air quality. Many buildings currently suffer from problems related to excessive moisture with mould formation, or present low humidity levels, giving rise to respiratory diseases. Moreover, since 1930, more than 100,000 new chemical compounds have been developed, and insufficient information exists for health assessments of 95% of chemicals that are used to a significant extent in construction products (Pacheco Torgal et al. 2012).

Increasing ventilation rate reduces the concentration of indoor air pollutants (except for of buildings in urban areas with a high level of air pollutants); however, this also increases energy consumption.
Some investigations (Fisk et al. 2011) show that improving indoor environmental quality in the stock of US office buildings would generate a potential annual economic benefit of approximately $20 billion. Unfortunately, most occupants are unaware of such health risks and prefer to reduce ventilation rates. It is then no surprise to find out that ventilation measurement across Europe shows that ventilation is in practice often poor, resulting in reduced ventilation rates (Dimitroulopoulou 2012).

A recent study (Galvin 2013) carried out in the city of Aachen, Germany, shows an interesting case of energy-inefficient manual ventilation, which means that energy efficiency is most influenced by occupants’ behaviour.

In the context of energy efficiency, it is preferable to reduce the toxicity of building materials, and avoiding the use of materials that release pollutants. EU has recently passed regulations that will make mandatory the environmental assessment of construction and building materials.


When comparing the basic requirements of the CPR and CPD, one can see that the CPR has a new requirement, no. 7 (Sustainable use of natural resources), and also that no. 3 (Hygiene, health and the environment) and no. 4 (Safety and accessibility in use) have been refined. This means that a new and more environment-friendly approach will determine the manufacture of construction products. A crucial aspect of the new regulation relates to the information regarding hazardous substances.

This means that commercialization of construction materials in Europe beyond 1 July 2013, will make their environmental assessment mandatory, thus facilitating choosing low-toxicity materials.

3 Nearly Zero-Energy Buildings

In the last decade, several high-energy performance building (HEPB) concepts have been proposed, from low-energy building through passive building and zero-energy building to positive energy building and even autonomous building (Thiers and Peuportier 2012). For the Building Technologies Program of the US Department of Energy (DOE), the strategic goal is to achieve “marketable zero energy homes in 2020 and commercial zero energy buildings in 2025”. However, commercial definitions maybe tainted by biased view, allowing for energy-inefficient buildings to achieve the status of zero energy thanks to oversized PV systems (Sartori 2012).
Rules and definitions for near zero-energy buildings or even zero-energy buildings are still subject to discussion at the international level (Dall'O et al. 2013). Some authors (Adhikari et al. 2012) use ZEB as “net zero-energy buildings” and NZEB as “nearly zero-energy buildings”. “Net” refers to a balance between energy taken from and supplied back to the energy grids over a period of time. Therefore, net ZEB refers to buildings with a zero balance as well that the NZEB concept applies to buildings with a negative balance.


One of the new aspects of the EPBD is the introduction of the concept of NZEB. Of all the new aspects set out by the new directive, this one seems to be the one with most difficult enforcement member states. The article 9 of the European Directive establishes that, by the 31 December 2020, all new constructions have to be NZEBs; for public buildings, the deadline is even sooner—the end of 2018.

Article 2 of the EPBD recast states that “‘NZEB’ means a building that has a very high energy performance, as determined in accordance with Annex I. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby”. The directive does not specify what is the concept of “low amount of energy”. The EPBD is also dubious on the meaning of “nearby” renewable resources. This broad definition could encompass 1 km or even 10 km and even any national energy grid in countries where the majority of the energy supply comes from renewable resources.

Since in the preliminary drafts, the directive was referring to “net zero-energy buildings”, some authors (Adhikari et al. 2012) believe that the global economic crisis of recent years has prompted lawmakers to scale back targets due to the fact that evidently a ZEB (net zero) would be too expensive.

Although each EU member state need to transpose into national laws, the directive’s provisions to account to its specific situation (climate conditions, economic aspects, building practices, etc.) so far only three countries had already made that transposition (Denmark, Sweden and Ireland). Therefore, in 21 September 2012, infringement procedures were started on 21 September 2012, against the 24 member states that did not declare full transposition.

