Energy in Buildings and Communities Programme

International Energy Agency

Cost-Effective Energy and Carbon Emissions Optimization in Building Renovation (Annex 56)

Guidebook for Policy Makers

October 2017

EBC is a programme of the International Energy Agency (IEA)

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Preface

The International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme. A basic aim of the IEA is to foster international co-operation among the 29 IEA participating countries and to increase energy security through energy research, development and demonstration in the fields of technologies for energy efficiency and renewable energy sources.

The IEA Energy in Buildings and Communities Programme

The IEA co-ordinates international energy research and development (R&D) activities through a comprehensive portfolio of Technology Collaboration Programmes. The mission of the Energy in Buildings and Communities (EBC) Programme is to develop and facilitate the integration of technologies and processes for energy efficiency and conservation into healthy, low emission and sustainable buildings and communities, through innovation and research. (Until March 2013, the IEA-EBC Programme was known as the Energy in Buildings and Community Systems Programme, ECBCS.)

The research and development strategies of the IEA-EBC Programme are derived from research drivers, national programmes within IEA countries and the IEA Future Buildings Forum Think Tank Workshops. The research and development (R&D) strategies of IEA-EBC aim to exploit technological opportunities to save energy in the buildings sector and to remove technical obstacles to market penetration of new energy efficient technologies. The R&D strategies apply to residential, commercial, office buildings and community systems and will impact the building industry in five focus areas for R&D activities:

- Integrated planning and building design
- Building energy systems
- Building envelope
- Community scale methods
- Real building energy use

The Executive Committee

Overall control of the IEA-EBC Programme is maintained by an Executive Committee, which not only monitors existing projects but also identifies new strategic areas in which collaborative efforts may be beneficial. As the Programme is based on a contract with the IEA, the projects are legally established as Annexes to the IEA-EBC Implementing Agreement. At the present time, the following projects have been initiated by the IEA-EBC Executive Committee, with completed projects identified by (*):

Annex 1: Load Energy Determination of Buildings (*)
Annex 2: Ekistics and Advanced Community Energy Systems (*)
Annex 3: Energy Conservation in Residential Buildings (*)
Annex 4: Glasgow Commercial Building Monitoring (*)
Annex 5: Air Infiltration and Ventilation Centre
Annex 6: Energy Systems and Design of Communities (*)
Annex 7: Local Government Energy Planning (*)
Annex 8: Inhabitants Behaviour with Regard to Ventilation (*)
Annex 9: Minimum Ventilation Rates (*)
Annex 10: Building HVAC System Simulation (*)
Annex 11: Energy Auditing (*)
Annex 12: Windows and Fenestration (*)
Annex 13: Energy Management in Hospitals (*)
Annex 14: Condensation and Energy (*)
Annex 15: Energy Efficiency in Schools (*)
Annex 16: BEMS 1- User Interfaces and System Integration (*)
Annex 17: BEMS 2- Evaluation and Emulation Techniques (*)
Annex 18: Demand Controlled Ventilation Systems (*)
Annex 19: Low Slope Roof Systems (*)
Annex 20: Air Flow Patterns within Buildings (*)
Annex 21: Thermal Modelling (*)
Annex 22: Energy Efficient Communities (*)
Annex 23: Multi Zone Air Flow Modelling (COMIS) (*)

Annex 24: Heat, Air and Moisture Transfer in Envelopes (*)
Annex 25: Real time HVAC Simulation (*)
Annex 26: Energy Efficient Ventilation of Large Enclosures (*)
Annex 27: Evaluation and Demonstration of Domestic Ventilation Systems (*)
Annex 28: Low Energy Cooling Systems (*)
Annex 29: Daylight in Buildings (*)
Annex 30: Bringing Simulation to Application (*)
Annex 31: Energy-Related Environmental Impact of Buildings (*)
Annex 32: Integral Building Envelope Performance Assessment (*)
Annex 33: Advanced Local Energy Planning (*)
Annex 34: Computer-Aided Evaluation of HVAC System Performance (*)
Annex 35: Design of Energy Efficient Hybrid Ventilation (HYBVENT) (*)
Annex 36: Retrofitting of Educational Buildings (*)
Annex 37: Low Exergy Systems for Heating and Cooling of Buildings (LowEx) (*)
Annex 38: Solar Sustainable Housing (*)
Annex 39: High Performance Insulation Systems (*)
Annex 40: Building Commissioning to Improve Energy Performance (*)
Annex 41: Whole Building Heat, Air and Moisture Response (MOIST-ENG) (*)
Annex 42: The Simulation of Building-Integrated Fuel Cell and Other Cogeneration Systems (FC+COGEN-SIM) (*)
Annex 43: Testing and Validation of Building Energy Simulation Tools (*)
Annex 44: Integrating Environmentally Responsive Elements in Buildings (*)
Annex 45: Energy Efficient Electric Lighting for Buildings (*)
Annex 46: Holistic Assessment Tool-kit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo) (*)
Annex 47: Cost-Effective Commissioning for Existing and Low Energy Buildings (*)
Annex 48: Heat Pumping and Reversible Air Conditioning (*)
Annex 49: Low Exergy Systems for High Performance Buildings and Communities (*)
Annex 50: Prefabricated Systems for Low Energy Renovation of Residential Buildings (*)
Annex 51: Energy Efficient Communities (*)
Annex 52: Towards Net Zero Energy Solar Buildings (*)
Annex 53: Total Energy Use in Buildings: Analysis & Evaluation Methods (*)
Annex 54: Integration of Micro-Generation & Related Energy Technologies in Buildings (*)
Annex 55: Reliability of Energy Efficient Building Retrofitting - Probability Assessment of Performance & Cost (RAP-RETRO) (*)
Annex 56: Cost-effective Energy & CO2 Emissions Optimization in Building Renovation
Annex 57: Evaluation of Embodied Energy & CO2 Equivalent Emissions for Building Construction
Annex 58: Reliable Building Energy Performance Characterisation Based on Full Scale Dynamic Measurements (*)
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Annex 70: Energy Epidemiology: Analysis of Real Building Energy Use at Scale
Annex 71: Building Energy Performance Assessment Based on In-situ Measurements
Annex 72: Assessing Life Cycle related Environmental Impacts Caused by Buildings
Annex 73: Towards Net Zero Energy Public Communities
Annex 74: Energy Endeavour
Annex 75 Cost-effective building renovation at district level combining energy efficiency and renewables

Working Group - Energy Efficiency in Educational Buildings (*)
Working Group - Indicators of Energy Efficiency in Cold Climate Buildings (*)
Working Group - Annex 36 Extension: The Energy Concept Adviser (*)
Working Group - Survey on HVAC Energy Calculation Methodologies for Non-residential Buildings

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Chapter 1

Objectives of the guidebook

Energy is crucial to the wellbeing and development of nowadays society and will remain important for the foreseeable future. With respect to the type and quantity of energy consumed, significant changes are ongoing and further major changes can be expected in the near future. There are also various policy objectives that shape energy policy, depending on the country context. Among these objectives, the following can be highlighted:

– minimizing any adverse effects on the climate and on the environment;
– providing energy access to all;
– securing energy supply;
– reducing dependence on energy imports;
– looking for new energy sources, routes and suppliers that offer local economic benefits;
– reducing local environmental pollution;
– driving job creation;
– achieving low energy costs for society.

Key strategic elements to reach such objectives are in particular the gradual transformation of the energy systems from fossil fuels to renewable energy, the increase of the efficiency of the energy systems, the reduction of energy use by consumers, the creation of fully integrated energy markets and the removal of unnecessary regulatory or technical barriers.

In many industrialized countries, the building sector has become an important target for reductions in energy use, related carbon emissions and resource depletion due to its relevance in these areas.
While many energy policies in these countries focus mainly on new buildings, it is crucial that the often poor energy performance of existing buildings is also improved.

The information provided in this guidebook aims to contribute to the reaching of the above-mentioned policy objectives. The guidebook is based on the results of a research project carried out within the IEA Energy in Buildings and Communities Programme (EBC) called "Cost-

Effective Energy and Carbon Emissions Optimization in Building Renovation (Annex 56)".

The guidebook was compiled to raise awareness among the players that can influence policies and standard definition and to engage them in the subjects of energy efficiency and renewable energy sources in the context of building renovation. Existing buildings present a tremendous potential, not only to reduce energy use and emissions, but also on other areas of the political agenda. It is the objective of this guidebook to highlight how energy related building renovation is a policy tool to achieve broad benefits to society.

In many developed countries, the renovation of the existing building stock is a relevant part of the actions to deal with climate change mitigation and to move towards a sustainable relation with our planet (European Commission, 2011). Building renovation that increases the energy performance of a building or that increases the share of renewable energy in its energy use, reduces carbon emissions and the emissions of local air pollutants. By renovating a building instead of replacing it with a newly constructed building, the depletion of resources is reduced and the amount of waste is minimized.

