EAI Endorsed Transactions
Smart Cities
Research Article EAI.EU

Residential buildings renewal towards to the Smart concept

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Abstract

The current global trends lead to fulfilment of specified environmental and economic objectives in all sectors of national economies. Buildings form a basic pillar of smart cities concept where all life processes and nerve centres of social life are read, in order to radically improve quality of life, opportunity, prosperity, social and economic development, thanks to the use of the new technology. The building sector has been identified by various studies as a sector that offers considerable potential for the cost-effective reduction of greenhouse gas emissions, making it an important field for climate protection action. A significant role towards realizing these objectives has in particular the implementation of the latest technologies and technical procedures in all processes at all levels. Smart buildings are no longer considered individually, but as a part of complex ecosystem. They must be adapted to the expectations of future users if they are to be properly used. This paper deals with the problematics of current technological, environmental and economic trends in renewal of residential buildings.

Keywords: residential buildings, renewal, energy efficiency, economic assessment.

Received on 1 March 2017, accepted on 13 October 2017, published on 19 December 2017

doi: 10.4108/eai.19-12-2017.153477

1. Introduction

The real estate and construction sectors can play a critical role in shaping energy use. Buildings now account for 40% of total primary energy consumption [1] and they are the biggest single contributor (approximately 36%) to European CO2 emissions that amount to approximately 5 gigatonnes for all sectors.

Building renewal is crucial if the EU is to meet its ambitious 2020 energy and climate goals: improving energy efficiency by 20% and achieving a 20% reduction of greenhouse gas emissions from 1990 levels. [1] Reaching the declared long-term target of reducing greenhouse gas emission levels by 80-95% by 2050 will therefore need a major effort to improve building energy efficiency. Approximately 40% of Europe's building stock predates the 1960s and is in dire need of renovation. [1] Given that the renovation cycle for buildings is approximately 30 years (probably less for commercial buildings) during which the performance of a building in principle does not change, it is necessary to ensure that new buildings and renovation measures on existing buildings optimize the energy saving potential. [2]

Nowadays attitudes towards climate change mitigation remain mixed across the globe. Moreover, most of the sector's energy efficiency investments are in new buildings rather than renewal, even though existing structures make up the biggest share of the world's buildings. This makes the huge challenge of cutting the energy footprint of the global building stock; an extraordinary opportunity exists to scale up efficiency measures in the real estate sector. [3] Anyway, these climate change targets will be nearly impossible to reach without industry's full participation.

According to some realized surveys (The Economist, The Buildings Performance Institute Europe) the great majority of construction and real estate companies in the

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world are mainly focuses on the construction of new energy-efficient buildings instead of renovation of the existing stock. However, precisely old buildings create a huge proportion of energy consumption and production of emissions. This situation is quite understandable in emerging markets such as China or India. What is quite surprising is that even highly developed markets such as Europe or the US, where the share of new buildings is relatively low compared to developing countries (share constitutes only 1%), focuses on the construction of new energy-efficient buildings before renovation of existing ones.

This is problematic because less efficient buildings will continue to waste energy for a long time to come. The fact that companies are focused on new construction is somewhat understandable as the investment can be more easily amortized over the lifecycle of the building. Fitting a structure with the latest energy-efficient heating and cooling systems, high-performance windows and insulation is far easier when starting on a new project than when dealing with an existing structure. Moreover, in existing buildings, it may be necessary to work while parts of the building remain occupied.

In 2012 the Economist Intelligence Unit realized a global survey focused on energy efficiency, energy savings and the regulatory environment, of 423 senior executives from four sectors: residential real estate, building construction, commercial real estate and the industrial real estate sector. Geographically, respondents were evenly split among the US, Europe, India and China. Organizations of all sizes were represented, and roughly half were from firms with revenue over US$500m. Forty percent of US survey respondents from the building sector accept no business responsibility for carbon emissions. In Europe, China and India, 84% of respondents cite emissions reductions as an important business responsibility. The attitude of US respondents is mirrored in the country's political process and the relative weakness of energy efficiency legislation. [3].