This is the best proof of the difficulties felt by the different EU members in the transposition of such “unspecifed” and “dubious” regulation.

Another novelty of the EPBD recast that can complicate transposition into national laws is the cost-optimality requirement. According to the Article 4 (1), Member States shall take the necessary measures to ensure that minimum energy performance requirements for buildings or building units are set with a view to achieving cost-optimal levels. The energy performance shall be calculated in accordance with the methodology referred to in Article 3. Cost-optimal levels shall be calculated in accordance with the comparative methodology framework referred to in Article 5 once the framework is in place.
Cost-optimal level is defined as “the energy performance level which leads to the lowest cost during the estimated economic lifecycle”. In order to calculate the cost-optimal level of minimum energy performance, member states are required to create a set of reference buildings, at national or regional level, to be used in the calculations. Recent investigations are helpful concerning this subject (Corognati et al. 2013; Hamdy et al. 2013; Kurnitski et al. 2011).

To complicate things, a little bit more let us considered for instance the impact of climate change itself on the energy requirements of the buildings. Crawley (2008) mentioned that “the impact of climate change will result in a reduction in building energy use of about 10% for buildings in cold climates, an increase of energy use of up to 20% for buildings in the tropics, and a shift from heating energy to cooling energy for buildings in temperate climates”. Depending on the climate zone, cooling loads are likely to increase by 50 to over 90% until the end of the century (Roetzel and Tsangrassoulis 2012). In addition to increased mean temperatures, there are likely to be more frequent heat waves like for instance the 2003 European heat wave that claimed the lives of over 35,000 people (Porritt et al. 2012). This means that current climate conditions of each member state can no longer be viewed as static which will complicate even more the transposition of EPBD recast for national laws. So, Kwok and Rajkovich (2010) suggested mitigation of GHGs as well as adaptation to climate change should be added into building energy codes and comfort standards. Recently, Ren et al. (2011) analysed climate change adaptation measures for buildings and their cost-effectiveness.

Be there as it may, new buildings have limited impacts on overall energy reduction as they represent just a tiny fraction of the existent building stock. Popescu et al. (2012) mentioned that the building stock renews slowly, by only 1–2% per year. Existing buildings constitute, therefore, the greatest opportunity for energy-efficiency improvements (Xing et al. 2011).

Besides, new homes use four to eight times more resources than an equivalent refurbishment (Power 2008), which constitutes an extra argument in favour of building refurbishment. However, Silva et al. (2013) mentioned that most of the current buildings regulations present simplified methodologies that do not allow the correct assessment of the buildings retrofit interventions.

The words refurbishment, retrofit and renovation are generally used interchangeably in the literature and by organizations involved in reducing the energy use and carbon emissions of the existing housing stock (Fawcett 2011).

Some authors (Torcellini et al. 2006; Jensen et al. 2009) mention that energy building refurbishment is a two-step approach, i.e. application of energy efficiency measures to a cost-optimal level and suppression of the remaining energy needs through on-site renewable energy production. More recently, Dall’O et al. (2013) defends a 3-step sequence to achieve a ZEB: retrofitting building materials to reduce energy demand, installing energy-efficient equipment, and finally, installing microgeneration technologies.
And if the concept NZEB is not easy to apply to new buildings, it will be much more difficult to apply in existent buildings.

Besides, energy-efficiency refurbishment has a sociological dimension that must be also addressed (Banfi et al. 2008).

The decision process is influenced by several factors like for instance the household size, household income, age composition of the household members and members’ education levels each affect retrofit decisions (Gamtessa 2013).

Stieß and Dunkelberg (2013) mention that reaching homeowners not yet aware of the benefits of such energy-efficiency improvements constitute a major challenge that requires the “implementation of coordinated campaigns at the local level with participating energy agencies, consultants, tradesmen, the local authorities, and the local press”.

It is truth that the EPBD recast does not cover existent buildings; however, the Energy Efficiency Directive (2012/27/EU) approved by the European Parliament on 25 October 2012, that each member states will have to transpose into national laws until 5 June 2014, addresses this types of buildings (Articles 4 and 5).