Although existing buildings represent a significant potential in these areas (BPIE, 2011), it has been hard to fully exploit this potential. The methodology developed within the context of this project to enable cost-effective building renovation towards a nearly zero energy and emissions objective, intends to highlight the full scope of benefits, direct and indirect, resulting from the renovation process and to evaluate how they can be taken into account in decision-making processes, helping policy makers in the development of energy related policies.

This guidebook presents guidance for the application of the referred methodology as well as presents a set of recommendations derived from the application of the methodology to typical and representative buildings and to a significant number of case studies collected among the participating countries. The methodology (graphically shown in Figure 1) allows the assessment and evaluation of energy related renovation options, including:

- a comprehensive assessment and evaluation of cost-effective reductions of primary energy use and carbon emissions within energy related building renovation, comprising also lifecycle impacts like embodied energy;

The methodological approach presented in this document aims at finding the optimal balance between energy efficiency measures and the use of renewable energy to achieve cost-effective solutions yielding maximum energy and carbon emissions reductions (Figure 1). The methodology also allows a broader approach by taking into account the additional benefits and the overall added value achieved in a renovation process.

- the evaluation of cost-effective combinations of energy efficiency measures and measures to increase renewable energy use;
- highlighting the relevance of the additional benefits (co-benefits) achieved in the renovation process.

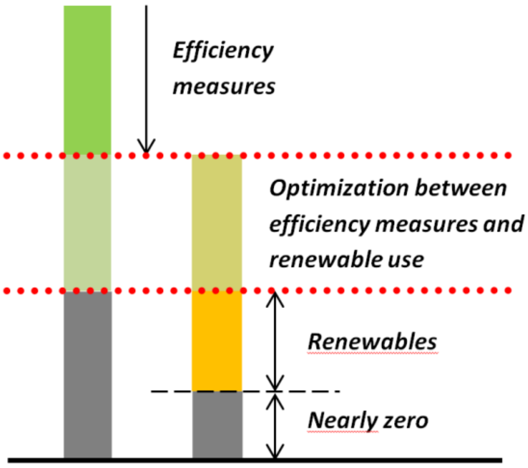

Figure 1 – Concept for an optimized combination of energy efficiency measures and renewable energy measures in building renovation with a nearly-zero energy and emissions target (Geier S., Ott W.).

Chapter 2

Change of mind-set towards building renovation

In building renovation, lack of information, limited access to capital to face the high investment costs and long pay-back times of these investments, are the most commonly cited reasons hampering the wide use of energy conservation and renewable energy deployment measures. Additionally, in many cases, those who pay for the energy renovation are not those who benefit from it, leading to a situation known as split-incentives situation. Therefore, energy renovation projects often run into barriers that hold up the projects. It is then an obligation that owners, technical consultants and policy makers find solutions to overcome these barriers.

It is of ultimate importance that policy makers, technical consultants and owners find solutions to overcome existing barriers to energy renovation projects.

Up to now, strategies to improve the energy performance in the building sector were largely focused on tapping and developing efficiency potentials of new buildings and more specifically on improving the building envelope. As for example, the European Energy Performance of Buildings Directive (EPBD) and its recast [European Parliament and the Council of the European Parliament, 2010] are putting a high emphasis on the high energy performance of the building, although the deployment of renewable energy is also addressed as a second step [Holl M., 2011]. However, in face of the above mentioned barriers, such an approach is not responding effectively to the numerous technical, functional and economic constraints of existing buildings.

In the "Shining Examples of Cost-Effective Energy and Carbon Emissions Optimization in Building Renovation Report (Figure 2), main barriers have been identified and grouped into four major categories:
- Information issues
- Technical issues
- Ownership issues
- Economic issues
[Mørck, O. et al., 2017]

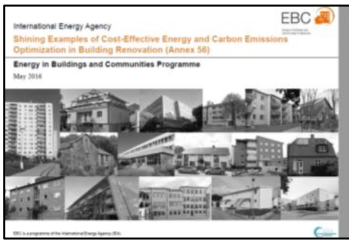

Figure 2 - Shining Examples of Cost-Effective Energy and Carbon Emissions Optimization in Building Renovation (Annex 56 - 2017)

Given the major challenge of mitigating climate change and the important share of carbon emissions caused by energy consumption in existing buildings, reducing carbon emissions within building renovations is an important objective and probably the most important one. Up to now, standards for building renovation have focused mainly on the reduction of energy use through energy efficiency measures, which also contribute to the reduction of carbon emissions. However, given the barriers building renovation has to face, it is interesting to compare the effects of renovation packages consisting of measures to increase energy efficiency and those considering measures to increase the share of renewable energy sources used and to put them into perspective comparing energy and carbon emissions reductions achieved.

Energy Efficiency and Renewables
How far is it expedient to go with energy efficiency measures and from which point renewable energy measures become more economical taking into account the local/regional context?

In fact, considering the goal of reducing carbon emissions, measures promoting the use of renewable energy can be as effective as efficiency measures and sometimes be obtained in a more cost-effective way. In existing buildings, the most cost-effective renovation solution is often a combination of energy efficiency measures and measures that promote the use of renewable energy. Hence, it is relevant to understand how far it is possible to go with efficiency measures (initially often less expensive measures) and from which point the use of renewables becomes more economical considering the local context.

Relevance of embodied energy and emissions
Considering that the better the performance of the buildings the more relevant embodied energy use and related emissions for building renovation become (materials and construction), is it relevant to consider these embodied impacts in building renovation assessment?

Each one of these types of measures will be also responsible for a certain amount of embodied energy related to the materials added to the envelope or to the technical systems. Indeed, the more the building energy demand is minimized, the more the embodied energy in the materials added (eg. envelope insulation), becomes more relevant. Similarly, renewable energy systems, such as ground source heat pumps, often have more embodied energy than conventional heating systems. It is known that as the energy performance of buildings increases, the embodied energy in the materials used in building renovation becomes more important, but its relevance is still not well-known.

Direct benefits and co-benefits
How to identify and take into account the global quality improvement, the economic impact of the intervention, the operating costs reduction, the additional benefits achieved (like comfort improvement), the increased value of the building and the fewer building physics related problems?

In the case of existing buildings, it can be observed that opportunities to significantly improve their energy performance are missed too often despite their cost-effectiveness if a life cycle cost approach is assumed. Often, this is because of the high initial costs involved but also because of lack of know-how and awareness regarding life cycle cost-effectiveness. Also, traditional approaches disregard benefits of building renovation measures beyond energy and costs. It is therefore relevant to explore and illustrate the range of cost-effective renovation measures to increase efficiency and deployment of renewable energy to achieve the best building performance (less energy use, less carbon emissions, higher overall added value achieved with the renovation) at the lowest effort (less investment, less life cycle costs, less intervention on the building, less users' disturbance).

To investigate related questions within the framework of the Annex 56 project, an adequate methodology for energy and carbon emissions optimization in building renovation was developed. The methodology intends to become a basis for extending and further developing the existing standards to be used by interested private entities and agencies for their renovation decisions as well as by governmental agencies for the definition of their renovation strategies, regulations and their implementation.

2.1 Energy consumption in buildings

According to the International Energy Outlook 2016 projections [IEA, 2016], there will be an increase of the energy consumption in all energy sources (Figure 3). Concerns about energy security, effects of emissions due to the burning of fossil fuels and sustained high world oil prices in the long term, support calls for increasing energy efficiency and for an expanded use of renewable energy sources. Despite policies and incentives, which in many cases still favour fossil energy in many countries, renewable energy is the world's fastest-growing source of energy, at an average rate of 2.6% per year, while nuclear energy use increases by 2.3% per year and natural gas use increases by 1.9% per year. Coal is the world's slowest growing form of energy, at an average rate of 0.6% per year, with latest numbers indicating that coal consumption is remaining stable or decreasing in many countries.

According to the International Energy Outlook 2016, projections for the energy consumption in buildings indicate it will increase until 2040 for all kinds of energy sources.

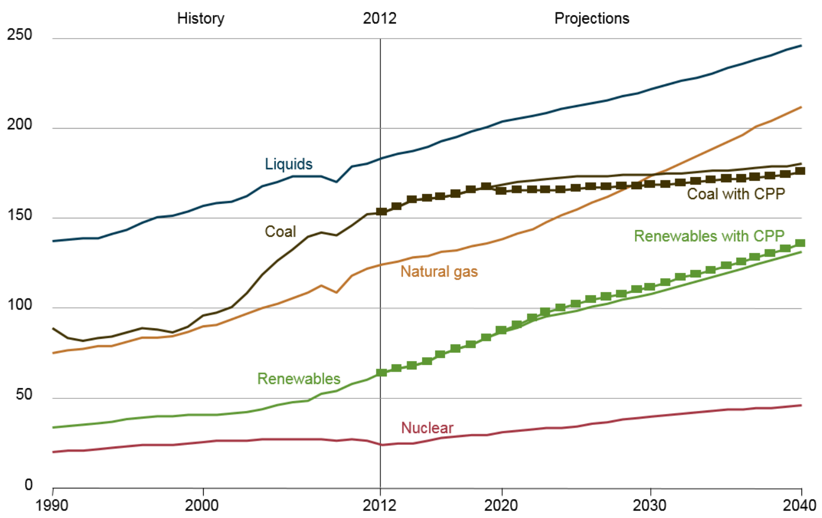

Figure 3 – World energy consumption by energy source (quadrillion Btu), 1990-2040 [IEA, 2016]. Numbers beyond 2012 are a projection.