2. Technological trends in residential buildings renewal

More knowledge of energy use prompts companies to go further in their measures to reduce consumption, including rigorous measurement of a business's energy footprint. According to building energy experts, heating and cooling account for between 20% and 60% of total energy use in a building, depending on a building's efficiency. [3]

New technologies and systems - from the ability to adjust lighting levels for individual users to a range of automated and wireless controls - mean companies can do more than reduce their emissions. They can also improve quality of life for building occupants. But if they do not look at how different systems interact and how to persuade users to change their behaviour, the building sector may miss both business and climate change mitigation opportunities.

IT-enabled energy systems can create buildings that are not only more efficient but are also healthier and more pleasant places in which to live or work. [3]

2.1. Savings technologies requirements

The maximum savings potential within the building sector has not yet been fully recognized. [4] Both the quality of measures and the speed of implementation (especially in building renovation) demonstrate the scope for improvement. [5] So far, European Member States have adopted different approaches and different ambitions in their building regulations, influenced by national political processes, building traditions and individual market conditions. [2]

Technologies to improve the energy performance of buildings, which should be taken into account, are:

Building envelope

Measures deal primarily with the reduction of heat transmission and improved air tightness of the building envelope with the intention of reducing transmission losses and losses from (too high) air-exchange. This includes: thermal insulation products (e.g. for insulating walls or roof); building materials (e.g. for walls) with low thermal transmission; measures to ensure air-tightness (e.g. sealants); measures to reduce the effects of thermal bridges (specific construction solutions for connections within facade and roof); high efficient glazing (e.g. triple glazing) and low energy window frames and doors (use of insulating materials, specific sealants, etc.).

Green facades in smaller amounts became a part of technological solutions in building's regeneration processes. Among their undoubted advantages can be included savings for heating. This is due to the ability of holding the air and prevent its circulation between the wall and greenery, especially in winter time. By contrast, in the summer it creates a pleasant climate in the building and as the leaves releases moisture in the air in the vicinity of facades there is a pleasant environment. Another undeniable positives include: sound insulation, production of oxygen and carbon dioxide retention, absorbing pollutants from the air, filtering particles of dust and prevent its dispersion. Another advantage is that climbing plants with its roots pumped out moisture from the foundation of the house (see Figure 1).

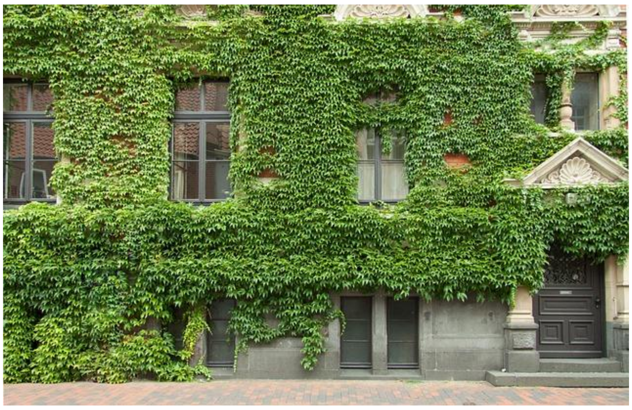

Figure 1. Example of green facade [16]

Roofs

Green roofs are not new or extraordinary in new construction of buildings, but this type of roofs are increasingly appearing also in the renovation of existing residential buildings. Their undoubted advantages are: oxygen production and retention of carbon dioxide, absorbing pollutants from the air, filtering particles of dust and prevention of its dispersion, preventing overheating of roofs, reducing temperature fluctuations between day and night, the function of heat and sound insulation, fire resistance, mitigation of humidity fluctuations, unlimited service life (with proper design), aiding the sewage system because it slow down the runoff of rainwater, creating a habitat for insects, aesthetic and recreational functions, the possibility of creating gardens for growing flowers and vegetables (see Figure 2).

