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Cost Optimization of Renewable Energy Service System for NZEH

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Abstract: *The paper presents the Levelized cost of energy – LCOE in the cost-optimal by linear optimization for energy services of Net Zero House Energy - NZEH, with Lisbon as the case study. The LCOE for the renewable technologies is applied in the optimization using solar collector biomass, geothermal, solar panel for the household energy services of space heating and water heating. The linear programing is able to give valid solution for simple options of separate technologies. Analyzing the costs that occur with such choices, it is showed that more renewable technologies to perform the same energy service, the more investment cost needed. Given the complexity in choosing the best technologies for energy services in NZEH – linear programming is not able to give such solutions that are best in efficiency, satisfy the required percentage of renewables and present a cost optimum.*

1 Introduction

The direction towards 100% renewable energy (RE) supply, particularly for the European Union vision of Net Zero Energy House - NZEH by 2020, needs stronger push and NZEH setup pilot. This also requires more practical validation that based on, for example, combined cost-optimal optimization technique. The optimization techniques for autonomous RE system have been discussed from previous to recent literatures. Many of previous approaches for the RE integration were the hybrid system with fossil fuel such as diesel and natural gas with grid-connected or small to medium scale stand-alone system [1].

NZEH focused in this paper requires prerequisite high energy efficient of the household itself in design and consumption habit. Studies have been done by a number of RE optimization focusing on the office building NZEH model by large scale renewables generation. It is still spaces to be filled by the NZEH at the community and residential level for one of the reasons is the fact that households' energy consumptions naturally have quite a large variation at the end-use from house to house. The NZEH balance focusing in this paper also requires 100% RE supply with matching energy conversion technologies.

In this context, the paper attempts to show the overview of cost-optimal optimization for NZEH. The following sections then show the case study of NZEH cost-optimal model taken for Lisbon.

2 Cost - optimal RE system for NZEH

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Optimal design and performance for NZEH through simulation tools and mathematical programming have been studied intensively in building sector along with gaining experiences for NZEH model. Conventional approach of the optimization solution for regional or community RE system is to minimize investment cost and CO2 emission as for example studied by [2]. However, many of the optimization models with the computational techniques left as the integration with the existing fossil fuel system.

An overall review introduced by [3] recommended that Genetic Algorithm - GA and Particle Swarm Optimization could be considered the most used and promising methods in hybrid RE system design. Important optimization technique review discussed by [4] also confirmed the significance of the multi-objective optimization in hybrid RE system including and mostly for cost reduction optimization. There have been case studies worldwide as well as in Europe on the implementation of NZEH using optimization technique. In terms of cost-optimal, renewables is crucial in achieving NZEH of which the cost reduction associated with renewables investment must be politically guaranteed [5].

In this paper, we present Levelized cost of Energy - LCOE, in the cost-optimal by linear optimization for energy services of the Net Zero House Energy, with Lisbon case study. The LCOE is applied for different renewable technologies in this optimization using solar collector biomass, geothermal, solar panel for household energy services of mainly space heating and water heating.

3 Cost optimization NZEH - case study for Portugal

The energy services of the optimization program for water and space heating and relevant calculations are presented in this section. It is noted that space heating accounts for 21.5% of the total household consumption in Portugal and of that water heating accounts for 23.5% which play as two largest items for household energy consumption. It is appeared that in the past years people's behavior in buying water and space heaters has been directed towards the initial purchase cost rather than life cycle cost. It is foreseen that the labels A ++ or A +++ can be only required from devices that include at least 50% of their energy source from a renewable option.

Technology options for water and space heating

Conventional heaters: The most traditional space heater can be found as wood furnaces in Portugal. It is chosen a common furnace model and pine wood. The heating options also consider modern biomass boiler which work with pellets and brackets and non-biomass boiler by natural gas or propane.

Heat Pumps: The heat pump system is another option for water and space heating run by electricity.

Solar heaters: The most common device is the described flat model which is considered in this work.

Linear optimization can only optimize one variable, which is chosen to be the energy consumption of each energy technology. Thus the program chooses the best suited (most efficient) technology for a given energy services. It is however assumed that the house was constructed to meet NZEH standard such as high insulation and energy efficiency. Heating is considered from December to February. The immediate renewable options consist of biomass heaters, thermosyphon systems and solar circulation systems. Partly renewable options are grid-connected as the Portugal's grid includes 48.1% of renewables (from 2008-2013). These grid-connected options could also get electricity directly from onsite production (PV, Wind or CHP). However, one solely renewable onsite option is not able to satisfy a 100% energy needs. Thus these results would be recommended for housing to install onsite options.

