ANNALS OF THE ORADEA UNIVERSITY
Fascicle of Management and Technological Engineering
ISSUE #1, MAY 2013, http://www.imtuoradea.ro/auo.fmte/

ON THE OPTIMIZATION OF ENERGY-EFFICIENT MODERNIZATION AND RENEWABLE ENERGY INVESTMENTS

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***Abstract*—**The aims of the Cost-optimum work group in the DEnzero project at University of Debrecen Faculty of Engineering is to make an economic analysis of energy efficient investments, to examine the macroeconomic effects of renewable energy investments and to develop software for evaluation of the energy efficient measures (building construction, renovation of existing building). The first step in the research is to overview the current European and national laws, regulations and guidelines. In this paper we summarize the most important aspects of legal framework established by the European Commission on energy efficient investments such as determination of global cost and the concept and the role of reference buildings.

***Keywords*—**cost-optimization, energy efficiency, renewable energy,

I. INTRODUCTION

THE reduction of energy consumption and the increase in the use of renewable energy may have a significant role to ensure sustainable development and to decrease greenhouse gas emission. The improvement of buildings' energy efficiency, energy saving and reduction of European Union member states' energy dependency is a major challenge for national economies. The examination and the evaluation of investments in energy efficiency measures require both economic and technical approaches since it is necessary to take into consideration the level of costs and technical requirements of energy efficient investments. Requirements of energy efficiency and cost-effectiveness must be satisfied at the same time. However, the investments in energy performance of buildings have effect not only on individuals and investors, but also may affect communities and the society as a whole. Accordingly the state's role is particularly important for promotion of investments. The state may have an incentive and a disincentive effect on energy efficient investments and the use of renewable energy. The following effects are included:

1) appropriate institutional, legal framework;
2) promotion of energy saving, development of renewable forms of energy;
3) energy taxation, tax credit, tax allowances;
4) regulation of energy investment (energy supply, energy demand-side);
5) environmental legislation and regulation, environmental policy;
6) energy research and training;
7) free technical and economic consultancy services, provision information;
8) application for investment in energy performance;
9) promotion employment opportunity;
10) state licenses and fees; and
11) subsidized loan, low interest loan [1]-[5].

It means that the earlier mentioned examinations demand an integrated approach, socio-economic, environmental and legal analyses should also be taken into account besides technical and economic approaches.

The question can arise how we can improve the energy efficiency of buildings under the condition of minimizing the cost level. The energy efficiency can be defined in several ways. According to the European Commission's Regulation No. 244/2012/EU the energy efficiency measures occur if the demand for primary energy decreases during modernization and alteration of a building [6]. The International Energy Agency defines energy efficiency in the following way:

"Energy efficiency is when something delivers more services for the same energy input, or the same services for less energy input" [7]. On the basis of an other definition energy efficiency is the ratio of physically effectively utilized energy and the total energy used.

Investment possibilities can be examined using several economic indicators such as net present value calculation, discounted return time, and internal rate of return [3], [8], [9].

Many factors are required to make investments decisions and to calculate the net present value of energy efficient investments for existing and new buildings, such as:

1) costs of energy efficient modernization and renewable energy investments (an initial costs, an annual costs, the residual value of the buildings and building elements at the end of the examined period);
2) savings from application of renewable energy sources for new buildings and renovations (reduction of energy consumption, reduction of CO_2 *emissions related to energy consumption);*
3) discounted rate;
4) external costs (cost of greenhouse gas emissions, prevention and restoration of environmental damages);
5) estimated lifetime.

The application of the cost optimum method established by the European Committee has to be taken into consideration for the evaluations of the investments and the formation of the model supporting.

"Directive 2010/31/EU requires the Commission to establish by means of a delegated act a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements" [6]. Member States have to define reference buildings since the cost optimal level can not be determined for each type of buildings. The definition of global cost is given in Directive 2010/31/EU the calculation of which is important to apply cost-optimum approach.

Global cost contains four main elements:
1) initial investment cost (labour cost, professional fees, taxes, other costs);
2) annual cost (operating cost, energy -,maintenance cost, replacement cost);
3) external cost (cost of greenhouse gas emission);
4) disposal cost (deconstruction of a building, removal of building elements).