Thereby green roofs slowing the drainage of rainwater, there is less burden on sewage system functions. While rainwater from these types of roofs can be drained into containers from which could be drawn (or by using a gravity system) and reused for irrigation of immediate vicinity of the building.

Figure 2. Example of green roof [17]

During the renewal processes on the roof could be placed alternative energy sources (e.g. solar panels or wind turbines).

Space heating

An active system is usually necessary to meet the demand for heating. This demand can be met by efficient and/or renewable energy systems (e.g. condensing boilers, heat pumps or wood-pellet boilers) in conjunction with suitable storage and distribution systems.

Hot water

Domestic hot water is often produced with the same system used for space heating, but it can also be supplied by combined systems (e.g. when integrating solar energy systems) or separate systems. High efficient storage and distribution systems are crucial for reducing heat loss.

Ventilation systems

Mechanical ventilation systems help to achieve the necessary air-exchange rates and can also limit losses from air-exchange by heat recovery systems.

Cooling systems

Passive cooling systems such as shading devices can help reduce or avoid cooling loads. Active systems can meet demand for heating. These are mainly electric systems but renewable systems are also available (e.g. solar cooling).

Lighting

This includes applications to increase the use of daylight (e.g. tubes or mirrors) and active systems for artificial lighting (e.g. low energy light bulbs).

A Lighting control system can be used to switch lights based on a time cycle, or arranged to automatically go out when a room is unoccupied. Some electronically controlled lamps can be controlled for brightness or colour to provide different light levels for different tasks. Lighting can be controlled remotely by a wireless control or over the Internet. Natural lighting (daylighting) can be used to automatically control window shades and draperies to make best use of natural light.

Building and Home automation and control

Other related measures include the implementation of management systems that introduce supervising/steering functions for the building. This may include centralized control of lighting, HVAC (heating, ventilation and air conditioning), appliances, security locks of gates and doors and other systems, to provide improved convenience, comfort, energy efficiency and security. The concept of the "Internet of Things" has tied in closely with the popularization of building and home automation. Home automation refers to the use of computer and information technology to control home appliances and features (such as windows or lighting). Systems can range from simple remote control of lighting through to complex computer/micro-controller based networks with varying degrees of intelligence and automation. Home automation is adopted for reasons of ease, security and energy efficiency. [6] Home automation systems include: sensors to measure or detect things like temperature, humidity, daylight or motion; controllers such as a PC or a dedicated home automation controller; actuators such as motorized valves, light switches and motors; buses for communication that can be wired or wireless; interfaces for human-machine and/or machine-to-machine interaction. [7]

Other building-related measures with impact on thermal performance
This can include, for example, external shading devices (see Figure 3).and other active and passive systems not covered by the other groups. [2] Automatic control of blinds and curtains can be used for: presence simulation; privacy, temperature control, brightness control, glare control, security (in case of shutters). [7]

Figure 3. External shading system [18]

3. Legislative framework

Full execution of existing regulation is needed to promote both energy-efficient new builds and retrofits, the latter being where most gains can be achieved. Indeed, most buildings present today in the EU will still be standing in 2050. Yet, renovation rates across the EU are low, standing at approximately 1% of the building stock. To reach the EU targets, renewal will need to double to 2-3% of existing stock. Only a minority of upgrades is substantial or what experts refer to as complex renewal. [1]

Government has a significant role to play in this process. Since older buildings are generally less efficient than new structures, increasing the rate of retrofitting offers a substantial opportunity for policymakers to profitably advance low-carbon objectives. Because retrofits get less attention than new, green buildings, however, this is not an easy goal to achieve. Policymakers can help by implementing measures that remove obstacles to retrofitting projects. These might include facilitating the contracting out of renewal efficiency to energy service companies, streamlining project approval procedures or providing technical assistance. Coming up with the right incentives will require careful thought, and measures may need to be adapted to individual markets and climates. [3]

Attracting large institutional investors in renewal finance will require energy efficiency project aggregators. Aggregators can be public or private and can appear either as a result of regulation or client demand. To be effective, however, they require clear energy performance objectives, standardized contract structures that allocate responsibility for performance, and data collection and transparency about results. [1]

