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TOWARD FUTURE: POSITIVE NET-ENERGY BUILDINGS

Abstract: *For a positive net building (PNEB), the paper presents its need, and tools to achieve its design. The PNEB should provide the maximum thermal comfort with a minimum of energy, primary energy, and exergy consumption, •and reduction of the use of energy resources, maximizing energy security, as well as the minimum impact on the environment. This very useful knowledge is also needed for identifying energy efficiency, as well as for dictating the right energy management strategies of a country. Then, the paper presents the software for a energy simulation and optimization of PNEB. After that, the paper describes the three examples connected to the PNEB. The first example is a simulation of a residential PNEB in Serbian conditions, second the optimization of photovoltaics panels area at Serbian zero-net energy building, third the description of an the building and optimizing energy performances, by placing the solar collector in the optimum position.*

Keywords: *Positive net building; simulation; optimization; EnergyPlus; OpenStudio; Genopt*

1. Introduction

Daniel M. Kammen, Director of the Renewable and Appropriate Energy Laboratory, University of California, Berkeley wrote the following in Nature[1]. “By 2020. humankind needs to be solidly on to the path of a lowcarbon society — one dominated by efficient and clean energy technologies. Several renewable technologies are ready for explosive growth. Energy-efficiency targets could help to reduce demand by encouraging innovations such as PNEBs and electric vehicles. Research into solar energy — in particular how to store and distribute it efficiently— can address needs in rich and poor communities alike. Deployed widely, these kinds of solutions and the development of a smart grid would mean that by 2020 the world would be on the way to an energy system in which solar, wind, nuclear, geothermal and hydroelectric power will supply more than 80% of electricity.”

Globally, the drive for PNEB is necessity and urgency to decrease carbon emission, and relive energy shortage. Several worldwide targets are established. First, the Energy Performance of Buildings Directive of EU states that all buildings built after 31 December 2018 will have to produce their own energy onsite [2]. Second, from beginning of 2020 in USA, all new Federal buildings will be designed to consume zero-net-energy and be zero-netenergy buildings (ZNEBs) by 2030 [3]. Third, to progress with the development and adoption of high performance buildings in USA, there is the

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Net Zero Energy Commercial Building Initiative. The initiative aims to achieve marketable net-zero energy buildings by 2025 through public and private partnerships [4]. Finally, UK Government sets out improvements to energy requirements in Building Regulations to include that all new homes has to be 'zero carbon' by 2016 [5].
The objective of this paper is to introduce definitions and general characteristics of PNEB that go beyond ZNEB, show software for their design and give theirZNEB, show software for their design and give their several examples.

2. Definitions

The schematic of a PNEB is shown in Fig.1.

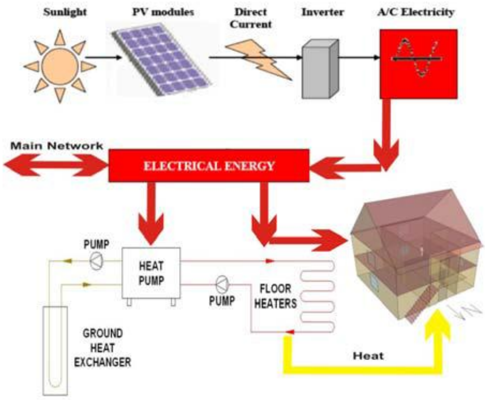

Figure 1. Schematic of a PNEB

2.1. Ordinary Definitions [6]

Positive-Zero Site Energy — PNEB generates more energy than it consumes. It usually produces electrical energy through PV modules and is connected to the grid. The building may either consume electrical energy from the PV modules or from the grid. The generated electrical energy may either feed the building or the grid. The electric energy supplies the grid when there is the electrical energy surplus. When there is electrical energy shortage the grid supplies electrical energy to the building. The ''positive-net'' concept means that yearly the excess electrical energy sent to the grid is larger than the amount received from the grid. The PNEB uses the power grid as an electrical storage battery.
Positive-Zero Source Energy — A building that produces and exports more energy as the total energy it imports and uses in a year, when accounted for at the source. "Source energy" refers to the primary energy required to generate and deliver the energy to the site. To calculate a building's total source energy, imported and exported energy is multiplied by the appropriate site-tosource conversion multipliers.
Positive-Zero Energy Costs — A building where the amount of money a utility pays the building's owner for the renewable energy the building exports to the grid is larger than that the owner pays the utility for the energy services and energy used over the year.
Positive-Zero Energy Emissions — A building that produces and exports more emissions-free renewable energy as it imports and uses from emission-producing energy sources annually. Carbon dioxide, nitrogen oxides, and sulfur oxides are common emissions that PNEBs offset.

