

Positive and Negative Aspects of ETICS

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Abstract. Thermal insulation of buildings brings the social benefits mainly through energy savings. However, the risk of producing undesirable negative impacts on the environment and the health of the population is not negligible. Proper selection of the appropriate variant and product should include an assessment not only of the thermal, technical, operational, economic but also health and environmental aspects. In assessing the environmental and health impacts, only CO and sulfur emissions are often evaluated. The impact of other very dangerous chemicals released during the production of ETICS components and subsequently during the operation of the building is investigated only marginally. This aspect will be given the utmost attention and individual variants will be carefully examined also in this point of view. The public does not usually have enough quality data on the various available ETICS variants. The chosen method of thermal insulation should also be felt by the user in a positive way, which will contribute to the comfort and high standard of living.

1 Introduction

It is generally considered important to save energy, to produce the products that are as healthy as possible for human health and the environment, financially most demanding and positively (subjectively) perceived by the general public. These aspects, however, are mostly mutually exclusive. The importance of the solution lies in finding a balanced compromise technology taking into account all the above mentioned aspects.

The problem is becoming more and more topical as human energy supplies are depleted and the impact on the environment and the health of the population is becoming more and more pronounced.

Thermal insulation systems are differently perceived by different groups with different social and economic interests. ETICS manufacturers and contractors strive to gain as much profit as possible and gain the largest market share. Therefore, they usually present only positive information about their products, comparing with competitors is often misleading, incomplete, sometimes even quite untrue.

Users, investors are divided into groups according to size and experience. Larger experienced investors generally have market insight, they can calculate costs and revenues and use them for choosing the right product, vendor, and technology. They can assess the

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price / quality ratio of the products offered, however, without including environmental and social impacts.

Smaller, less experienced investors often succumb to advertising pressure, they lack information or experience. They often choose variants and products only by price, or the price plays a dominant role for them. They can not judge the price / quality ratio of the products offered, the environmental, health and social influences at all.

Thermal insulation of buildings has all the benefits of society in particular in energy savings. However, the risk of producing undesirable negative impacts on the environment and the health of the population is not negligible. The right choice of suitable variant and product should include not only thermo-technical, operational, economic as well as health and environmental aspects.

In assessing the environmental and health impacts, only CO and sulphur emissions are often evaluated, only quantitatively. The impact of other very dangerous chemicals released during the production of ETICS components and subsequently during the operation of the building is investigated only marginally, nevertheless papers [1-3] deal with more dangerous influences. This aspect will be given the utmost attention and individual variants will be carefully examined also in this respect.

The general public generally does not have sufficient quality technical and environmental data on the various available ETICS variants. His image is mostly made of superficial, distorted information. Then he can invest unnecessary funds into health-not-too-favourable variants. The chosen way of thermal insulation should be felt by the owner (or the user) even in a positive way, which will contribute to the comfort and high standard of living. The sociological research will identify attributes that have a positive impact on public perceptions. The results of this survey will then serve as one of the input attributes for the resulting multi-criteria analysis.

If we already have all the relevant data on all aspects discussed above, we can proceed to the final evaluation of the best options. For this purpose, sophisticated mathematical procedures will be used to find the best variants absolutely independent and unbiased.

The resulting software will be applicable to all institutions that should independently and professionally assess certain variants of building envelopes, are responsible for proper technical execution, provide subsidies, or prepare conditions for their provision. It will also be very useful for all investors, designers and contractors. Data Envelopment Analysis (DEA) was used as the mathematical tool to find the above described best (or at least “very good” solution). Its theoretical background will be described in the next capture.

2 Theoretical approach DEA

DEA models are designed as specialized model instruments for evaluating the effectiveness, efficiency, and productivity of homogeneous production units. DEA involves the use of linear programming methods to construct a non-parametric piecewise surface (or frontier) over the data, so as to be able to calculate efficiencies relative to this surface. DEA models derive from the concept that for each given problem there exists a so-called production possibility set consisting of all possible (feasible) combinations of inputs and outputs. The set of feasible possibilities is determined by the so-called efficiency limit. Production units with combinations of inputs and outputs lying on the efficiency limit are considered as efficient (“good”) units.

Our solution uses the BCC model, designed in 1984 by Banker *et al.* [4]. This model assumes variable returns to scale; data are contained by a convex set and therefore more than one unit can be designated as efficient. The model can either maximize outputs (output-oriented) or minimize inputs (input-oriented). Similar DEA approach was used in [5], where the effectiveness of extended EU countries from economic and environmental

indicators point of view was evaluated or in [6] and [7], where the good solutions for motorway underpasses were found.

