# *LIFE - CYCLE COST ANALYSIS (LCCA) OF ENERGY INTERVENTIONS IN HELLENIC BUILDING STOCK WITH EMPHASIS ON THE REPLACEMENT OF THE HEATING SYSTEM/PRODUCTION OF DOMESTIC HOT WATER*

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## Overview

Buildings are at the core of the EU's energy efficiency policies [1]. This is because they take up approximately 30-40% of the final energy consumption and for 36% of greenhouse gas emissions[2, 3]. Improving the energy efficiency of the building stock in Europe is, therefore, a major goal, not only for achieving the EU's 2030 targets but also to meet the long-term objectives set by the low carbon economy roadmap 2050 [4]. The Directives 2010/31/EU (Energy Performance of Buildings Directive-EPBD) [5] and the 2012/27/EU (Energy Efficiency Directive – EED) [6] introduced specific measures for improving the energy performance of the European building stock. To that direction, their amendements, 2018/844, 2018/2002 and 2024/1275 Directives, respectively [7, 8, 9], focus on nearly Zero-Energy Buildings (nZEBs) definition both for new and renovated buildings, as well as the long term renovation strategies through cost-effective approaches. Further, since nZEB constitute one of the main pillars of the energy policy of European Union (EU), EPBD requires Member States to formulate policies and establish specific measures for promoting the refurbishment rate of existing buildings in order to diminish their energy consumption to nZEB levels. The present study evaluates the interrelation between cost effectiveness and energetic and environmental performance of technologies, with emphasis on those, upgrading space heating and Domestic Hot Water production. Life – Cycle Cost Analysis is a well established methodology which provides reliable results on a long term basis and has drawn a lot of attention by the scientific community. For Greece, previous studies have assessed and identified the financial gap between energy efficiency interventions and the nZEB thresholds [10,11]. A significant financial gap was quantified for different building types -Single Family House (SFH) buildings, Multi-family House (MFH) apartment blocks and office buildings, depending on construction period and Climate Zone. The current study, not only compares the technoeconomic performance of competitive interventions, but also re-evaluates their results, taking into account updated energy prices, primary energy factors and emission factors, reflecting energy market multiverse.

## Methods

The study compares energy interventions in typical buildings of the Greek building stock. The competitive energy interventions to be evaluated are the replacement of the existing central heating system and/or domestic hot water (DHW) production with the following alternative energy efficiency measures:

- A modern condensing gas boiler system (central installation or autonomous system per apartment)
- A combined condensing gas boiler systems (central installation or autonomous system per apartment) utilizing additionally renewable energy source (i.e solar thermal for DHW production only)
- An autonomous heat pump per apartment or central heat pump only for office building
- A hybrid system as a combination of medium temperature heat pump and condensing gas boiler technology.

Alternatives for replacing window frames and/or reinforcing insulation have also been evaluated, looking forward to synergies of reduced installed capacity and consequently lower CAPEX for the heating appliance. The latter, will also addresses the necessity of reaching nZEB status for buildings in the near future, as a prerequisite EU Fit for 55 targets. In each replacement scenario the final & the primary energy savings due to the intervention are quantified (in kWh/m$^2$ a).

In the next step the total costs are calculated as average annual cost of use (Euro/m$^2$ a), average cost of use over the life time of the installation (20 years - Euro/m$^2$)) and the discounted payback period (in years).

In addition to the economic benefits, the simulation results allow the estimation of the environmental benefits from the reduction of $CO_2$ emissions per year of use and during the life time of the installation/system.
The simulations are carried out in the following typical buildings:

- ✓ Single-family house,
- ✓ A 3- storey apartment building with a shop on the ground floor and
- ✓ A 5-storey building for exclusive office use.

The total of the above buildings represents almost 85% of the country's building stock and numbers more than 610,000,000 m$^2$ of heated spaces (Source: Hellenic Statistical Authority - ELSTAT).

The energy simulations are performed by a functional program structured according to the defined and calculated parameters of the National TEE-KENAK 1.31 software version. All input parameters for the calculations are in accordance with the corresponding technical guideline (TOTEE 20701-1:2017). The economic evaluation of each intervention is carried out with a functional program that meets the requirements of EN 15459-1 "Heating systems and water based cooling systems in buildings - Energy performance of buildings Part 1: Economic evaluation procedure for energy systems in buildings.". On innovative aspect of the technoeconomic evaluation, increasing its' accuracy, is that baseline prices for natural gas and electricity are derived directly from each scenario's simulated primary energy consumption. As known, the natural gas prices tend to decrease as consumption increases, reflecting bulk pricing benefits and tiered tariff structures. In contrast, electricity prices generally rise with higher consumption, mainly due to progressive tariff schemes. These opposing trends emphasize the need for targeted energy policies and efficient consumption planning across different energy sources.

## Results

The study, which will be fully completed in the coming weeks, confirms that it is essential to evaluate all alternative technologies in an objective and holistic way: this includes considering both the initial investment and operating costs, as well as their environmental impact. With a scientific approach, results that differ from some clichés are obtained; for example, heat pumps can offer higher energy performance in some situations but they don't exhibit the best Life Cycle Cost and Discounted Payback Period results.

## Conclusions

Life Cycle Cost Analysis (LCCA), as the most comprehensive approach, could support to a more accurate and informed decision in regards to the most cost-effective and sustainable solution for space heating and domestic hot water production.

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