Embodied energy [7]
Life positive net energy building (L-PEB) is defined that during entire life it produces more energy than it spends for the embodied energy of building components and its energy use [6].The net energy ratio (NER) is a as the ratio of the decrease on annual energy use to the increase in annualized embodied energy. The higher NER better more effective is move toward L-ZEB.

2.2. Energy

Energy consumption
In ZNEHs, energy may be used for space heating, space cooling, DHW heating, lighting, and appliances, etc. Technologies for lighting and appliances should be energy efficient to minimize use of electrical energy

that has to be generated by the building. In future buildings, space heating should be efficient. In this direction, technologies for space heating are usually ground coupled heat pumps (GCHP) as they give round 3 times reater amount of heat energy than that of electrical energy with which it was run. The heat pumps may be used for heating and cooling when the direction of refrigeration fluid is reversed. The most often it is a GCHP with hydronic floor heating or air space heating.

Energy generation

Technologies for heat & cold generation from geothermal energy use electrical energy to operate. These devices are called heat pumps. They should be energy efficient and have the highest COP (to use as low amount of electrical energy as possible). Technology used for DHW heating may be heat used by solar collectors and electrical energy produced by the PV modules, or the heat pump driven by electrical energy. The most efficient heating may be performed by either solar collector with electric backup. Technologies that are used for energy generation should be energy efficient and to use as low surface area as this is possible. These technologies are generation of heat energy by solar collectors, and electrical energy by the PV modules and wind power. When there are energy generation with the PV panels and solar collectors, one should determine the ratio between areas of the PV modules and of solar collectors. However, there is also simultaneous generation of heat and electricity by hybrid PVT panels.

Building envelope

In future buildings, a building envelope should minimize heat transfer. In cold climate, the building envelope has to be super insulated and air tight. Special double glazed windows are used at the south wall that are filled with argon and have low heat emissivity film coating.

Rule of thumb

However, the amount of energy generated by the PV modules and solar collectors located on the building roof is limited as there is shortage in surface (space) needed for energy generation. Consequently, the rule of thumb of design of ZNEH is to minimize energy consumption in the building. This would minimize required energy generation and surfaces required for this energy generation.

Cost effectiveness

Energy saving and producing technologies should be cost effective. That means minimum construction costs for these houses and their fastest penetration into practice. The highest cost is the cost of its GCHP heating system and the PV modules. To minimize these costs, the designer has to minimize heating and cooling loads to these homes. For designer, the most interesting questions are that of area of the PV modules and financial attractiveness of their installation. As these technologies are still relatively expensive, the government should enhance financial attractiveness of the investment in such devices.

3. Simulations and optimizations

3.1. Simulation software – EnergyPlus

EnergyPlus is made available by the Lawrence Berkley Laboratory in USA [8]. EnergyPlus interface is shown in Fig.2. EnergyPlus evelopment began in 1996 on the basis of two widely used programs: DOE-2 and BLAST. The software serves to simulate building energy behavior and use of renewable energy in buildings. The renewable energy simulation capabilities include solar thermal and photovoltaic simulation. Other simulation features of EnergyPlus include: variable time steps, userconfigurable modular systems, and user defined input and utput data structures. The software has been tested using the IEA HVAC BESTEST E100-E200 series of tests. To model, the building and renewable energy systems in EnergyPlus environment, we used models of different components that are embedded in EnergyPlus such as that of PV-array, inverter, flat-plate solar collector, storage tank, tempering valve, and instantaneous water heater. Water in the storage tank was heated by solar energy and water in the instantaneous water heater by electricity.

3.2. Simulation software – Google SketchUp

Google SketchUp is a free 3D software tool that combines a tool-set with an intelligent drawing system. Building in Google Sketch-up environment is shown in Fig.2. The software enables to place models using realworld coordinates. Most people get rolling with SketchUp in just a few minutes. There are dozens of ideo tutorials, an extensive Help Centre and a worldwide user community.