Monetary incentives are the most popular form of regulation. But while many companies favour tax rebates and grants, expedited permitting for energy-efficient buildings can be a significant nonfinancial incentive, particularly in the commercial segment. Despite the general acceptance of regulation not all of it is considered effective. Legislation can be a clumsy tool. For example, those mandatory building efficiency ratings are only effective if sub-metering is also introduced. When the efficiency in buildings is going to improve, it is necessary to understand at a primary level how buildings are operating. It's mean that it is necessary to understand activities of individual tenants and landlord influenced areas of a building, for creating the complex report.

Absence of regulation can be as much of a barrier as poorly designed measures. The industry lacks a universal definition of what constitutes a green building as well as consistent data sources and metrics on green buildings. This makes implementation of green projects difficult and therefore the sector does not contribute as much as it should to controlling CO2 emissions.

Governments need to understand how they can influence the market. There is clear evidence that legislation can in fact shape market behaviour. This is demonstrated most powerfully in Europe, where strict standards have led a large proportion of companies to audit their energy use. The European experience suggests not only that policymakers can use regulatory tools to promote energy efficiency investment, but also that by combining mandates with incentives, they can facilitate competition for higher efficiency buildings.

Policymakers can play an important role in shaping energy use in the real estate and construction sectors. Measures could include wider use of mandates, auditing, incentives for sub-metering and the introduction of building performance ratings systems.

Government can do more to raise consumers' awareness of the social and economic advantages of low-energy buildings, thus stimulating market demand. Increasingly sophisticated technologies and systems can help to remove many of these barriers and increase the return on investments inefficiency. [3]

4. Current approach

Designing tomorrow's buildings today inevitably means questioning the economic logic that will enable them to be funded. It is difficult to move from idea to realization, when the integration of renewable energies and new technologies increases construction costs by 25-30%. On this front, all the players are unanimous: it will only be possible to finance projects if they take into account the entire life cycle of buildings. The overall cost approach is developing: social landlords are becoming more and more aware of their tenants' costs and of the reduction in carbon footprint. [8]

Whatever the energy-saving strategy, energy management is as important as technology. As energy efficiency becomes more widely accepted, companies are seeing their investments in a more holistic way, taking a longer-term view of investments. When companies move beyond equipment upgrades and integrate energy management into their business models, the potential energy savings increase dramatically.

Companies have come a long way in their approach to energy efficiency. Most are tackling their energy footprint with measures to improve heating, HVAC and lighting. And many are going further - incorporating energy consumption into their overall strategy, including it in risk management and taking a longer-term view of their investments. [3]

To start, the buildings sector needs to better understand its energy consumption and potential reductions. This requires knowledge of the cost of energy investments, adoption of auditing and potentially the use of voluntary standards audited by third parties. Companies also need to do more to enhance the efficiency of existing structures.

The market needs clear long-term signals, rational expectations and opportunities for a reasonable return on investment. But with buildings responsible for such a large proportion of global greenhouse gas emissions, it is a task that should be embraced with urgency by both governments and the private sector. [3]

5. Economic and environmental assessment of residential buildings

5.1. Energy assessment of buildings

The assessment needs to incorporate the following aspects:

- Calculation of the buildings net energy use;
- Calculation of the energy delivered (energy supplied to the building, e.g. natural gas from the grid; energy produced by the building itself and delivered back to the market is subtracted) to the building for heating and cooling, ventilation, domestic hot water and lighting including auxiliary energy;
- Energy generated by the building itself (e.g. via photovoltaic systems or combined heat and power);
- Calculation of the overall primary energy use. Primary energy is the energy from renewable and non-renewable sources which has not undergone any conversion or transformation process. [2]

The energy audit should include:

1. Identification data on the owner of the building and about the energy audit processor.

2. The subject of energy audit. It shall indicate the basic information on the subject of energy audit: the purpose of processing energy audit; identification of the subject of energy audit (building name, street, descriptive / registration number, municipality, district); information on use of the base material (e.g. bills for energy supply, the available design documentation, on-site inspection, custom control measurements, thermal diagnostics, photographic documentation, the national technical regulations (standards) and others).