According to Article 4, member states will have to define “establish a long-term strategy for mobilizing investment in the renovation of the national stock of residential and commercial buildings, both public and private. This strategy shall encompass:

(a) an overview of the national building stock based, as appropriate, on statistical sampling;
(b) identification of cost-effective approaches to renovations relevant to the building type and climatic zone;
(c) policies and measures to stimulate cost-effective deep renovations of buildings, including staged deep renovations;
(d) a forward-looking perspective to guide investment decisions of individuals, the construction industry and financial institutions;
(e) an evidence-based estimate of expected energy savings and wider benefits.

A first version of the strategy shall be published by 30 April 2014 and updated every three years thereafter and submitted to the Commission as part of the National Energy Efficiency Action Plans”.

As to Article 5 content, it requires that “each Member State shall ensure that, as from 1 January 2014, 3 % of the total floor area of heated and/or cooled buildings owned and occupied by its central government is renovated each year to meet at least the minimum energy performance requirements”.

Many books have been written about building refurbishment and some recent ones even contain interesting insights on “sustainable” refurbishment. However, some of those books are not focused on energy efficiency, several others lack any content on toxicity aspects or nanotech high-performance building materials, but most of them have absolutely nothing on complex decision support systems. This book thus provides essential reading to everyone that deals with energy-efficiency building refurbishment.
4 Book Outline

The Deutsch policy framework related to the energetic refurbishment of buildings is the subject of “Policy Instruments: The Case of Germany”. It includes relevant strategies and concepts as well as governmental targets. The specific cases of the Deutsch building code “Energy Saving Ordinance” and the “Renewable Energy Heat Law” are analysed. This chapter also includes an overview on financial incentive programmes related to energy-related refurbishments. Important market instruments are described.

“Built Environment Life Cycle Process and Climate Change” deals with the influence of climate change on the built environment. It presents a model of the built environment life cycle process for climate change mitigation and adaptation.

“Benefits of Refurbishment” describes some of the benefits associated with refurbishment actions.

It summarizes the results of the energy and environmental assessment of a set of retrofit actions implemented in the framework of the EU Project (Bringing Retrofit Innovation to Application in Public Buildings).

The modelling of the occupant behaviour impact on the buildings energy prediction is the subject of “Modelling the Occupant Behaviour Impact on Buildings Energy Prediction”. It suggests a “model for occupant behaviour within the building in relation to energy consumption, along with a building energy consumption model, is proposed based on stochastic Markov models”.

“Uncertainty in Refurbishment Investment” identifies and classifies uncertainties that characterize and make refurbishment investment a highly uncertain endeavour over the project life cycle. Recommendations about managing these uncertainties during the project evaluation phase are provided. This chapter includes “a new approach to project evaluation based on the option pricing theory is presented along with a case study example”.


“Life Cycle Energy Performance Evaluation” presents the “concepts and methodology to evaluate life cycle energy performance of buildings, including embodied energy of the different components, systems and processes”. The chapter introduces the concept of “net energy ratio” to the built environment, presenting it as an indicator to support optimization of building refurbishment strategies from a life cycle energy perspective. A practical application for the refurbishment of an Irish typical house is also shown.

“Refurbishment Scenario to Shift Nearly Net ZEBs Toward Net ZEB Target: An Italian Case Study” addresses an Italian case study concerning several refurbishment scenarios to shift nearly net zero-energy building towards net zero target. The refurbishment strategy is based on a LCA, in which the LCI model is carried out by using the SimaPro software. Energy payback time and the emission payback time are assessed in order to compare the different scenarios.
“A Multiple-Case Study of Passive House Retrofits of School Buildings in Austria” covers the refurbishment of four Austrian schools towards the energy-efficiency level of the Passivhaus standard.

“State of the Art on Retrofit Strategies Selection Using Multi-Objective Optimization and Genetic Algorithms” reviews “the research and development in the decision support processes in building retrofit. The advantages and drawbacks of the various methods in each category are also discussed”.

“Multiple-Criteria Analysis of Life Cycle of Energy-Efficient Built Environment” describes a life cycle of energy-efficient built environment model as well as two systems (Energy Efficient House DSS for Cooling and Decision support system for assessment of energy generation technologies).

