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OPTIMIZING ENERGY CONSUMPTION IN THE METROPOLIS

OPTYMALIZOWANIE ZUŻYCIA ENERGII W METROPOLIACH

A b s t r a c t

The proliferation of building management systems is limited only by the imagination of their developers as well as by technological progress, which allows for the remote control of all the available systems that aid us in making buildings more energy efficient, due to the fact that energy prices continually rise. The maximizing of a building's energy efficiency has now become an inseparable component of their design. Due to the comparison of the two constituents of the sum of a building's use of energy: that of the building itself and that of the user, an optimized energy efficiency scenario allows us to foresee the need for energy and its future costs. On the metropolitan scale, with tens of millions of structures, hundreds of millions of users and distances that greatly affect transportation costs, large amounts of energy are consumed. It is of great importance to pursue the development of intelligent systems that will be capable of minimizing energy use with intelligent building management systems, seemingly predestined for this role.

Keywords: energy efficiency, metropolitan scale

S t r e s z c z e n i e

Nasycenie systemami sterowania w budynku ogranicza jedynie wyobraźnia oraz postęp technologiczny, który pozwala na zdalne sterowanie wszystkimi dostępnymi systemami wspomagającymi oszczędne funkcjonowanie budynku, ponieważ koszt energii nieustannie rośnie. Maksymalizacja efektywności energetycznej obiektu, staje się niezbędnym elementem projektowania. Wynikający z zestawienia dwu składowych sumy energii niezbędnej do funkcjonowania samego budynku i jego użytkownika, zoptymalizowany scenariusz energetyczny pozwoli na prognozowanie zapotrzebowania na energię a także przyszły jej koszt. W skali metropolitalnej, przy dziesiątkach milionów obiektów, setkach milionów użytkowników oraz odległościach generujących kosztowny transport, konsumowane są ogromne ilości energii. Niezbędne jest poszukiwanie nowych technologii i sposobów minimalizowania jej zużycia, dla którego to celu inteligentne sterowanie systemowe wydaje się posiadać już obecnie wystarczające predyspozycje.

Słowa kluczowe: efektywność energetyczna, skala metropolitalna

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1. Introduction

Every building that is designed with energy efficiency in mind, is in terms of cybernetics, a complex system based on a set of design solutions and the internal and external factors that stem from these solutions. In order for the system to work in an optimal fashion on multiple levels, such as the purely functional, those that originate from the environmental and urban context of its localization and those that arise from the philosophical principles of designing architecture, each level needs to be logical and controllable at the least. Only when these criteria which seem simple at a glance, but which in practice are repeatedly proven to be quite problematic are met, can the adaptation of the building (an autonomic, internally complex, but controllable system) to the role of an active element of the larger energy optimization system on a metropolitan scale, be accomplished. Zipser [1] compares the metropolis to a living organism, due to the multitude and mutability of the inter and extrametropolitan relations between its constituent parts: its sectors and entire clusters of buildings and "urban organisms". The functioning of such an "urban organism" requires vast amounts of energy. Its acquiring in traditional economic systems is tied to equally vast costs in each of its stages of production, not to mention the costs of distribution and preventive action against shortages. Attempts made towards the reduction of the need for energy have a very large impact on the functioning of the entire ecosystem on a global scale, due to the metropolises being the largest energy consuming entities in all of its available forms.