3. Description of the status quo, which indicates the characteristics of the building (building category, a description of the building and building structures, geometrical parameters, total floor space, form factor, operating mode, etc.); description of the technical installations in buildings (technical systems, heating, hot water, ventilation, cooling, lighting), identification of deficiencies.

4. Basic data on energy inputs and outputs of energy consumption in the building for at least the last three calendar years (including a description of the method of assessment); on energy costs.

5. Thermal assessment of packaging structures of the building; energy assessment. Assessment of building envelope and roof cladding from which will be identifiable at least the following data: area of construction, heat transfer coefficient; evaluation whether construction is suitable or not; the detailed structure of each building structures; overall rating of packaging constructions; assessment of buildings in terms of satisfying the minimum necessary requirements of heat for heating.

6. Proposed measures to reduce energy by renovation of buildings through construction works and their economic and environmental assessment. It should take into account: the type and minimum thickness of thermal insulation, taking into account the quality of the original design envelope and influence of thermal bridges; heat transfer coefficient for windows and doors by the technical regulations.

Minimal output of environmental assessment for each proposed measure is the reduction in carbon dioxide (CO2) and particulate matter and other selected pollutants (CO, NOx, SO2).

7. Proposed measures to reduce energy use of technical equipment in the building. These include: heating system; domestic hot water systems, including energy services; the lighting system; the ventilation and air conditioning system.

8. Energy evaluation of buildings, taking into account the expected state after the implementation of the proposed building modifications and replacement of technical equipment in the building. It proves the premise of satisfying the minimum energy performance requirements for buildings.

Energy audit has recommending character for decision making by the owner / operator of the building. It does not constitute a restrictive framework for the detailed design of measures to improve the energy performance of buildings, respectively to improve the energy performance of buildings. [9]

Figure 4. Energy efficiency classification of buildings [19]

5.2. Economic assessment of energetic systems in buildings

Economic evaluation is widely used:
- to assess the economic potential of energy efficiency measures in buildings;
- to compare various solutions to energy efficiency measures in buildings (e.g. types of equipment,; fuels);
- to evaluate the economic performance of the overall design of the building (e.g. a compromise between energy needs and energy efficiency of heating systems);
- to determine the effect of possible energy conservation measures on an existing heating system on energy consumption with energy-saving measures and without them. [10]

When the economic assessment is based on a set of standard conditions, and current energy prices in determining the energy savings potential and the cost of its acquisition (the proposed measures). Further from the preliminary estimate of investment costs according to current prices of construction products and construction works on the market without taking into account ancillary coerced costs taking into account the service life of the proposed measure, the calculation period of 30 years and the discount rate. The outcome of the economic assessment are the economic indicators, namely:

1. The simple payback period,
2. Discounted payback period.
3. The Net Present Value,
4. The internal rate of return.

Net Present Value

Although we know a few methods for the calculation of the economic evaluation of energetic systems in buildings, specified below in greater detail is a Net Present Value (NPV) because this method is most commonly used in practice.

According the Energy Performance of Buildings Directive recast [5] as a method for an economic assessment suggests the net present value. The net present value is a standard dynamic method for the financial assessment of long-term projects. It measures the excess or shortfall of cash flows, calculated at their value at the start of the project. [2]

The NPV represents the difference between expenses and income of the investment project which relate to a certain period, usually at the inception of the project by discounting. [11]

The NPV is considered a basic criterion for deciding on acceptance or rejection of the investment project. [12]

An appropriate calculation of NPV can be performed by using the global cost calculation method, and can be described by the following formula (1):

$$C_g(\tau) = C_I + \sum_j \left[\sum_{i=1}^{\tau} \left(C_{a,i}(j) \times R_d(i)\right) - V_{f,\tau}(j)\right] \quad (1)$$