Renewable energy is the world's fastest-growing source of energy, at an average rate of 2.6% per year, while coal is the world's slowest growing form of energy, at an average rate of 0.6% per year.

In the European Union, consumption of energy in 2012 was almost at the same level as it was in 1990.

In 2014, buildings were the major consumer group (households and service buildings) with over 38 % of the final energy use.

In the EU-28, gross inland consumption of energy in 2012 was almost at the same level as it was in 1990. Between these years, consumption increased by 12.4 % from a low point of 1 631 Mtoe in 1994 to a peak of 1 840 Mtoe in 2006. Thereafter, consumption fell most years to reach a new low in 2014, which was 12.7% below the peak of 2006. An analysis of the end use of energy in the EU-28 in 2014 shows three dominant categories, namely, transport (33.2 %), industry (25.9 %) and buildings (38.1 % - 24.8 % from households and 13.3% from service buildings) [Eurostat, 2016a].

During the 10-year period from 2004 to 2014, the consumption of electricity by households fell in the EU-28 by 1.3 %. There was a much faster reduction in a certain number of EU Member States, in particular, Belgium (with a reduction of 28.6 %), while reductions of more than 10% were also recorded for the United Kingdom and Sweden. At the other end of the range, household electricity consumption rose in a majority (18) of the Member States, generally by less than 10.0 %. Among the seven Member States with higher increases in electricity consumption, the largest expansions were recorded in Romania (48.1 %), Lithuania (27.1 %), Spain (21.8 %) and Bulgaria (20.8 %). Overall household electricity consumption is likely to be influenced, in part, by demographic events (average number of persons living in each household and by the total number of households), but also by the extent of ownership of electrical household appliances and consumer goods as well as the use of energy saving devices [Eurostat, 2016b].

European Union energy mix during the period 1990 to 2014 registered a gradual decline in the share of petroleum products and solid fuels, from a combined share of 65.0 % of the total consumption in 1990 to 50.7 % in 2010 and 50.5 % in 2013.

EU-28 energy mix during the period 1990 to 2014 registered a gradual decline in the share of petroleum products. The share of solid fuels fell relatively quickly during the early years of the period under consideration, before stabilising between 1999 and 2007, falling sharply again in 2008 and 2009 and then increasing through to 2012. The combined share of petroleum products and solid fuels fell from 65.0 % of total consumption in 1990 to 50.7 % in 2010 and 50.5 % by 2013, reflecting a move away from the most polluting fossil fuels. A modest increase in their consumption was, however, observed in 2014 (51.2 % of the total energy mix), perhaps reflecting the relatively low price of oil. The share from nuclear energy rose to a peak of 14.5 % in 2002 but dropped back to 13.3 % by 2007 and 13.5 % in 2012, before increasing somewhat in 2013 and 2014 to reach 14.1 %. By contrast, the share of EU-28 gross inland consumption accounted for by renewable energy sources was 12.5 % in 2014, 2.9 times its share

(4.3%) of the energy mix in 1990. The relative importance of natural gas also increased relatively quickly during the 1990s and more slowly thereafter, to peak at 25.4 % in 2010; the share from natural gas fell during the next four years to reach 21.4 % in 2014, a share that was below the observed one 10 years earlier [Eurostat, 2016a].

The extrapolation of current trends in energy supply and use suggests that existing goals to mitigate carbon emissions and to reduce non-renewable energy consumption will not be met. To change the looming path it is crucial to identify existing and promising reduction potentials.

Considering current trends, existing goals to mitigate carbon emissions and to reduce non-renewable energy consumption will not be met.

With a share of nearly 40% of the final energy use and some 35% of carbon emissions, the building sector represents the largest energy consuming sector and is considered as «the largest untapped source of cost-effective energy saving and emissions reduction potential (at least) within Europe, yet the sector continues to suffer from significant underinvestment» [BPIE, 2013]. This holds particularly for the stock of existing buildings, whose energy related improvement is highly relevant for mitigating carbon emissions and energy use. However, it is still a challenge to unleash these potentials.

With a share of nearly 40% of the final energy use and some 35% of the carbon emissions, the building sector represents the largest energy consuming sector and is considered as «the largest untapped source of cost-effective energy saving and emissions reduction potential».

2.2 National policies (and legal requirements)

The building sector has the largest potential for significantly reducing carbon emissions compared to other major emitting sectors. This potential is relatively independent of the cost per ton of $CO2_{eq}$ achieved (IPCC, 2007). With proven and commercially available technologies, the energy consumption in both new and existing buildings can be cut by an estimated 30 to 80 percent with potential net profit during the building life-span. Furthermore, there are technologies available to strongly reduce carbon emissions of buildings by switching to renewable energy carriers.

In Europe, improving the energy performance of the existing building stock is crucial, not only to achieve the EU's 2020 targets (European Commission, 2010) but also to meet the longer term objectives of a climate strategy as laid down in the low carbon economy roadmap 2050 (European Commission, 2011). Reducing energy required for heating has been a major focus of building energy policies in the European Union, where the existing building stock is large, the rates of replacement are relatively low and the majority of the population lives in cool to moderate climate zones. The EU Energy Performance of Buildings Directive (EPBD) is the key policy framework for driving low energy consumption in new and existing buildings. Introduced in 2002, it creates an integrated basis for the implementation of performance-based, rather than prescriptive building codes and supporting policy strategies. It sets common targets for absolute reductions in energy consumption across the EU member states. In 2010 the Directive was recast with more stringent energy reduction targets, including the requirement for member states to implement "Nearly Zero Energy" building codes.

2.3 The climate change mitigation challenge

Climate change is one of the major challenges of this century. At EU-level, ambitious targets for reducing carbon emissions have been formulated. The EU's goal of reducing carbon emissions by 80% - 95% by the year 2050 compared to 1990 level is ambitious, considering the vast amount of daily activities that cause emissions and the limited reductions that are expected in some sectors (Figure 4). This is the case for the transport sector, particularly the aviation sector, where the emissions can only be eliminated with great effort and facing serious challenges. The same happens in agriculture, where emissions can hardly be eliminated to a large extent.

Action in all main sectors responsible for Europe's emissions will be needed, but differences exist between sectors on the amount of reductions that can be expected.

The goal of reducing carbon emissions by 80%-95% by 2050 compared to 1990 level can only be achieved if emissions from the building sector are completely eliminated.

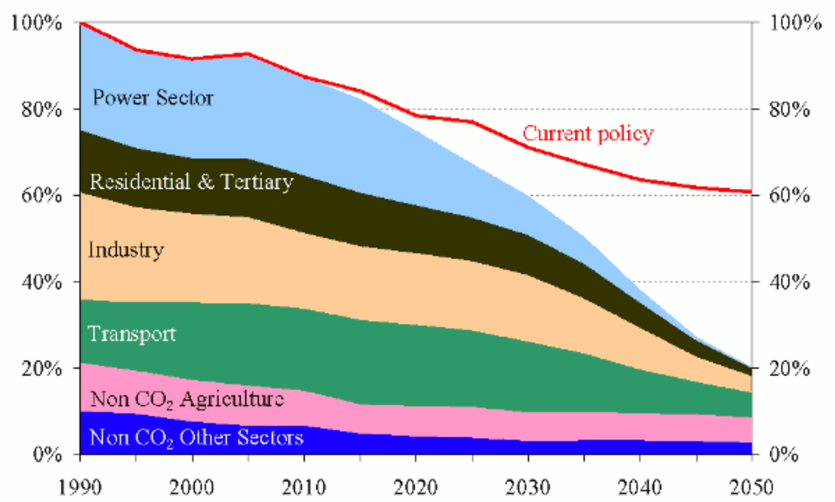

Figure 4 - Possible 80% cut in carbon emissions in the EU (100%=1990)

This means that an overall 80%-95% reduction of carbon emissions can only be achieved if in the building sector a 100% reduction of carbon emissions is pursued.

The targets for the building sector set by energy policy and climate policy have so far focused on reducing primary energy use in buildings. The measures to reduce primary energy use have been mainly focused on energy efficiency measures on the buildings envelope, which simultaneously reduce carbon emissions and primary energy. However, apart from the energy efficiency measures, there is also the alternative way of lowering carbon emissions by switching from fossil fuel based systems to renewable energy based ones.

By putting a focus primarily on the reduction of primary energy use in the building sector and not on the reduction of carbon emissions, a risk is created to overlook the emissions reduction potential of renewables and to miss the emission reduction targets.