“Toxicity Issues: Indoor Air Quality” reviews “main indoor pollutants and their sources. Considering existing World Health Organization (WHO) guidelines for IAQ and toxicity, the pollutants considered here are: asbestos, biological pollutants, benzene, carbon monoxide, formaldehyde, naphthalene, nitrogen dioxide, particulate matter, polycyclic aromatic hydrocarbons, radon, tetrachloroethylene, and trichloroethylene”.

“Toxicity Issues: Radon” is related to radon as a source of indoor air contamination. It shows that post-construction remediation like soil depressurisation systems seems to be more cost-effective than the use of protection measures installed during construction like radon-barrier membranes which have a significant failure rate. Since radon concentration is very dependent on the air change rate (ACH), it is important to maintain adequate air ventilation. However, in some situations, the cost of additional heating to eliminate the heat losses would exceed the total costs of remediation by soil ventilation as much as eightfold. This chapter also shows that there are optimum temperature and relative humidity which minimize radon levels.

“Ventilation: Thermal Efficiency and Health Aspects” focus “on the performance of ventilation, both in reducing adverse effects of indoor air on building occupants and in reducing the energy required for this”. It explores the specific merits and limitations of ventilation as a strategy to renew air. It discusses the different ventilation concepts and their performance focusing on “technologies that allow to reduce ventilation heat loss without increasing the exposure of occupants to airborne pollutants, more specifically air to air heat exchangers, exhaust air heat pumps and demand controlled ventilation”.

“Insulation Materials Made with Vegetable Fibres” provides a guide to the fundamentals and latest developments in building insulation technology based on vegetable fibre materials.

“High-Performance Insulation Materials” addresses two classes of superinsulation technology: vacuum insulation panels (VIP) and microporous thermal insulations. The chapter discusses the special features of these thermal insulations and presents best-practice examples. The chapter also includes an overview on future trends in R&D for thermal insulation.

“Thermal Energy Storage Technologies” gives a general overview on thermal energy storage (TES) technologies.
“Phase-Change Materials Use in Nearly Zero Energy Building Refurbishment” displays several examples concerning the use of PCMs for new buildings, highlighting the more appropriate options for refurbishment. Application of “highly energy-efficient windows and skylights with silica nanogel as a strategy in the building refurbishment” is the subject of “Nanogel Windows”.

This new window “seems to have the largest potential for improving the thermal performance and daylight in fenestration industry, because of very low conductivity and density and a good optical transparency”. The chapter includes a state-of-the-art review of nanogel windows in building applications. It also includes a discussion on the proprieties of nanogel glazing in terms of thermal, lighting and acoustic insulation solutions. The “potential of the nanogel windows for energy saving in order to achieve a nearly zero-energy building is described thanks to the results of a case study”.

“Switchable Glazing Technology: Electrochromic Fenestration for Energy-Efficient Buildings” outlines the basics of electrochromic glazing technology. It “allow the transmittance of visible light and solar energy to be changed reversibly and persistently by the use of an electrical signal”, which is an important feature in energy-efficiency technologies. The chapter discuss device designs and component materials. Several practical electrochromic glazing designs are introduced with focus on a foil-type construction applicable as a lamination material between glass panes.

The “global market potential of solar thermal, photovoltaic (PV) and combined photovoltaic/thermal (PV/T) technologies in current time and near future” are the subject of “Solar Photovoltaic/Thermal Technologies and Their Application in Building Retrofitting”. The chapter covers “major features, current status, research focuses and existing difficulties/barriers related to the various types of PV/T”. It describes “research methods, including theoretical analyses and computer simulation, experimental and combined experimental/theoretical investigation, demonstration and feasibility study, as well as economic and environmental analyses, applied into the PV/T technology were individually discussed, and the achievement and problems remaining in each research method category”.

References

COM (2011) 808 final. Horizon 2020—the framework programme for research and innovation
COM (2011) 885/2. Energy Roadmap 2050
COM (2011) 571 final. Roadmap to a resource efficient Europe
COM European Commission (2008) Communication from the commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: 2020 by 2020—Europe’s climate change opportunity
IPCC (Intergovernmental Panel on Climate Change) (2007) Climate change 2007: synthesis report. IPCC, Geneva


Pike Research (2011) Energy efficient buildings: global outlook


Ryan L, Selmec N, Aasrud A (2012) Plugging the energy efficiency gap with climate finance