A mathematical representation of the dual input-oriented BCC model is shown below. Let us assume we have units U_1, \dots, U_n . Also assume we have m inputs and r outputs. We denote the input matrix as $X = \{x_{ij}, i = 1, \dots, m, j = 1, \dots, n\}$ and the output matrix as $Y = \{y_{ij}, i = 1, \dots, r, j = 1, \dots, n\}$. The model for unit U_q is formulated as follows, minimizing the function

$$z = \theta_q - \varepsilon(\mathbf{1}^T s^+ + \mathbf{1}^T s^-) \tag{1}$$

under the conditions

$$X\lambda + s^- = \theta_q x_q,$$

$$Y\lambda - s^+ = y_q,$$

$$\mathbf{1}^T \lambda = 1,$$

$$\lambda, s^-, s^+ \geq 0,$$

where θ_q is the efficiency of unit q ; x_q is the q th column of the X matrix; y_q is the q th column of the Y matrix; $\lambda = (\lambda_1, \dots, \lambda_n)^T \geq 0$ is the weight vector; s^+ and s^- are vectors of additional variables in limitations for inputs and outputs, $\mathbf{1}^T = (1, \dots, 1)$; and ε is an infinitesimal constant that usually equals 10^{-8} .

Efficient ETICS systems were taken to be those which had the highest possible technical parameters and with the lowest possible costs and environmental impacts. Therefore we select minimized input matrix X – costs and environmental impacts, maximized output matrix Y – technical parameters.

The results matrix provides a large amount of information, in particular identification of “good” solutions (units). Inputs that result in the highest inefficiency and which therefore should be improved where possible are also marked.

3 Application of DEA

In this capture it will be described how DEA model was used to find the above described best (or at least “very good” solution).

Let us explain first what are the negative and positive aspects of ETICS. Heat insulation systems use different materials and layers of different thicknesses. The most commonly used materials are expanded polystyrene (EPS), phenolic foam (PF), woodfibre board (WFB), polyisocyanurate boards (PIR) and mineral wool (MW). Dozens of different variants of various thicknesses of these materials can be combined. Each of them has different advantages and disadvantages, positive and negative aspects, some can be quantified very accurately, others are difficult. Positive aspects include, in particular, an increase in the building's thermal resistance and associated energy and heating costs. Negative aspects include increased construction costs, higher technological demands and undesirable environmental and health impacts. A particular thermal insulation system can have very good technical properties and at the same time have high negative environmental impacts.

Other systems can be advantageous at low costs at the expense of poor technical parameters or negative effects on human health. DEA assesses all these aspects in summary and looks for good and bad solutions. It also provides a lot of valuable information about which aspects the system is good or bad.

Positive aspects (an increase in the building's thermal resistance and associated energy savings) can be easily calculated and are clearly presented by producers. There are, unfortunately, also many negative aspects. These were not presented by producers at all or not in proper numbers. Negative aspects need to be investigated during production, transport, construction, use and subsequent demolition and recycling. The abbreviation used is called LCA (life cycle assessment).

Environmental categories were taken as D. Tingley used in [8]. In DEA minimized X matrix covers climate change, ozone depletion, Human toxicity (cancer effects and non-cancer effects), particulate matter, ionizing radiation on human health, ionizing radiation on ecosystems, photochemical ozone formation, acidification, terrestrial eutrophication, freshwater eutrophication, marine eutrophication, freshwater ecotoxicity, land use, water resource depletion, mineral, fossil resource depletion.

Let us have a closer look at the environmental categories:

climate change – well known CO₂ equivalents is said to cause the negative climate change,

ozone depletion – influence to ozone depletion from the World Meteorological Organisation used to convert gases to CFC-11 equivalent,

Human toxicity (cancer effects and non-cancer effects) – covers outdoor inhalation, ingestion of drinking water and indirect ingestion toxins built up in plants and animals,

particulate matter – intake fraction of fine particles estimated from emissions,

ionizing radiation on human health – transfer of contamination to the environment and potential exposure,

ionizing radiation on ecosystems - Comparative Toxic Unit for ecosystems,

photochemical ozone formation – emissions that cause increasing ozone concentration in troposphere,

acidification – atmospheric transportation and deposition of emissions whilst accounting ecosystems,

terrestrial eutrophication – based on accumulated exceedance, assessment of soil and atmospheric conditions and accounts for sensitivities,

freshwater eutrophication – estimates nutrient concentrations that have transferred to a freshwater aquatic environment,

marine eutrophication – marine aquatic environment, assessing nitrogen equivalent concentrations,

freshwater ecotoxicity - Comparative Toxic Unit for ecosystems, this accounts for exposure, potential transport and effects on ecosystems,

land use – assesses the quality deficit of the land occupied, using soil organic matter as a quality indicator,

water resource depletion – considers water use and relates this to local scarcity,

mineral and fossil resource depletion - Utilises abiotic (physical, non-biological resources) depletion potential, a ratio between the annual resource extraction and the reserves available.

4 Conclusions

The DEA approach applied for the finding of the good solutions of various variant of ETICS were described. Positive aspects in particular, an increase in the building's thermal resistance and associated energy and heating costs and negative aspects taking into account

increased construction costs, higher technological demands and undesirable environmental and health impacts were studied. Negative aspects covered climate change, ozone depletion, human toxicity (cancer effects and non-cancer effects), particulate matter, ionizing radiation on human health, ionizing radiation on ecosystems, photochemical ozone formation, acidification, terrestrial eutrophication, freshwater eutrophication, marine eutrophication, freshwater ecotoxicity, land use, water resource depletion, mineral, fossil resource depletion.

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