The investigations that were carried out during the project showed that there is, in general, a large potential for cost-effective renovations that reduce carbon emissions and primary energy use and that both energy efficiency measures and measures to switch to renewable energy contribute to these objectives.

2.4 Setting targets for building renovation

For the time being in Europe, the concepts of the recast of the Energy Performance of Building Directive (EPBD) prevail in the discussion on future energy performance standards for buildings. The directive is based on a two-step approach which assumes that the improvement of energy related building performance starts first with cost-effective energy related efficiency measures up to at least an efficiency level that corresponds to the cost optimal package of energy related renovation measures. To achieve zero or nearly zero energy or emissions buildings, either additional efficiency measures or the supply of renewable energy, generated on-site, can be applied to further reduce carbon emissions and remaining non-renewable energy use.

Today's standards do not respond effectively to the numerous technical, functional and economic constraints of existing buildings and often the requirements, mainly targeted to energy efficiency measures, result in expensive processes and complex procedures, seldom accepted by users, owners or promoters.

In the case of building renovation, it has to be explored in more detail whether the priorities in the two step approach still hold considering cost-effectiveness. In fact, at the time being, stepwise renovation practices are widespread and often favour the choice of measures for the use of renewable energy before any other measure (especially if the heating system has to be replaced). Thereby, carbon emissions and non-renewable primary energy use can already be reduced significantly and cost-effectively.

Having in mind the overall objective of slowing down climate change, the use of renewable energy can be as effective as energy efficiency measures and sometimes be obtained in a more cost-effective way. Therefore, in existing buildings, the most cost-effective renovation solution is often a combination of energy efficiency measures and the use of renewable energy.

The following list describes key analysis issues for existing buildings related to measures, renovation and replacement timing and economics. It also contrasts them with issues for new home construction, highlighting the need for specific targets and standards for building renovation.

Design constraints — a new building is an abstract entity until it is built. Changes can be made easily during the design stage when there are few constraints caused by existing conditions. This is not true for existing buildings. For example, in new buildings, it is easy to add foam insulation to the exterior of the wall during construction to reduce losses. For existing buildings, however, the presence of existing exterior finishing (e.g., wood siding or brick) can make adding exterior foam insulation challenging.

Costs — adding or replacing a component in an existing building can have different labour and material costs when compared to a new one. For example, adding foam sheathing to the exterior wall may require removing old siding and adding new siding, which significantly increases the labour and material costs compared to the same level of insulation in new construction.

Equipment sizing — for new buildings, the heating, ventilation and air-conditioning (HVAC) systems can be right-sized based on the design of the building, so there is often an HVAC down-sizing cost benefit due to reduced loads of the building. For existing buildings, however, down-sizing cost benefits can only be achieved when the HVAC system is replaced.

Remaining life span of equipment — in new construction, all equipment and components begin their working lives at the same time—when the building is built. In an existing building, each piece of equipment may be at a different point in its lifetime at the time of renovation. Therefore, the cost-effectiveness of upgrading the equipment at the time of renovation must be compared to the cost-effectiveness of waiting until wear-out to replace or upgrade the equipment.

Financing — in building energy optimization analysis for new constructions, the cost of energy measures is included in the mortgage and the interest portion of the mortgage payment is usually tax deductible. For existing buildings, renovation costs are often financed over a shorter period via cash payments or a home equity loan. Whether energy related renovation measures are deductible from taxes depends on country specific tax laws.

Chapter 3

A new approach

The need for a drastic reduction of carbon emissions in the building sector, associated with the specific constraints of the existing buildings, require changes in the approach to mitigating climate change in this sector. Thus, a new methodology is proposed to be used in the decision making process for energy related building renovation, allowing to optimize energy consumption, carbon emissions and overall added value of the renovation process in a cost-effective way (in Figure 5, the project report with the Methodology for Cost-Effective Energy and Carbon Emissions Optimization in Building Renovation).

The approach to the large-scale renovation of the existing building stock relies on three major issues to be addressed:

- Buildings are in general long lasting structures and their renovation implies large investments and the development of long-term strategies considering a life-cycle approach;

- Carbon emissions need to be considered in standards and target setting at least at the same level as energy;

- Energy and carbon optimized building renovation usually have several side effects often yielding substantial additional benefits, which can be as important as energy cost savings (like increased user comfort, fewer problems with building physics etc.). These co-benefits have to be identified and combined with the impacts of carbon emissions and energy reduction measures in the decision making process.

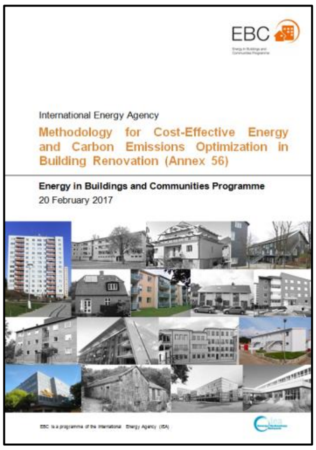

Figure 5 – Methodology for Cost-Effective Energy and Carbon Emissions Optimization in Building Renovation (2017)

3.1 Life cycle analysis in policies

Defining targets only for new buildings and acting only on new buildings is not enough to achieve the established long term carbon emissions reduction targets (in line with the recent Paris Agreement) mainly because of the low rate of replacement of the existing building stock.

Switching conventional heating systems to renewable energy based ones, increasing the extent of energy related building renovation whenever one or more building elements are in need of renovation anyway and making use of the buildings' potential for using solar energy to produce electricity, represent the biggest potential for energy savings and carbon reductions in the building sector.

Improving a building's energy performance and switching to renewable energy, is not just a contribution to mitigating climate change and to save resources, but often also saves costs. Furthermore, energy building renovation serves to manage the risk of potentially higher energy prices in the future. In that sense, building renovation allows to manage risks similar to strategies which reduce other market and policy risks. The analysis of the cost-effectiveness of a certain measure or renovation package of measures is done using a cost/benefit analysis using several possible methods. The simplest method is the simple payback method calculation, where the payback period is the length of time required to recover the cost of an investment and the longer these periods are, the less attractive such investments are. The simple payback does not take into account any benefits or costs that occur after the initial investment has been recovered and therefore there's a tendency for the cheapest solutions to become the most attractive ones. This simplified analysis leads to the missed opportunity of improving the buildings' energy performance in a more effective way, although it is frequently used in standards and national regulations.

On the other hand, the life cycle costs analysis may include the total lifespan of the building or the period for which the renovation is being planned. Costs and benefits of each alternative are analysed along their life time and expressed in annualized costs or net present value (NPV). It includes the investment costs, energy costs, operation and maintenance costs and any residual value of the building at the end of the period considered in the analysis. Life cycle costs (LCC) analysis is an adequate approach because it accounts for all cash outflows and inflows over the period under analysis and it also discounts the value of the money to adjust the cash to its present value.

Decisions on energy related building renovation not based on life-cycle calculations lead to missed opportunities regarding the level up to which carbon emissions and energy use can be reduced cost-effectively.

3.2 Carbon emissions

The investigations that were carried out during this project showed that there is, in general, a large potential for cost-effective building renovations that reduce both carbon emissions and non-renewable primary energy use. Both energy efficiency measures and measures to promote the use of renewable energy sources contribute to these objectives.

Introducing a target to reduce carbon emissions from buildings undergoing a major renovation, supplementing existing energy targets, allows to cost-effectively reach the nearly zero carbon emissions level.

It was observed that renewable energy measures often have the potential to reduce carbon emissions more strongly and at fewer costs than energy efficiency measures. This underlines the importance of taking into account renewable energy measures in future policy making.

Nevertheless, important reasons were also identified to justify keeping carrying out energy efficiency measures. Among these reasons are the ones assuring thermal comfort and other co-benefits that can result from those measures such as the reduction of problems related to building physics (such as humidity and mould) or aesthetics improvement. Besides that, as some natural resources are scarce, it makes furthermore sense to reduce the energy consumption of buildings, even if by using these resources the buildings immediately reach nearly zero carbon emissions and non-renewable primary energy use. Moreover, while a combination of a heat pump with a PV system or with electricity from the grid having a significant share of renewable energy allows to effectively reducing carbon emissions, there continues to be an interest to increase the energy efficiency of a building having such an energy system. If the electricity consumption for driving the heat pumps is thereby reduced, fewer natural resources are used to produce the electricity; additionally, electricity from renewable energy may be scarce in winter time, when most energy is required for heating.

3.3 Co-benefits

The renovation of the existing building stock, improving significantly its energy performance, can deliver a broad range of additional benefits to the economy and society

The renovation of the existing building stock, improving significantly its energy performance, can deliver a broad range of additional benefits (co-benefits) to the inhabitants of the buildings and to society. However, the evaluation of the benefits from energy related renovation programmes and policies focusses mainly on energy savings, leading to the underestimation of the positive impacts of building renovation, which may lead to sub-optimal investment decisions and policy design.