Two scenarios are simulated and optimized with linear program: 2-people, 75m2 apartment, and 4-people, 100-m2 single family house. The following scenarios will be shown for water and space heating in the annual delivered energy option and the LCOE of chosen technologies.

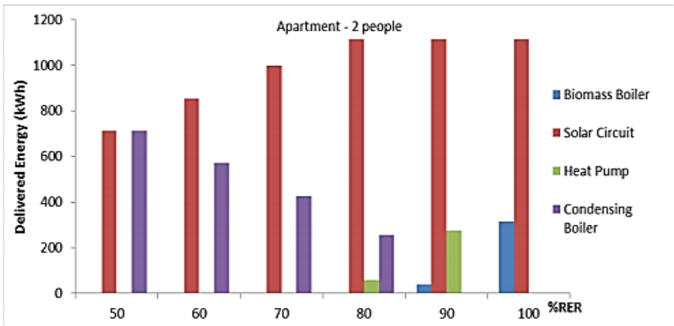

Fig. 1 Delivered energy options for water heating – Apartment

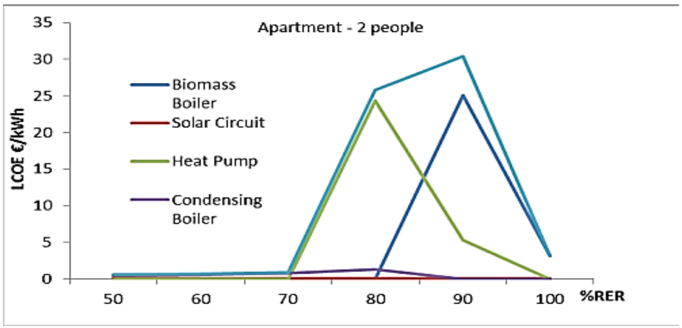

Fig. 2 LCOE for water heating – Apartment

For apartment water heating, the program chooses the technology within their efficiencies. Considering 50% RE, the program takes 50% RE Solar circuit and a 50% non-RE. In defining more % RE, the program implements the Solar Circuit until the delivered energy reaches the limit due to weather conditions. The program implements the heat pump for the option of lower than 100% RE , which is grid-connected of 48% RE. For 100% RE option, the program is forced to implement the Biomass boiler which in last instant is the 'backup' for the Solar Circuit. From *Fig.2* one can see that when a technology is just used to fill the requirement of % RE, it does not pay off for investment cost. The Solar Circuit has a LCOE value of 0,1€/kWh (assuming 15 years). Seeing from the total investment costs, the cheapest investment could be done with 50% RE. Therefore, the investment costs increase with raising % RE. In a long run, the renewable options are able to make economically feasible.