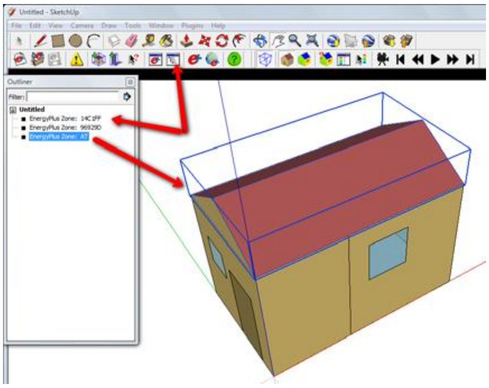

Figure 2. Building in OpenStudio environment

3.3. Simulation software – OpenStudio

The OpenStudio is free plug-in that adds the building energy simulation capabilities of EnergyPlus to the 3D SketchUp environment. A house in OpenStudio environment is shown in Fig.3. The software allows you to create, edit and view EnergyPlus input files within SketchUp. The plug-in uses the standard tools provided by SketchUp. The software adds as much extra detail as you need to zones and surfaces. The plug-in allows you easy to create a building geometry from scratch: add zones, draw heat transfer surfaces, draw windows and doors, draw shading surfaces, etc. You can save what you have drawn as an EnergyPlus input file. The plug-in also allows users to launch EnergyPlus simulations and view the results from within SketchUp.

3.4. Optimization software - GenOpt

GenOpt is an optimization program for the minimization of a cost function evaluated by an external imulation program [9]. Optimization and simulation data flow paths by using Genopt are shown in Fig.3. GenOpt serves for optimization problems where the cost function is computationally expensive and its derivatives are not available or may not even exist. GenOpt can be coupled to any simulation program that reads its input from text files and writes its output to text files. The independent variables can be continuous variables (possibly with lower and upper bounds), discrete variables, or both, continuous and discrete variables. Constraints on dependent variables can be implemented using penalty or barrier functions. GenOpt is written in Java so that it is latform independent. GenOpt is applicable to a wide range of optimization problems. GenOpt has a library with adaptive Hooke-Jeeves algorithm.

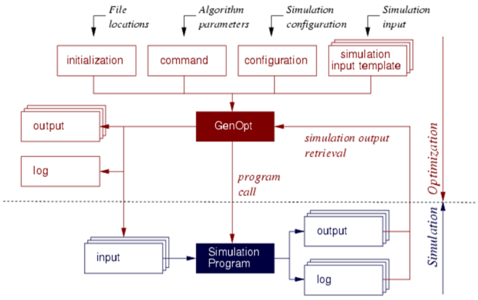

Figure 3. Optimization by using Genopt

4. EXAMPLES

4.1. Residential PNEB in Serbian conditions [11]

This article reports investigations of a residential building in Serbian conditions energized by electricity from photovoltaics (PVs), and the electricity grid. The building uses electricity to run its space heating system, lighting and appliances, and to heat domestic hot water (DHW). The space heating system comprises floor heaters, a water-to-water heat pump, and a ground heat exchanger. The schematic of this PNEB is shown in Fig.1. The PV system generates electricity that either may be consumed by the building or may be fed-in the electricity grid. The electricity grid is used as electricity storage. Three residential buildings are investigated. The first residential building has PVs that yearly produce smaller amount of electricity than the heating system requires. This is a negative-net energy building (NNEB). The second building has the PVs that produce the exact amount of electricity that the entire building annually needs. This is a zero-net energy building ZNEB. The third building has PVs that entirely cover the south-facing roof of the building. This is a PNEB. These buildings are presented by a mathematical model, partially in an EnergyPlus environment. For all buildings, simulations by using EnergyPlus software would give the generated, consumed, and purchased energy with time step, and monthly and yearly values. For sure, these buildings would decrease demand for electricity during summer, however they will increase this demand during winter when there is no sun and start of space heating is required. Depending on the size of PV array this building will be either NNEB, or ZNEB, or PNEB. However it is crucial for such a building to be connected to the electricity grid. The smaller payback for investment in the PV array is obtained for buildings with larger size of PV array. The feed-in tariff for the generation of electricity in Serbia should be under the constant watch to be corrected accordingly for larger penetration of this technology in the Serbian market.