While co-benefits could basically act as a driver for building renovation, the problem is that they are not perceived adequately by the users benefitting from them or by the investors taking the renovation decisions. The problem also extends to specialists supporting investment decisions: energy specialists tend to focus solely on energy-related effects such as primary energy consumption and costs, and professionals from other fields, such as health professionals, are unlikely to be consulted in the context of building renovations. This means that information to increase the perception of co-benefits, as well as interdisciplinary cooperation, is needed to fully take into account the extent of the non-energy benefits and to let them influence investment decisions and policy design.

information to increase the perception of co-benefits, as well as interdisciplinary cooperation, is needed to fully take into account the extent of the non-energy benefits and to let them influence investment decisions and policy design.

Several studies have already analysed co-benefits of energy efficiency investments in the built environment, showing that they can act as a supporting instrument to reach policy goals in several areas. Table 1 gives an overview on co-benefits of building renovation for society.

Co-benefits of energy efficiency investments in the built environment can act as a supporting instrument to reach policy goals in several areas

Table 1 Co-benefits from energy and emissions related building renovation to the society

Category	Subcategory	Description
Environmental	Reduction of air pollution	Outdoor air pollution is reduced through reduced fossil fuel burning and the minimization of the heat island effect in warm periods. Less air pollution has positive impacts on the environment, health and the reduction of building damages.
	Construction and demolition waste reduction	Building renovation leads to a reduction, reuse and recycling of waste if compared to the replacement of existing buildings by new ones.
Economic	Lower energy costs	Decrease in energy costs due to reduced energy demand
	New business opportunities	New market niches for new companies (like ESCOs) possibly resulting in higher GDP growth when there is a net effect between the new companies and those that are pushed out of the market.
	Job creation	Reduced unemployment by labour intensive energy efficiency measures
	Subsidies avoided	The decrease of the amount of subsidized energy sold (in many countries energy for the population is heavily subsidized).
	Improved productivity	GDP/income/profit generated as a consequence of new business opportunities and job creation
Social	Improved social welfare, less fuel poverty	Reduced expenditures on fuel and electricity; less affected persons by low energy service level, less exposure to energy price fluctuations
	Increased comfort	Normalizing humidity and temperature indicators; fewer air drafts; reduced heat stress through reduced heat islands.
	Reduced mortality and morbidity	Reduced mortality due to less indoor and outdoor air pollution and reduced thermal stress in buildings. Reduced morbidity due to better lighting and mould abatement.
	Reduced physiological effects	Learning and productivity benefits due to better concentration, savings/higher productivity due to avoided "sick building syndrome".
	Energy security	Reduced dependence on imported energy.

Also at the building level, relevant co-benefits exist like increased user comfort, fewer problems with building physics, improved aesthetics, etc.. They should be considered in the decision making process for building renovation. In fact, for private owners, investors and promoters, the value of a building depends on the willingness to pay by the customer whether in a sale process or in a rental one. In the case of energy related building renovation, this willingness to pay depends on the expectation of future reduced costs on energy bills and building operation, but also on other benefits not related to energy costs that result from energy related building renovation measures.

Some of the co-benefits whose connection with specific renovation measures have been identified are:
-Thermal comfort
-Natural lighting and contact with the outside environment
-Improved indoor air quality
-Reduction of problems with building physics
-Noise reduction
-Operational comfort
-Reduced exposure to energy price fluctuations
-Aesthetics and architectural integration
-Useful building areas
-Safety (intrusion and accidents)
-Pride, prestige, reputation
-Ease of installation

These benefits are often difficult and nearly impossible to quantify and to measure accurately, which makes it much more difficult to add their contribution into a traditional cost-benefit analysis framework.

Figure 6 illustrates direct benefits and co-benefits of energy related building renovation measures.

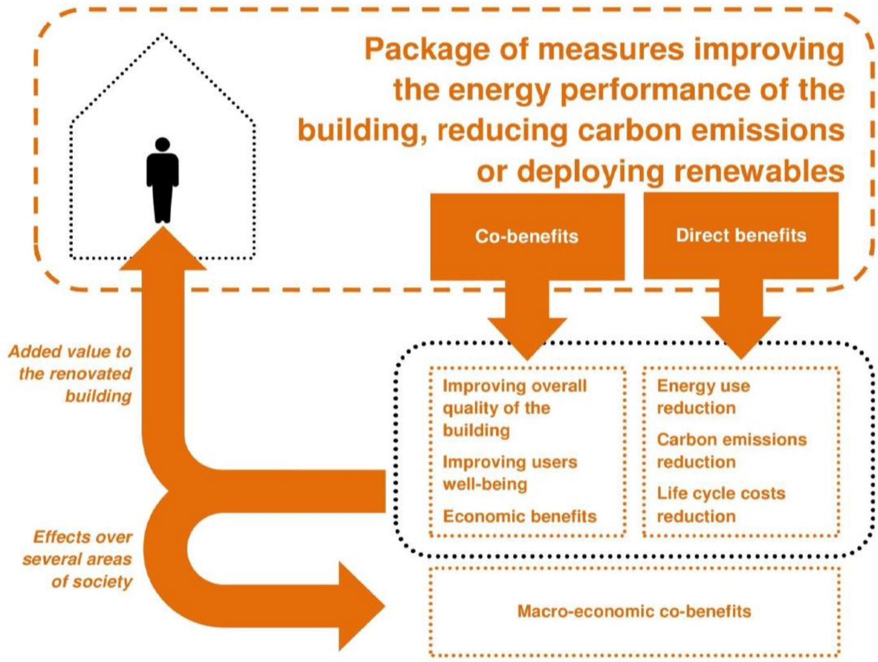

Figure 6 – Direct benefits and co-benefits from cost-effective energy and carbon emissions related building renovation and their relationship to the overall added value

3.4 Inputs from generic calculations and case studies

For the development of the methodology within the project, generic calculations were carried out for representative buildings of the various participating countries. Also, a collection of successful renovation case studies was gathered in different countries and different contexts. From the analysis of these examples, it is possible to observe that far reaching energy renovation is possible and that difficulties are manageable and can be overcome.

From the analysis of the case-studies in different countries and contexts, it is possible to conclude that far reaching energy renovation is possible and that difficulties are manageable and can be overcome.

The generic calculations showed that in the investigated cases, a switch to renewable energy reduces carbon emissions more significantly than energy efficiency measures in one or more elements of the envelope. It was also confirmed that in order to achieve high emission reductions, it is more cost-effective to switch to renewable energy and to carry out less far-reaching renovation measures on the building envelope than to focus on energy efficiency measures alone. In order to promote a large-scale cost-effective reduction of carbon emissions in the building sector, it is advisable to put a strong focus on the application of renewable energy measures.

A switch to renewable energy reduces carbon emissions more significantly than energy efficiency measures in one or more elements of the envelope.

Nevertheless, it was also confirmed, for a large share of the analysed buildings, that a combination of energy efficiency measures with a switch to a renewable energy system does not significantly change cost-optimal efficiency levels. This shows that a switch to a renewable energy system often does not negatively influence the cost-effectiveness of efficiency measures. As there are other important reasons than reducing carbon emissions for carrying out energy efficiency measures, it therefore makes sense to carry out both efficiency measures and a switch to renewable energy.

A switch to a renewable energy system often does not negatively influence the cost-effectiveness of efficiency measures.

The impact of embodied energy use and embodied emissions of renovation measures has been found to be smaller than for new building construction, yet it plays a role for high efficiency buildings and for heating systems based on renewable energy or district heating. When the heating system is based on renewable energy or district heating with waste heat and renewable energy, the effects of embodied emissions are becoming more important, because the reductions of emissions achieved with additional insulation are smaller. This may lead to awkward situations in which increases in efficiency standards increase overall life-cycle carbon emissions including embodied emissions.

The impact of embodied energy is smaller than for new building construction, yet it plays a role for high efficiency buildings and for heating systems based on renewable energy or district heating.

Among the gathered examples of renovation projects in case studies, various energy efficiency measures were identified leading to energy consumption reductions through the improvement of the performance of the building envelope and by recovering heat from the ventilation losses. Various renewable energy measures, such as the use of solar panels or renewable-based district heating solutions to complement the remaining needs, were also identified. Each combination is a result of the existing context, the available solutions and sources and significant integration efforts. Depending on the climate severity, period and quality of construction, among other factors, the buildings behave differently, creating different baselines and consequently requiring different intervention strategies.

Depending on the climate severity, period and quality of construction, the buildings behave differently, creating different baselines and consequently requiring different intervention strategies.

In the investigated case studies, many of the energy efficiency measures included in the renovation address the boundaries with poor thermal performance (roofs, ceilings, walls, windows and floors with insufficient or no insulation), with a particular focus on those in need of renovation due to wear.

In the investigated case studies, energy efficiency measures were typically carried out to reduce the energy demand while improving the occupants' comfort and reducing the amount of energy needed from renewable energy sources. The shift to renewable energy was implemented either by connecting to existing district heating structures fuelled by biomass or waste combustion, or using biomass-based heating systems. Many also included solar thermal panels for domestic hot water production and/or space heating or solar photovoltaic (PV) panels for energy production to be self-consumed or injected in the grid.