As we have already mentioned, it is important to carry out social and economic examination and to identify and analyze the external effects of nearly zero-energy buildings and the use of renewable energy sources. The use of renewable energy sources is beneficial not only for individuals, communities and some parts of the society but for the society as a whole as well [10]-[12]. Consequently, it is essential to examine the impact of the investments on the environment and the external effects of the investments, i.e. to identify the positive and negative effects and to examine whether these factors can be measured.

The global costs can be measured from macroeconomic and financial points of view. Actually, global cost calculation is based on the net present value calculation. During the determination of macroeconomic global costs the external costs are taken into account beside financial costs. The global cost for one measure is the following:

$$\mathbf{C_{g,t} = C_0 + \sum_{i=1}^{t} \left(\frac{C_{a,i}}{(1+r)^i} + C_{gge,i} \right) - RV_t} , \qquad (1)$$

where t is the number of years, C_0 is the initial investment cost for the starting year, $C_{a,i}$ is the annual cost, $C_{gge,i}$ is the measurable costs of greenhouse gas emission such as carbon costs during i -th year, RV_t is the residual value of the energy-efficiency measures at the end of the examined period (t).

Besides costs, revenues are also taken into account in the calculation of profitability and returns on investment that can be realized from investment possibilities. Revenues from energy saving constitute the larger part of total revenues in the case of existing buildings, which is the result of modernization or/and replacement of non renewable energy by energy from renewable sources such as wind, solar, aero thermal, geothermal, hydrothermal biomass, landfill gas energy. According to the European Commission's guidelines for establishing a comparative methodology framework to calculate cost-optimal levels of minimum energy performance requirements for buildings and building elements, renewable energy is not taken into account cost-optimal calculations, only the non-renewable part of primary energy has to be considered [13]. It means that the above mentioned energy saving can be found in the reduction of costs in fact. Total energy consumption contains the revenues from energy saving, because the amount of total cost is reduced by the used renewable energy.

II. THE COMPARATIVE METHODOLOGY FRAMEWORK

The European Commission's Regulation No. 244/2012/EU establishes a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for new and existing buildings and building elements. The methodology framework specifies rules for comparing energy efficiency measures, measures incorporating renewable energy sources based on the primary energy performance and the cost attributed to their implementation. It also lays down how to apply these rules to selected reference buildings with the aim of identifying cost-optimal levels of minimum energy performance requirements [6]. The cost-optimal methodology is technologically neutral and ensures a competition of measures over the estimated lifetime of a building or building element [6].

A basic idea of the regulation is that the measures have to meet the requirements of national support schemes and the minimum energy performance requirements for nearly zero-energy buildings, and they shall also be compatible with air quality and indoor comfort levels according to the standards.

According to the Regulation the energy efficiency measures for both new and existing buildings shall be defined for all input parameters for the calculation that have a direct or indirect impact on the energy performance of the building [6].

In European Union the member states are free to use and adjust already existing catalogues and databases of reference buildings for the purpose of the cost-optimal calculations, e.g. the work carried out under the Intelligent Energy Europe (IEE) programme can be used, in particular: *"Typology approach for building stock energy assessment"* (TABULA) and *"A set of reference buildings for energy performance calculation studies"* (ASIEPI).

In the framework of the IEE Project TABULA building typology approaches used in certain European countries have been evaluated and on this basis a common concept has been developed. A national typology consist of a classification scheme according to building size, age and further parameters and a set of exemplary buildings representing these building types. "Building Typology Brochures" was published demonstrating for each building the effect of conventional and of ambitious measures including passive house components [14]. "TABULA WebTool" provides an online calculation of the exemplary buildings from all countries. In the framework of the project building stock models have been created for seven countries. The basic concept developed during TABULA can be applied in different countries not only on the national level, but also for the assessment of regional and local housing stock subsets [14].

According to the project report *"Typology Approach for Building Stock Energy Assessment. Main Results of the TABULA project"* [14] there is a large variety of buildings according to the national architectural history and different building types. Against that background the TABULA project aimed at laying a basis for models of the building portfolio by handling this variety and providing a public data source of the building sector [14]. "This was achieved by the making of building typologies which classify the national residential building stocks and provide information of typical building characteristics with regard to thermal quality of the building envelope and the applied heating systems" [14].