2. Local or central energy production and distribution

Assuming that a certain amount of energy, regardless of its form, is crucial for an individual to function within an urban environment, a straightforward relation can be observed between the amount of required energy and the number of persons that consume it. In relation to centers of population density, the targets of energy distribution are set, while its flow is different when it comes to the seasons of the year, weather conditions, geographical location and urban density. Taking into account the difficulties that arise from the necessity of producing energy and the costs that are required for its distribution, two strategies for its production are seen to emerge: one that relies on a central, focused production method with high parameters, losses and costs of distribution and one that is decentralized, locally based and diverse in terms of energy production methods with local consumption, low quantity and parameters regarding distribution and with smaller distances that lead to lower losses and costs. Each of these two systems has its advantages and disadvantages. The system that is currently in use around the world is widely known, which is why this work will go into the finer details of only the local method of energy production and distribution. Paradoxically, the central energy production system is far more manageable, allowing for the precise measurement and supervision of energy use regarding its changes due to atmospheric conditions. This system however, is highly dependable on the performance of its distribution sector and its susceptibility to failure and external threats (earthquakes, terrorist or military aggression). The local system, which is based on the production of small amounts of energy close to its receiving end, is harder to manage in a coherent way, whilst it is far more resilient to outside factors. A combination of this way of thinking about energy production with optimization of its use, allows for the creation of a multitude of design solutions that increase energy efficiency. It also allows energy producers to utilize a distributed control system which oversees the various subsystems of a building. One of the more useful ideas to be implemented in the field of distributed energy production is the combination of designing passive buildings with a low or very low energy consumption with diverse, distributed means of energy production from a variety of sourcessuch as solar power. The prices of solar power generation systems are becoming more and more affordable, which along with the development of local power production and storage, may lead to a future where the development of large and costly energy generation and distribution systems is at least lessened. The controlling of a decentralized network of individual energy sources would be necessary only if overproduction resulted in the necessity of redirecting surplus power to other receivers. This could be achieved with the existing system of power distribution. Decentralized energy production systems, while more difficult to manage, are more resilient to outside threats than central systems.

3. Maximizing a building's thermal insulation and its impact on health

This problem really comes down to one question. Is living in a thermos really healthy? While discussing the problems of the extremes of energy efficiency, Kusionowicz [2] describes in her work the various dangers that arise from insufficient ventilation which commonly occurs in the increasing pursuit of more draconic forms of saving energy. Presently, the technical solutions used in air conditioning rely on external power sources, most notably from the public power grid. The wide use of heat recuperators causes more of the air that is used within a building to be reused, which in turn reduces the amount of external air being supplied to it. In the event of a power outage, buildings fitted with this technology are highly susceptible to being insufficiently ventilated due to the level of insulation and air-tightness that is becoming commonly associated with these technologies. This situation can cause the emergence of moulds, fungi and other allergens, which may pose serious health hazards to a building's users and inhabitants. One must also consider the somewhat peculiar design solutions regarding the form of passive buildings, which might prove troublesome to the building's users and diminish their functionality. Passive houses have been in use for a relatively short amount of time, so the field of studying their impact on the long term health of their inhabitants is still quite undeveloped. By analogy to the results of research into other new building technologies that have an impact on the climate of building interiors, we can assume that passive houses will not be entirely neutral to our health.

4. Energy efficient urban planning

In order to better illustrate the problem, I will demonstrate a simple example. Assuming that an average sized metropolis is home to around a million inhabitants, which under the assumption of it having an evenly distributed built environment, gives us around 200 000 "building units" (for further simplicity they will be considered as free-standing single family houses). It is approximated that the yearly power demand for a single family home[1], in a climate similar to that of Poland and located in an averagely shielded space, amounts to around 24 500 kWh. By extending that demand to our theoretical metropolis, its power demand can be calculated as 4 900 000 000 kWh. According to internet sources, a passive house needs about four times less energy than a regular one[2]. These simple calculations indicate that energy efficient buildings used on a metropolitan scale could result in a decrease in energy use by three quarters of the present level, which, assuming that 1 kWh = 1 PLN, could amount to savings of up to 3 675 000 000 PLN per year. Savings of this magnitude are worth considering, especially when we take into account the present existence of metropolises with 20 million inhabitants, not to mention the planned mega-metropolises of China that are estimated to have a population of 250 million! Passive and energy efficient buildings however, are not the complete answer to the problem due to the fact that the reality of the urban environment is much more complicated than the theoretical musings presented above. Attempts to design[3] and construct[4] energy efficient and ecologically friendly cities are currently being undertaken with varying degrees of success. The basic obstacle to the idea of energy efficiency are the high costs of constructing such buildings, their fittings and infrastructure, as well as the human factor: the habits of the general population, which often stand in opposition to the comparably high standards required of them by the machinery that makes their dwellings more energy efficient in terms of their operation and regular maintenance. There is also one far more significant problem. Energy producers and distributors are not interested in the development of alternative energy sources, as they undermine their market position. The wide use of photovoltaic cells in Germany has already exposed the danger to large energy companies.