Energy efficiency measures are usually taken as a first step to reducing the energy demand while improving the occupants' comfort and reducing the amount of energy needed from renewable energy source production.

The case studies illustrate the necessity of assessing for each type of situation and each building separately, which renovation strategy is more adequate. However, it could also be shown that a common approach can be applied looking at the renovation process as a whole, which includes the three main elements of the proposed approach: to take a life cycle perspective, to take adequately into account carbon emissions in addition to taking into account primary energy and to take into account achievable co-benefits.

The renovation process must take into consideration contributions and advantages of acting in each element towards an overall evaluation of the building, not only in terms of costs but also in terms of energy and carbon emission reductions and achievable additional benefits.

Chapter 4

Strategies for building renovation

The investigations developed during the project showed that there is a large potential for cost-effective building renovations with far-reaching reductions in carbon emissions and primary energy use through the application of energy efficiency measures and measures to promote the use of renewable energy.

It was recognized that it is important to differentiate between cost-effectiveness and cost-optimality and to understand cost-effectiveness from a life-cycle perspective.

From the results achieved, it is clear that optimized building renovation is not only a technical and economic issue but also a matter of strategy/ approach. Political targets and related political actions are relevant to both aspects.

4.1 Cost-optimality vs cost-effectiveness

It is of utmost importance to highlight the difference between cost-effectiveness and cost-optimality. Among the possible energy related renovation solutions that are cost-effective (with respect to a reference case), the cost optimal solution is the one with the least life cycle costs.

Cost-optimality refers to the most cost-effective renovation package, usually not meeting existing ambitious energy and carbon emission targets. Cost-effective solutions comprise also solutions going beyond cost optimality allowing achieving more ambitious energy and carbon emission targets.

The reference case is understood to refer to the initial situation of the building combined with measures that would be necessary "anyway", just to restore the functionality of the building elements for another life cycle without improving its energy performance.

It is important to understand cost-effectiveness from a life-cycle perspective. Building renovation measures do not pay off in a few years, but rather bring economic advantages in the long run. In order to highlight the benefits of building renovation, it is necessary to focus on the long-term perspective and not just compare investment costs of renovation measures or focus on measures with short payback times.

In the case of building renovation, cost optimal energy related renovation measures usually do not yet allow achieving high levels of energy performance and reduced emissions, being in fact not very ambitious. Therefore, to achieve the level of improvement that is necessary to achieve the climate related targets, the range of economically viable renovation measures has to be extended to renovation measures beyond the cost optimal level but being still cost-effective. Figure 7 illustrates these concepts.

Building renovation measures do not pay off in the short term, but rather bring economic advantages in the long run.

Cost optimal energy related renovation measures are not very ambitious.

The range of economically viable renovation measures has to be extended to renovation measures beyond the cost optimal but being still cost-effective with respect to the reference case.

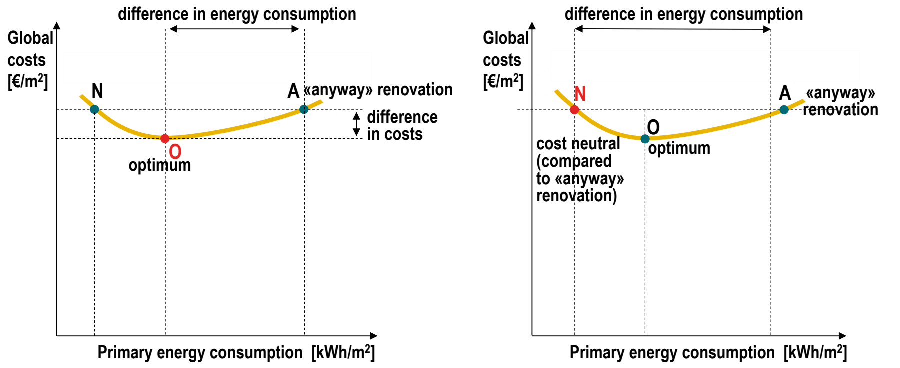

Figure 7 - Global cost curve after renovation (yearly costs for interest, energy, operation and maintenance), starting from the reference situation "A" («anyway renovation») towards renovation options yielding less primary energy use than in the case of the anyway renovation. "O" represents the cost optimal renovation option. "N" represents the cost neutral renovation option with the highest reduction of primary energy (BPIE 2010, p. 15, supplemented by Ott, W. et al., 2014))

4.2 Which building elements should be renovated

Different building components contribute to the overall performance of the building. These components can be summarized in three categories: passive elements, technical systems and energy source.

Passive elements are those related to the energy needs of the building and are in fact the elements of the building envelope (for example walls, roofs, windows) but also the ones regarding solar gains through windows and their storage or the existing shading systems. These elements influence the overall energy needs of the building (energy demand).

The existing energy needs of the building, resulting from the performance of the building elements, have then to be covered by technical systems: heating, cooling, ventilation and domestic hot water production. Each of these elements has its own performance, leading to better or worse efficiency.

At last, these technical systems may use different energy sources with origin in fossil fuels or from renewable energy sources.

Therefore, the amount of energy (and related emissions) needed to have a building at a specific comfort level, depends on the overall performance of the building elements, the efficiency of the technical systems and the energy sources that are used. In the case of building renovation, a large number of factors influence which measures are technically possible and economically viable for a given building. The identification of cost-effective solutions yielding far reaching energy or carbon emissions reductions is, therefore, a much more complex process than for new buildings. Relevant synergies and trade-offs between the three above mentioned approaches can and must be achieved.

Synergies between the performance of the building elements, the efficiency of the technical systems and the energy source used can be achieved in the renovation process.

To achieve in more effective way large reductions of energy use and carbon emissions in existing buildings, it is important that standards, targets and policies take into account the complexity of building renovation while seeking cost-effective solutions. Flexibility is needed to give renovation strategies a chance to enable the transformation of the building stock towards low energy use and nearly zero emissions. This includes the flexibility to reach these targets step by step over time.

Standards, targets and policies must take into account the complexity of the building renovation process while seeking for cost-effective solutions minimizing carbon emissions and energy use.

4.3 Approach and strategy

Renovation projects are often limited by case-specific constraints and interdependencies and do not comprise a complete set of measures on the building envelope and on the energy system. The reasons are in particular financial constraints and non-synchronism of renovation needs of the energy related building elements at stake. What is recommendable in a given situation can only be answered on a case by case basis, by assessing different packages of renovation measures which take into account immediate renovation needs, financial resources and, at least, midterm planning of upcoming renovation needs. There might be situations in which a switch to a renewable energy system is made without improving the energy performance of the building envelope if the envelope does not need renovation yet. But the related advantages and disadvantages have to be assessed for the particular situation, taking costs, thermal comfort and possible building physics related problems carefully into account.

In order to improve the energy performance of a building, it is important to improve the energy performance of all the elements of the envelope to a certain extent. It is well known that for each single building element, there are decreasing marginal benefits of additional insulation. For example, increasing the insulation thickness of a wall from 12 cm to 30 cm has usually less impact on energy savings than limiting the insulation of the wall to 12 cm and adding a 10 cm layer of insulation to the roof.

It is often more important to improve the energy performance of all the components of the building envelope to a certain extent than to significantly improve the performance of just a few. However, more far-reaching measures are often not more costly from a life-cycle perspective than measures with low-efficiency.

But, at the same time, it is recommendable to choose ambitious energy efficiency levels in order to not miss opportunities within building renovation. Insulation measures with a high level of efficiency are often at the same level of cost-effectiveness as measures with a low level of efficiency. Once the insulation measures are carried out, however, it is usually not cost-effective anymore to add further insulation at a later stage, because the marginal cost/benefit ratio becomes unfavourable.

It is recommendable to choose ambitious energy efficiency levels in order not to miss opportunities within building renovation.

The moment of replacement of the heating system is a good opportunity to combine a switch to renewable energy together with the application of energy efficiency measures on the building envelope. As the energy needs of the building are reduced, the peak capacity of the heating system can be reduced as well. This is a key driver for making many energy efficiency measures on the building envelope cost-effective in combination with a switch of the heating system. If this opportunity is missed, and the capacity of the heating systems is determined without taking into account improvements on the building envelope, subsequent energy related renovation of the building envelope will be less cost-effective and the heating system will be more expensive because of the higher capacity needed.

Even if energy or carbon emission targets can be reached to some extent by using renewable energy without making use of energy efficiency measures, there are numerous reasons for carrying out energy efficiency measures during building renovation:

Even if energy use or carbon emission targets can be reached exclusively by switching to renewable energy sources, there are numerous reasons for also carrying out energy efficiency measures during building renovation.

- Energy efficiency measures increase thermal comfort and have also other co-benefits;

- Energy efficiency measures are often necessary to ensure sufficient thermal quality of the building envelope and to prevent damages resulting from building physics related problems;

Stepwise renovation is frequently a preferred option but it is necessary to have a medium to long term plan for the different steps to ensure sustainable renovations.