"One of the challenging tasks of the ASIEPI project was to develop a method to compare the energy performance requirement levels of the countries of Europe" [15]. The ASIEPI method can be adapted to future developments as a comparison method. Several fixed (equally big and equally shaped) cases were investigated in the project: a detached house, a semi detached house and a row house. It can be stated, by the project report *"Comparing Energy Performance Requirements over Europe: Tool and Method"* [15], that house typologies and the effectiveness of energy saving measures can vary largely per country or region, even though the main energy saving measures are fixed in a way to make the national calculations as comparable as possible. In the model the energy saving measures were chosen also on simplicity and comparability. The amount and complexity of systems and the complexity of the building physics was kept as low and simple as possible. As a result a calculation tool (ASIEPI Excel Tool) was developed based on simplified approaches and estimated performance values for several components. The ASIEPI Excel Tool is a reasonable alternative as long as the comparison method uses simple cases only.

III. REFERENCE BUILDINGS

Regulation No. 244/2012/EU gives the definition of a reference building: it is a "hypothetical or real reference building that represents the typical building geometry and systems, typical energy performance for building envelope and systems and typical functionality. The main purpose of a reference building is to represent the typical and average building stock" [6].

By Annex 1 of Regulation No. 244/2012/EU, reference buildings can be established by selecting a real example representing the most typical building in a specific category or creating a 'virtual building' which, for each relevant parameter includes the most commonly used materials and systems. Member states have to establish reference buildings for single-family buildings, apartment blocks, multifamily buildings, office buildings and for other buildings. "Different building stocks might require different categorization. In one country, differentiation based on construction materials might be most appropriate, while in another country this may be the age of the building" [13]. Subcategories can be defined by age, size, climate conditions, orientation and shading, construction products in load carrying and other structures.

According to the Regulation for each building category, at least one reference building shall be established for new buildings and at least two for existing buildings subject to major renovation. The implementation of the Cost-optimal Methodology in EU Countries is presented in [16], and reference buildings for Austria and for Germany are defined by the Buildings Performance Institute Europe (BPIE) in the case studies [17] and [18], respectively. Reference buildings can be established on the basis of the characteristics of the national building stock. "Reference buildings and their characteristics shall correspond to the structure of current or planned energy performance requirements" [6]. For existing buildings at least one measure has to be applied representing a standard renovation necessary to maintain the building. For new buildings, the currently applicable minimum energy performance requirements shall constitute the basic requirement to be met.

A reference building can be characterized by the building geometry, shares of window area on the building envelope and windows with no solar access, floor area, description of the building, building technology, average energy performance, component level requirements in the case of existing buildings and building geometry, shares of window area on the building envelope and windows with no solar access, floor area, typical energy performance, component level requirements in the case of new buildings. A basic reporting table for energy performance has to contain information about climate condition, building geometry, internal gains, building elements, building systems, energy building need, energy generation at the building site, energy consumption. List of measures can be taken into account in cost-optimal calculation: wall insulation, windows, share of window area of total building envelope, building-related measures, heating system, DHW, ventilation system, space cooling system; measures based on RES, change of energy carrier.

By the Regulation a package of measures, efficiency measures that are cost-effective may allow the inclusion of other measures that are not yet cost-effective, but which could add substantially to primary energy usage and CO_2 savings associated with the total building concept – provided that the overall package still provides more benefits than costs over the lifetime of the building or building element.

According to the Guidelines accompanying Regulation No 244/2012 possible measures to be considered related to building structure and to the systems [13]: total wall/roof construction of new buildings or additional insulation system of existing walls/roofs;; all parts of slab subjected to insulation system of new buildings or additional insulation system of existing slabs; all parts of ground floor construction and foundation or additional insulation system of existing floor construction; increased thermal inertia with usage of exposed massive building materials at the interior space of buildings; better framing of doors and windows; better sun shading; better air tightness; building orientation and solar exposure; change of share transparent/opaque surfaces; openings for night ventilation; installation or improvement of heating system at all sites; monitoring and metering devices for temperature control of space and water temperature; installation or improvement of hot water supply system; installation or improvement of ventilation; installation or improvement of active or hybrid cooling system; improvement of utilization from daylighting; active lighting system; installation or improvement of PV systems; change of energy carrier for a system; change of pumps and fans; insulation of pipes; direct water heaters or indirect water storage heated by different carriers; solar heating and cooling installations; intensive night ventilation; micro CHP with different carriers.

ACKNOWLEDGMENT

The publication is supported by the TÁMOP-4.2.2.A-11/1/KONV-2012-0041 project. The project is co-financed by the European Union and the European Social Fund.

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