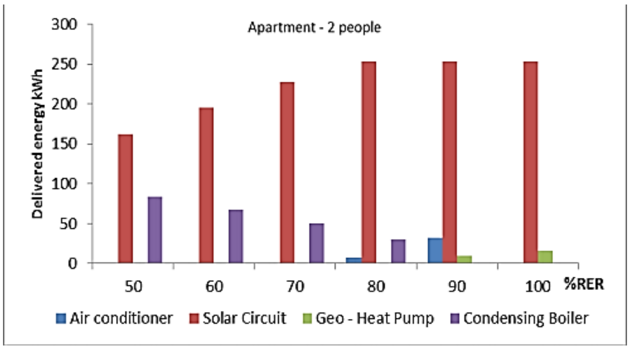

Fig. 3 Delivered energy options for space heating – Apartment

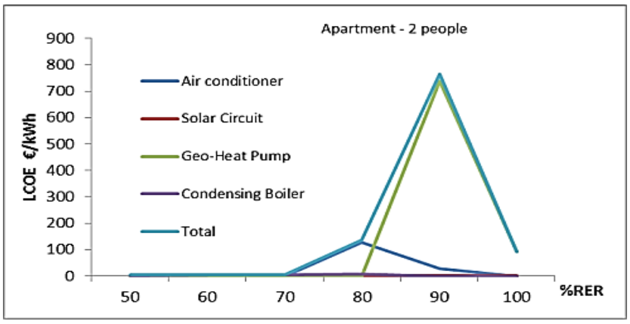

Fig. 4 LCOE for space heating – Apartment

For space heating, the program cannot support 100% RE for this service. It does not choose a wood furnace, because more than one room is requuired heating. It is needed to use the installed technology at their maximum capacity. Space cooling should be implemented taking into account the options chosen for water and space heating. On the other scenario of 4-people single house, the results show that when increasing %RE, the program tends to implement the immediate renewable options as expected. As the heat pump is grid connected, it tends to vanish with increasing %RE. The solar circuit system is able to satisfy about 30% of the water heating needs with renewables. The program then uses the boiler in order to achieve higher %RE. The heat pump can be seen as a remarkable technology as it consumes less and delivers for lower %RE values which is around a half of all energy. For space heating, the program does not get more than 70% as shown in *Fig. 5* and *Fig. 6*.

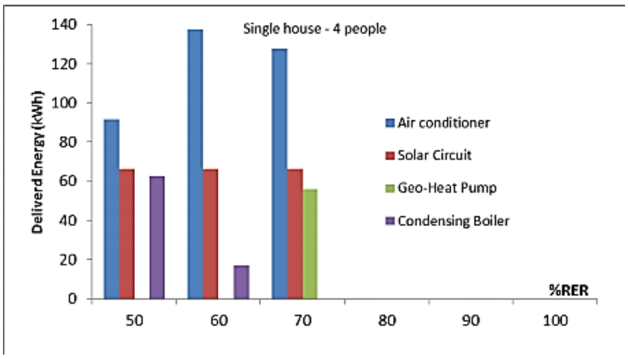

Fig 5.Delivered energy options for space heating – Single house

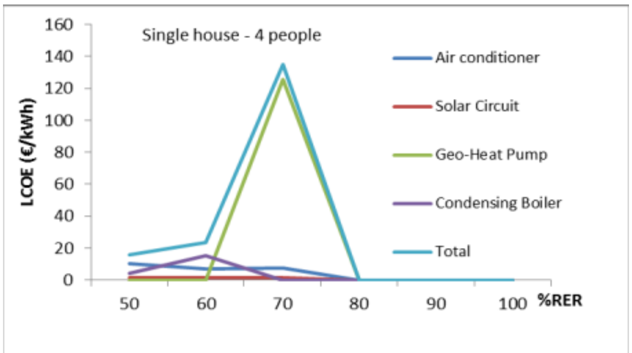

Fig 6. LCOE for space heating – Single house

For example, when 70% RE is set, the biomass boiler creates the first maximum. When reducing the heat pump, its value at 90% increases the whole LCOE technology since it produces more kWh. It would be more practical to implement biomass boiler in such a situation. When setting the program for more renewables it then gets additional costs. It could be said that from these options, in order to achieve a cost optimum there should be less variety in technology choices.

4 Discussion and conclusion

Due to the complexity of the energy-system integration and the inconsistency of renewable resources, it is required more robust and valid optimization tools in order to examine and test such a system to the optimal setup for proper implementation of a supply system of 100% RE that needs the combination of economical and technical criteria. The authors [6] proposed that designing for 100% RE house is inevitably of trial and error process for optimal design solution. Other authors in [7] also discussed control strategies for optimization process in order to find the best fit of possible conversion energy technology with the energy services. Previous literatures also focused on sizing for hybrid renewable system in trading-off with the cost. The reserve capacity of the system that requires the additional storage is also constrained by economic criteria. Authors in [8] mentioned the strategy on the LCOE and reduce the lost from fixed demand and controllable demand.

Furthermore some authors such as [9] emphasized on the high variation of residential consumption that it is not simple to fully identify. It is also needed considering the dynamic of all the electric appliances as discussed in [10] by introducing more valid threshold of each energy service.

Nonetheless, the linear programing is able to give valid solution for simple options. The heat pump and biomass heating can be seen as a remarkable technology as it consumes less and delivers for lower %RE values which is around a half of all energy. Analyzing the costs that occur with such choices, it is showed that more renewable technologies to perform the same energy service, the more investment cost needed. Given the complexity in choosing the best technologies for energy services in NZEH – linear programming is not able to give such solutions that are best in efficiency, satisfy the required percentage of renewables and present a cost optimum. For the further study it is needed to implement the problem with more advance technique such as GA.

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