- Carrying out energy efficiency measures is often also cost-effective when carried out in combination with a switch to renewable energy. A reduction of the energy use of the building through energy efficiency measures allows reducing the capacity of the installed heating system, which increases cost-effectiveness and the range for deploying renewable energy systems;

- If the electricity mix is to a large extent emissions-free, because of high shares of renewable energy or nuclear energy, only energy efficiency measures can ensure that electricity use in buildings is reduced.

Given the high investments that are needed, or because building elements may reach the end of their life at different times, a stepwise renovation may be a wise option. For a sustainable stepwise renovation process it is necessary to have a medium to long term plan for the different steps, making sure that building elements added over time are matched to each other and that potential problems arising from their introduction at different times are avoided to the extent possible.

Chapter 5

Financing mechanisms, funds, incentives, renovation programmes

Many governments use financial incentives such as capital subsidies, grants, subsidized loans and rebates to encourage building owners and occupants to invest in energy efficiency measures and equipment. In particular, governments have targeted space heating and cooling because of the high degree of energy waste through poor insulation and air leakage in existing buildings. In this regard, financial incentives to promote the insulation and retrofitting of exterior walls, ceilings, attics, lofts, floors, window frames and band joints, as well as hot water storage tanks, boilers and water pipes, are most common.

There are various types of subsidies for promoting building renovation. A common objective of them is to overcome the major barrier of high initial costs. They have been used to finance better insulation, such as roof insulation, in the U.K., more efficient equipment, such as refrigerators, in Germany and energy audits in France. Some governments have also introduced soft loans schemes whereby loans for installing energy efficiency equipment are offered at a subsidized interest rate. Other governments prefer to use fiscal measures such as tax incentives to encourage investment in energy savings and efficiency measures in buildings. For the residential sector, tax credits and tax deductions are most popular, while for the commercial sector often tax concessions and accelerated depreciation are used.

It is recommendable that financial schemes and incentives are prepared to promote the building renovation beyond the cost optimal level.

To reach the long term climate objectives it is crucial to obtain the largest possible impact from building renovation in terms of contributing to the reduction of carbon emissions or primary energy use. Therefore, it is advisable to carry out the furthest reaching renovation packages which are still cost-effective compared to the reference case, rather than to be limited to the cost-optimal renovation package. Taking into account the co-benefits that can be achieved, the renovation measures that are considered to be cost-effective can be extended even further. However, given the relevant investments that are needed and the lack of cost-effectiveness in some cases, it is recommendable that financial schemes and incentives are prepared to promote this additional step.

Given the existing synergies between renewable energy measures and energy efficiency measures, the replacement of the heating system is an excellent opportunity to carry out renovation measures on the building envelope as well. It is, therefore, recommendable that standards and other policy measures, for example, subsidies, create incentives to combine renovation measures on the building envelope with the shift to a renewable energy based heating system.

It is recommendable that standards and other policy measures create incentives to combine renovation measures on the building envelope with the shift to renewable energy based systems.

Chapter 6

Recommendations and conclusions

The work developed within this project allowed to formulate a set of recommendations that should be considered by policy makers in the definition and design of new policy programs and regulations. These recommendations focus on three major vectors that are expected to be addressed by policy makers:

a) Strategic thinking in the development of energy policies;

b) Standard setting;

c) Incentives.

The main goal is to create awareness about various aspects of building renovation which are so far often not adequately taken into account, allowing for a better definition of upcoming standards, rules and regulations. A change of mind-set is proposed.

Introduce targets to reduce carbon emissions from buildings, supplementing existing energy targets - renovation of buildings must reach nearly zero carbon emissions

Recommendation

#1

Introduce carbon emissions targets in addition to energy targets

It is advisable to introduce a target to reach nearly zero carbon emissions in existing buildings undergoing a major renovation, complementing existing energy efficiency requirements. If this is not cost-effective because, for example, the heating system would not have to be replaced anyway in the near future, exceptions can be made or subsidies can be allocated for these cases considering the co-benefits from a macroeconomic perspective. For buildings connected to a district heating system, it is possible to reach the goal of nearly zero carbon emissions collectively by changing the energy source of the district heating system. In such cases, it is advisable to develop the most favourable strategy in cooperation with building owners.

Switching heating and other technical systems to renewable energy should tend to become mandatory

It is adequate to make a switch to renewable energy mandatory when a heating system is replaced, similarly to energy improvements of the building envelope. Exemptions may still be granted from such a rule if the building owner can show that such a measure would not be cost-effective from a life-cycle perspective or subsidies can be allocated for these cases considering the co-benefits from a macroeconomic perspective. Exemptions could also be made if a building is connected to a district heating system which either already has a high share of renewable energy or for which a plan exists to switch to renewable energy.

Recommendation #2

Shift to technical systems based on renewable energy

Whenever the building integrated technical systems are changed, on-site use of renewable energy sources should be prioritized, considering that it can give the residents a significant comfort and stability regarding energy price fluctuations. When these measures are visible, the owners get an enhanced sense of pride and prestige and an improved sense of environmental responsibility. These are additional benefits (co-benefits) of measures promoting the use of renewables.

Consider the design of incentives or other mechanisms to promote the shift to renewable energy sources

Recommendation #3

Create incentives to support a shift to renewable energy

Usually, renewable energy systems have higher investment costs than conventional heating systems. Even if such systems are often cost-effective from a life cycle perspective, it is recommended to design incentives or other financial mechanisms to support this shift.

Promote through regulations the use of synergies between renewable energy measures and energy efficiency measures

Recommendation #4

Promote the combination of energy efficiency measures with renewable energy

It is recommendable that standards and other policy measures, for example subsidies, create incentives to combine renovation measures on the building envelope with a replacement of the heating system, in order to make sure that reductions in energy use and emissions are achieved most efficiently. Exceptions could be made for buildings connected to a district heating system, which already has a high share of renewable energy or for which a switch of the district heating system to renewable energy sources is already planned.

Orientation towards cost-effectiveness rather than cost-optimality to achieve a sufficiently sustainable development of the building stock

Recommendation

#5

Shift from cost-optimality to cost-effectiveness

It is recommendable that standards do not limit themselves to make an energy performance level mandatory up to the cost-optimal level but to make also further measures mandatory as long as they are cost-effective with respect to a reference case.

Depending on the original condition of the building, improving all elements of the building envelope often means going beyond the cost optimal level (since in a comprehensive package of measures the improvement of certain elements may not be cost-effective). However, in these circumstances, the packages of measures can remain cost-effective when compared to the reference case and the improvement of all elements of the building envelope is usually the way to maximize the added value achieved with the co-benefits.

Making use of opportunities when renovations are made "anyway"

Recommendation

#6

Make use of all opportunities

It makes sense that standards for achieving improvements in energy performance focus on the situation when one or more building elements are in need of renovation anyway.

An understanding of the current status of the building stock is essential to clearly define the strategy and timing for building renovation.

Take into account the complexity of building renovation in standards, targets, policies and strategies

Recommendation

#7

Make regulations flexible

To achieve a large reduction in energy use and carbon emissions in existing buildings most effectively, it is important that standards, targets and policies take into account the complexity of building renovation while seeking for cost-effective solutions. Flexibility is needed to give renovation strategies a chance to enable the transformation of the building stock towards low energy use and a nearly zero emissions level. This includes the flexibility to reach these targets step by step over time.

Ensure good quality in design and execution of building renovation

Recommendation

#8

Promote quality and accuracy in design and execution

No matter what renovation measures are chosen, good design and good execution are decisive for the added value of the building, to ensure the expected co-benefits from the related renovation measures. Therefore, promoting the quality in design and execution of building renovation is crucial for their success and acceptance.

A minimum level of energy efficiency must always be assured to provide comfort and to assure the maximization of the co-benefits resulting from building renovation

Recommendation

#9

Assure a minimum level of energy efficiency

Depending on the original condition of the building and its context, cost optimal packages of renovation measures only considering investment and operational costs are often not very ambitious regarding energy performance, mainly due to certain specific measures that are not cost-effective.

To maximize the co-benefits resulting from energy related renovation measures, all main elements of the building envelope should be improved to a minimum energy performance level in accordance with the local climate requirements. In most cases, this improvement represents just a small increase in the global costs when compared to the cost optimal solution and still remains cost-effective when compared to the reference case which includes an “anyway renovation”. A far-reaching solution maximizes the co-benefits achieved with the intervention and consequently the added value of the building.

In case of limited financial resources, it is more important to improve the energy performance of as many building elements as possible than to strive for maximum energy performance of just particular building elements

Recommendation

#10

Whole building renovation is preferable instead of maximizing the energy performance of just one or few individual elements

In the existing building stock, buildings often have several building elements with low efficiency performance. A higher impact is achieved if several building elements are involved in the building renovation process than just act on a single building element alone.