Cg (τ) - global costs referring to starting year τ 0;
CI - initial investment costs;
Ca,I (j) - annual costs year "i" for energy-related component j (energy costs, operational costs, periodic or replacement costs, maintenance costs);
Rd (i) - discount rate for year I (depending on interest rate);
Vf, τ (j) - final value of component j at the end of the calculation period (referred to the starting year τ 0). Here also disposal cost (if applicable) can be taken into account. [13]

The global costs
Are defined by: the initial investment costs at the start of the measure, plus the present value of the sum of the running costs (e.g. fuel costs) during the calculation period, minus the net present value of the final value of components at the end of the calculation period. [2]

Investment costs

The methodology takes into account the investment costs of measures that are related to the energy performance of a building.

These include: investments related to the efficiency of the building envelope: measures to reduce the thermal transmittance of building elements, low-energy windows and doors, measures related to air tightness; investment in energy supply systems for space heating and domestic hot water: fossil or renewable supply systems, including storage and distribution; ventilation/air conditioning: ventilation systems with or without heat recovery, active cooling systems; investments in lighting systems; other energy-related investments such as external shading devices, building automation/smart buildings; installation costs of systems and components. [2]

Annual costs
Annual costs include costs for energy carriers that cover the demand for space heating and cooling, ventilation, domestic hot water and lighting, including auxiliary energy. They also include operational costs, maintenance costs and costs for periodic replacement. Income from produced energy (e.g. via photovoltaic systems or combined heat and power) can be subtracted from the costs for energy carriers. The lifetime (service lifetime) of measures should be set according to the information set out in European standards (e.g. EN15459). Energy prices have an influence on the final results of the methodology. The EPBD recast specifies that the Commission must provide information and guidance with respect to long-term energy price developments. Possible sources of information might be price scenarios developed by the International Energy Agency (IEA). [2]

Interest rates
The choice of real interest rates (interest rate adjusted to inflation rate) is an important input for this calculation. [14] The assumed rates will differ depending on the perspective (private or societal). The final methodology should therefore include guidance on applicable interest rates. [2]

The disadvantage of NPV is that it is the absolute variable that does not reflect the exact rate of return. However, this problem is solved by profitability index, which is closely linked to the NPV. Another problem with this method can determine its determinants, such as expected cash flows and discount rates. Despite these disadvantages, the method of Net Present Value is considered accurate and reliable method to determine the economic efficiency of the project. [11]

In assessing / designing the energy efficiency measures, respectively design of the building as a whole, it is necessary to consider the costs over the entire life of the building; the growth of various costs over time, including growth in energy prices; labour costs and price changes of materials. When comparing the different proposals of building it is necessary take into account synergies between considered systems. A comprehensive economic evaluation provides to investors objective information on investment opportunities (for the assumptions). Comparison of different designs of buildings on the basis of an economic evaluation may motivate the owner to invest in buildings with low energy demand, which will be returned in the form of reduced energy costs. [10]

6. Conclusion

The complex renewal process could be very complicated and challenging. Therefore, it should be noted that it is very important that all other stakeholders (industry, project developers, homeowner associations, NGOs, scientific organizations, etc.) are actively involved to the process of buildings renewal. This ensures that the various perspectives are taken into account to make the methodology on cost-optimal requirements a useful tool for promoting smart and efficient buildings in Europe.

The EU has more than one hundred public financing mechanisms to promote energy efficiency in the building sector. Most of them rightly focus on existing stock. The financing, however, largely comes through grants and subsidies which, in a context of cash-strapped governments still dealing with a public debt crisis, are not the most effective use of limited public funds.

The implementation of energy efficiency-related directives varies by country, which limits the ability of property owners to achieve economies of scale across the region. Therefore it is the concern for EU Member States to implement to their own legislation laws and regulations for promoting energy-efficiently renewal, which should be sufficiently effective and flexible. Through the enough effective mechanism could be then ensure the use of a resources - public money should be used to leverage more private finance. [15]

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