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Energy Upgrade of Existing Dwellings in Greece; Embodied Energy Issues

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Abstract

When energy upgrade measures are suggested for existing buildings, usually the market availability of the selected technology, in relation to costs are taken into consideration; the latter are usually expressed as the investment payback period, in relation to the savings from energy bills that are achieved. Yet, the embodied energy payback period is not taken into consideration, in relation to the respective energy savings; this payback period is considered to be very crucial since it is an indicator of whether the specific energy saving measures should be followed, so that their embodied energy is paid back within the rest of the building's life span, showing finally whether the building should be energy upgraded or not, from a holistic energy point of view.

In this work a "typical" dwelling building apartment is considered in all four climatic zones of Greece. Materials and techniques are examined on this building, so as to achieve the minimum requirements of the existing legislative energy upgrade, as well as transforming it into a nearly zero energy building (nZEB). The parameters used are according to the Greek legislation with regards to occupancy and building use. Materials and techniques investigated are chosen with market availability criteria. A parametric analysis of materials and techniques with different embodied energies is considered and their payback periods are examined for all case studies. Conclusions are drawn on which materials and techniques should be preferred and which should be avoided for the energy upgrade of existing buildings in the climatic zones of Greece, in order to achieve the minimum legislative energy consumption requirements or an nZEB, based on their energy payback period.

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Keywords: embodied energy; energy payback period; nZEB; energy upgrade; dwelling

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1. Introduction

The cost of a product may rise or fall, depending on the market, the price of oil and raw materials. Thus its payback period rises or falls, respectively, regardless of its external costs (including environmental ones), which are not taken into consideration in the product price up to date. However, its embodied energy, carbon dioxide emissions for its production, distribution and installation are fixed numbers which end up in a specific energy or CO_2 emissions payback period, regardless of the product's economic value or market fluctuations.

In research papers, embodied energy is usually taken into consideration for new buildings, with the assumption of 50 years building life span[1,2,3,4]. Little discussion has been made on the embodied energy and its payback period of the energy upgrade actions of existing buildings. The embodied energy payback period of insulation materials, when applied to uninsulated buildings, in Greece, varies from 0.5 months for materials with low embodied energy, such as cork, to almost two years (23 months) with materials with higher embodied energy (polyurethane)[5]. It has been found out[6] that for different climatic zones in France, the embodied energy payback period of the energy upgrade of existing buildings with various thermal insulation products, sometimes may reach beyond the building's life expectancy when the material's embodied energy is too high.

In this paper, the payback period of the embodied energy for the energy upgrade of a theoretical building to: a) the minimum existing legislative requirements and b) a nearly Zero Energy Consumption Building in the four climatic zones of Greece is examined, regarding the embodied energy of the materials and technologies used for the building's energy transformation.

Nomenclature

d_{insul}	thickness of new insulation layer [m]
d_j	thickness of new structural layer, apart from insulation layer [m]
j	new structural layer
λ_{insul}	thermal conductivity of new insulation layer [W/(mK)]
λ_j	thermal conductivity of new structural layer, apart from insulation layer [W/(mK)]
U_{new}	overall heat transfer coefficient of energy upgraded component [W/(m^{2}K)]
U_{exist}	overall heat transfer coefficient of existing component [W/(m^{2}K)]

2. Methodology

So as to estimate the payback period of the embodied energy of components added to a building for its energy upgrade in the four climatic zones of Greece, energy savings are calculated, using the simulation software TRNSYS[7]. The energy performance of the examined building is considered in four different scenarios; one where the building is not insulated, which corresponds to buildings built before 1979 (scenario 1), regarding their building envelope (insulation of external walls and openings), one where it is insulated according to[8] (buildings of the period 1980-2010) (scenario 2) and one which is insulated according to[9] (buildings from 2010 up to date) (scenario 3) and to which both buildings of scenarios 1 and 2 are energy upgraded. At last, one scenario where the building of scenario 3 and all previous scenarios are turned into a Zero Energy Building (scenario 4) is examined. The structural details of the energy upgrade of the building envelope is according to[10], for external insulation on walls, insulation on the roof and insulation on the floor.

The embodied energy of materials and components used is collected from existing bibliography. Two types of thermal insulation are considered in each case study, combined with different opening types; one where "ecological" materials, with lower embodied energy are used (cannabis as insulation and double glazed clear windows with timber frame) and one where the most commonly used materials in Greece are considered (extruded polystyrene as insulation and double glazed clear windows with aluminum frame), which is referred as "conventional". For reasons of comparison, the rest of the materials for the energy upgrade of the building (plaster, mortar, etc.) remain the same