5. Structure of an energy efficient city

In order to design the urban layout of an energy efficient city one needs to thoroughly research the technologies used to produce energy that is needed for the functioning of such a settlement. One must also pick a particular technology, the requirements of which will be taken into consideration when developing the layout. The urban designer has complete freedom when it comes to atomic energy, not taking into account the appropriate safety zones, however, as the events in Japan unfold, there is currently no completely safe technology that allows us to "forget" the dangers of its failure, produces a continuous supply of energy and has no considerable impact on our environment. Depending on the choice of a primary energy source for the city, its urban form will need to be adapted to its means of generating power. In the case of a distributed system of various renewable energy sources, the urban

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1 The average single family house with an area of 150–200 m^2, which does not have electric heating, a heat pump or air conditioning should use up around 12.5 Kw of electric energy. The average energy use of such a home is estimated at 1030 kWh [4].

2 While analyzing the energy demand of a passive house it turns out that it is four times smaller than that of a typical housing structure and consumes 15 kWh/m^2 per year, which is around 1.5 l of fuel oil or 1.5 m^3 of earth gas per 1 m^2 of the building per year [5].

3 Cities by Foster, OMA and other authors.

4 Masdar City in the UAE.

layout will have to be different for each of these systems. In terms of volume geometry, an ideal city from the point of energy conservation would be a sphere, due to the fact that it provides the smallest amount of exterior surface for the largest volume. This allows for optimum energy retaining properties, however it also means that most of the city would be deprived of daylight. From the point of view of absorbing sunlight energy, an urban form ideal for this process would require shaping its structures in a way that provides optimum exposure to light from at least four directions. The use of wind generators, tidal waves of water bodies or geothermal energy, would in each of these cases require an adaptation of the urban form to properly suit the energy generation method. Thus, the question arises whether there is an existing ideal urban form, which could theoretically provide optimal working conditions for each of the presently known forms of acquiring renewable power? Quite possibly such a form does exist, however it is not certain that currently an example of a metropolitan city that meets the requirements of a truly energy efficient city can be found. We do know however, that the attempts to create one in China [6] have been a commercial failure. This has not deterred this country from its course in attempting to build cities that are self-sustainable [7] in terms of power.

6. Conclusions

It is necessary to conduct multidirectional research in the field of increasing the energy efficiency of existing buildings, as well as in the field of developing urban forms and layouts that are aimed at aiding the technologies used to generate renewable energy adapted to their local environments and climates. The process of gradually depleting fossil fuels on a global scale requires that this research be intensified. This is also true of technical and technological research into better management of renewable energy in the daily lives of communities and individuals. The higher the population and urban densities, the more potential there is in thinking along the categories of increasing energy savings in multiple fields and in different sectors of the economy and our daily lives.

References

[1] Zipser T., Lecture „The Idea of the City. Machine or Tissue" from the conferrence „The Idea of the City – Time, Place, Form", Kraków 2013, CD.

[2] Kusionowicz T., *The Problems of Designing Human Habitation Structures: A Selection of Issues. Monography: Architecture*, Wydawnictwo Politechniki Krakowskiej, Kraków 2008.

[3] Celadyn W., *Energy Concepts For Builidngs. Methods of Presentation (Koncepcje energetyczne budynków. Metody prezentacji)*, Czasopismo Techniczne 2-A/2/2011, 15-25 (http://suw.biblos.pk.edu.pl/resourceDetails&rId=829).

[4] http://www.a-zero.pl/zapotrzebowanie-na-energie-elektryczna.html

[5] http://styl-zycia.ekologia.pl/ekologiczny-dom/Dom-zuzywa-najwiecej-energii-na-ogrzewanie,12043.html

[6] http://www.chronmyklimat.pl/gospodarka-rynek-co2/16034-chinski-plan-uzdrowienia-srodowiska
[7] http://termodom.pl/epbd/energooszczednosc/habitat_2020___samowystarczalne_miasto