4.2. Optimizing performances – tilt slope and azimuth angle in Belgrade, Serbia [12]

In Serbian households, the high amount of domestic hot water (DHW) is used for shower, tap, cloths-washing, and dish-washing. It is customary to use electricity for heating of DHW. As around 70% of electricity is produced by using low quality coal with high greenhouse emission, it is important and the most rewarding to use solar energy for DHW heating instead of electricity. Accordingly, in Serbia and worldwide, the most rewarding application of solar energy is that it replaces electricity for heating of DHW in households.1 In addition it is important to have a high efficiency of conversion of solar energy to heat. Then, the highest amount of avoided electricity and avoided fossil energy may be expected. During its operation, the solar collector in some solar DHW system (SDHWS) has to take the optimal position to generate the highest amount of heat. The solar collector takes the north south direction. Here, the variable tilt flat-plate solar collectors in Belgrade, Serbia. Investigated to enhance performance of stationary solar collectors. These tilts should be determined to be optimal and yield the highest amount of heat that will avoid electricity consumption.

For the different variable tilt SCs, the investigations yield their optimum tilts that maximize the solar fraction, avoided electricity, and avoided fossil energy by the SDHWS. In addition the research study the deficit in the solar fraction when the tilt in practice is not optimal. After that the values of the avoided electricity are compared for all cases in order to show the real need for optimal position SC in practice.

4.3 Optimization of photovoltaics panels area at Serbian zero-net energy building [13]

Photovoltaic (PV) energy conversion is one of the more promising renewable energy technologies which contribute significantly to a sustainable energy supply and which may help to mitigate greenhouse gas emissions. PV energy conversion represents the direct conversion of sunlight into electricity. Over the last five years, the global PV industry has grown more than 40% each year.

Kapsalaki [14] says that a radical approach for the mitigation of the energy demand is the concept of the zero-net energy building (ZNEB). By definition, ZNEB produces all energy it consumes during year, i.e., yearly electrical energy supplied to the electricity grid balances the amount received from the electricity grid. Positive-net energy building (PNEB) produces more energy than it consumes during year, i.e., yearly electrical energy supplied to the electricity grid is higher than the amount received from the electricity grid. Negative-net energy building (NNEB) produces less energy than it consumes during year—yearly electrical energy supplied to the electricity grid is lower than the amount received from the grid. In this , the energy consumption is analyzed for a residential building located in Kragujevac, Serbia. The building is designed with PV panels installed on the roof. Electricity generated by the PV array is limited by the size of PV array.

In buildings, energy is used for space heating and cooling, domestic hot water (DHW) heating, lighting, and electric equipment. The analyzed building has an electrical space heating system. The PV system can generate more or less electricity than the amount of electricity needed for the entire building. When the PV system would not directly satisfy the building needs for electrical energy, then the rest of electricity will be used from the electricity grid.

When the PV system would satisfy the building needs for electrical energy, then the rest of the PV generated electricity will be fed-in the electricity grid. For water heating in the DHW system, the electrical energy produced by the PV modules will be used.

The major aim of this investigation is to determine the portion of PV panels on the roof in order to minimize the consumption of primary energy. The primary energy refers to energy required to generate and deliver the electricity by grid to the site.

In this paper, the EnergyPlus, Open Studio plug-in in Google SketchUp, Hooke-Jeeves algorithm, and Genopt were used. To calculate the total primary energy, the imported and exported energy is multiplied by the appropriate site-to-source conversion multipliers.

5. Conclusion

The paper shows that PNEBs are in strong need worldwide. The most important fact is that throughout their life PNEBs should provide the maximum thermal comfort with minimum of energy, primary energy, and exergy consumption, and minimum of CO_2 emission. PNEBs require up-to-date technologies for efficient energy consumption and energy generation from solar and geothermal energy. The PNEBs may be designed done by using software for energy simulation and optimization. The PNEBs would be successfully used for residence, research, office, archive, and business.The PNEBs would be successfully used for residence, however their behavior should be simulated and optimized before their application in practice.

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