However, it is advisable to choose a high efficiency level as target if the energy performance of an element of the building envelope is improved since it is much cheaper to achieve a high insulation standard for a certain building element in one step rather than to insulate first to some degree and to increase the energy performance at a later stage. Often, measures that reach high efficiency levels are at the same level of cost-effectiveness as the low efficiency measures.

Additionally, energy efficiency measures are the source of many co-benefits, particularly those improving building quality, such as the reduction of problems with building physics, increase of useful building areas and improved safety against intrusion, and the resident's comfort and physical wellbeing, such as increased thermal and acoustic comfort, increased use of day lighting and better indoor air quality. To maximize the co-benefits from energy related building renovation, it is more relevant to improve as many elements of the building envelope as possible than to significantly improve just few of them.

In promoting the use of renewable energy sources, particular attention should be given to the proper integration of renewable energy systems.

Recommendation

#11

Take into account the challenges of integrating renewable energy

At the building level, measures for the use of renewable energy sources usually have as co-benefits the reduction of the exposure to energy price fluctuations. Residents with systems based on renewables (with the exception of systems based on wood pellets) are more comfortable regarding future variations on the energy prices because they are less dependent on energy from the market.

Some renewable energy systems present specific challenges regarding their integration into existing buildings. Some of these systems (e.g. photovoltaic or solar thermal) present a challenge for their integration into the architectural characteristics of the existing buildings, while others (e.g. geothermal heat pumps) present technical or financial challenges to be implemented. On the other hand, some of these systems (e.g. air/air or air/water heat pumps or wood pellets boilers) are much easier to implement than most energy efficiency measures and may allow reducing the depth of the interventions on the building envelope.

Consider energy related building renovation as an opportunity to increase building (stock) value

Recommendation

#12

Take into account the added value resulting from the building renovation

The economic value of the existing building stock is an important asset whose value can be potentiated in an optimized way. By saving future energy costs, energy related building renovations increase the value of the renovated buildings. The co-benefits further contribute to improving the building value.

Assure inclusion of tenants in building renovation processes

Recommendation

#13

Take into account the opinion of the users

In rented buildings, tenants should be involved in the renovation process, so that they can feel more engaged in that process and consider the renovation as positive and understand the long-term environmental benefits.

Quite often, the relation between housing companies and residents is critical for the acceptance of the latter towards building renovation. The relationship between them should be improved, in terms of laws and regulations, so that these two players can be more coordinated towards the motivations and benefits of building renovation.

References

Almeida, M., Ferreira, M., Rodrigues, A. (2017). Co-benefits of energy related building renovation - Demonstration of their impact on the assessment of energy related building renovation (Annex 56). Edited by Manuela Almeida, University of Minho, Portugal. ISBN: 978-989-99799-2-5. Available online in http://www.iea-annex56.org/.

Blomsterberg, A., Pedersen, E., Baptista, N., Fragoso, R. (2017). Owners and Residents Acceptance of Major Energy Renovations of Buildings (Annex 56). Edited by Manuela Almeida, University of Minho, Portugal. ISBN: 978-989-99799-7-0. Available online in http://www.iea-annex56.org/.

Bolliger, R., Ott, W. (2017). Investigation based on calculations with generic buildings and case studies (Annex 56). Edited by Manuela Almeida, University of Minho, Portugal. ISBN: 978-989-95961-6-0. Available online in http://www.iea-annex56.org/.

BPIE (2010). The Buildings Performance Institute Europe: Cost Optimality – Discussing methodology and challenges within the recast Energy Performance of Buildings Directive, Brussels.

BPIE (2011). Europe's Buildings Under the Microscope –A Country-by-country Review of the Energy Performance of Buildings. ISBN: 9789491143014.

BPIE (2013). Staniaszek, D.; Rapf, O.; Faber, M.; Nolte, I.; 2013: "A guide to developing strategies for building energy renovation", Buildings Performance Institute Europe.

Brand, S. (1995). How Buildings Learn: What Happens After They're Built. Penguin Books. ISBN-10: 0140139966, ISBN-13: 978-0140139969.

Dineen, D.; Howley, M.; Holland, M (2014). Energy in Transport—2014 Report; Energy Policy Statistical Support Unit, Sustainable Energy Authority of Ireland: Dublin, Ireland.

European Commission, (2010). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – Energy 2020. A Strategy for Competitive, Sustainable and Secure Energy (10.11.2010, COM(2010) 639Final), European Commission., Brussels.

European Commission, (2011). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – A Roadmap for Moving to a Competitive Low Carbon Economy in 2050 (8.3.2011, COM(2011) 112 Final), European Commission, Brussels.

European Parliament and the Council of the European Parliament, (2010). Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast), Off. J. Eur. Union.

Eurostat (2016a). (http://ec.europa.eu/eurostat/statistics-explained/index.php/Consumption_of_energy)

Eurostat (2016b). (http://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_production,_consumption_and_market_overview)

Greenpeace International (2014). Energiewende: The energy transformation in Germany. In Proceedings of the Background Briefing for the IPCC WG3 Report, Berlin, Germany, 7–11 April 2014; pp. 1–4.

Hall, S.; Foxon, T.J.; Bolton, R. (2016). Financing the civic energy sector: How financial institutions affect ownership models in Germany and the United Kingdom. Energy Res. Soc. Sci. 2016, 12, 5–15.

Holl, M. (2011). The EU Commission's upcoming proposal on the cost optimal framework methodology"; EU-Commission DGE, Wels, Sustainable Energy Days

International Energy Agency (IEA) (2012). Energy Technology Perspectives 2012 Pathways to a Clean Energy System; International Energy Agency: Wien, Austria.

International Energy Agency (IEA) (2015). Energy and Climate Change; World Energy Outlook Special Report; International Energy Agency: Wien, Austria.

International Energy Agency (IEA) (2016). International Energy Outlook 2016.

IPCC, (2007). Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland.

Konadu, D.D.; Mourão, Z.S.; Allwood, J.M.; Richards, K.S.; Kopec, G.; McMahon, R.; Fenner, R. (2015). Land use implications of future energy system trajectories—The case of the UK 2050 Carbon Plan. Energy Policy 2015, 86, 328–337.

Lasvaux, S., Favre, D., Périsset, B., Marouha, S., Citherlet, S. (2017). Life-cycle Assessment for Cost-Effective Energy and Carbon Emissions Optimization in Building Renovation (Annex 56). Edited by Manuela Almeida, University of Minho, Portugal. ISBN: 978-989-99799-3-2. Available online in http://www.iea-annex56.org/.

Leiby, P.N. (2007). Estimating the Energy Security Benefits of Reduced U.S. Oil Imports; Oak Ridge National Laboratory: Oak Ridge, TN, USA.

Mørck, O., Höfler, K., Maydl, J., Venus, D., Sedlák, J., Struhala, K., Østergaard, I., Thomsen, K., Rose, J., Jensen, S., Zagarella, F., Ferrari, S., dalla Mora, T., Romagnoni, P., Kaan, H., Almeida, M., Ferreira, M., Brito, N., Baptista, N., Fragoso, R., Zubiaga, J., Blomsterberg, A., Citherlet, S., Périsset, B. (2017). Shining Examples of Cost-Effective Energy and Carbon Emissions Optimization in Building Renovation (Annex 56). Edited by Manuela Almeida, University of Minho, Portugal. ISBN: 978-989-99799-5-6. Available online in http://www.iea-annex56.org/.

Navarro, A.M.; Sambodo, M.T. (2013). The Pathway to ASEAN Energy Market Integration; Philippine Institute for Development Studies, Discussion Paper Series; Philippine Institute for Development Studies: Quezon, Philippines.

Ott, W., Bolliger, R., Ritter, V., Citherlet, S., Favre, D., Perriset, B., Almeida, M., Ferreira, M. (2014). Methodology for Cost-Effective Energy and Carbon Emissions Optimization in Building Renovation. Edited by Manuela Almeida, University of Minho, Portugal. ISBN: 978-989-95961-6-0. Available online in http://www.iea-annex56.org/.

Romagnoni, P., Cappelletti, F., Peron, F., Dalla Mora T., Ruggeri, P., Almeida, M., Ferreira, M. (2017). Tools and procedures to support decision making for cost-effective energy and carbon emissions optimization in building renovation (Annex 56). Edited by Manuela Almeida, University of Minho, Portugal. ISBN: 978-989-99799-4-9. Available online in http://www.iea-annex56.org/.

Strbac, G.; Konstantelos, I.; Aunedi, M.; Pollitt, M.; Green, R. (2016). Delivering Future-Proof Energy Infrastructure; Report for National Infrastructure Commission; University of Cambridge Energy Policy Research Group: Cambridge, UK.

Venus, K., Höfler, K. (2017). Evaluation of the impact and relevance of different energy related renovation measures on selected Case Studies (Annex 56). Edited by Manuela Almeida, University of Minho, Portugal. ISBN: 978-989-99799-6-3. Available online in http://www.iea-annex56.org/.

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