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USING VERTICAL GARDENING TO IMPROVE THERMAL INSULATION IN URBAN CONDITIONS

Lytvyn Bohdan Bohdanovych[1], Kosyk Oksana Ivanivna[2]
[1]Bachelor,
Taras Shevchenko National University of Kyiv, Kyiv, Ukraine,
e-mail: lytvynbogdan164@gmail.com, orcid: 0009-0007-8405-7555
[2]PhD, Associate Professor,
Taras Shevchenko National University of Kyiv, Kyiv, Ukraine,
e-mail: o_kosyk@knu.ua, orcid: 0000-0003-0873-3180

*Abstract. The **purpose** of this work is to emphasize the importance of thermal insulation in the conditions of a modern city and to offer a more natural alternative to existing materials. The constant growth of the urban population leads to an increase in the demand for housing. Young people move to cities for new opportunities, which leads to increased energy consumption, which has a direct negative impact on the environment. This endless cycle is mostly about efficiency. Improving the thermal properties of each house will make it possible to create an economically efficient system suitable for use in all existing housing, we would achieve a great percentage of saved money on heating and cooling, as well as reduce our dependence on fossil fuels, which in turn allows to save much more on infrastructure, specified equipment and subsidies for this industry.*

*This research employs a comprehensive **methodology** by analyzing existing works on urban «heat island» effect and it`s mitigation, as well as data on creating a more sustainable water management systems and examples of using vertical gardening in construction for both newly built and existing housing.*

*The **results** of the study illustrate the significant improvements in thermal insulation that can be achieved by integrating vertical gardens into urban structures. Through a combination of experimental data and existing implementations, it has been observed that the presence of vertical gardens leads to a noticeable increase of heat insulation. These results highlight the potential of incorporating vertical gardens as a sustainable solution to enhance the thermal performance of urban buildings.*

*This **scientific novelty** of this research contributes to the scientific literature by offering a new perspective on the role of vertical gardening in urban thermal insulation. The identification of optimal plant species and configurations for specific urban contexts adds a new dimension to sustainable urban design, emphasizing the importance of green infrastructure in addressing contemporary environmental challenges.*

*The **practical implications** of this research are substantial for architects, urban planners, and policymakers. The findings provide actionable insights into leveraging vertical gardening as a sustainable strategy to reduce energy consumption, retrofit existing buildings to meet the criteria for sustainable housing and mitigate the urban «heat island» effect.*

Key words: vertical gardening, urban heat island, insulation, energy saving, retrofit.

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INTRODUCTION

Global energy consumption is estimated to reach 580 Terajoules this year, which is an insane number, considering that 83% of it comes from fossil fuels. [1] And most of this energy is consumed by regular households by heating and cooling. This number will only increase, considering that world-wide urbanization will continue growing. Most of it comes in the form of creating sub-urban areas as it commonly appears throughout North America – one/two story buildings for one family. The other form is mostly described as «15 minute cities», where we have densely built-up residential areas in close proximity to commercial and recreational zones with a strong reliance on high voltage grid and great need for a centralized heating system, which is widely used on the European continent. Both variants have their pros and cons, but one parameter holds still – energy consumption. When you have an American style neighborhood, each household has to rely on its own supply of heat and as of now, it mostly comes in the form of gas furnaces. In Europe, it is necessary to have at least one thermal power plant in the vicinity of the city, and it is provided by burning coal and scrap. And this without taking into account how much electricity is being used in summer time to provide cooling. To mitigate that, countries are creating a system of subsidies to encourage people to alter their consumption pattern by installing heat pumps, solar panels and insulation on houses, which costs a lot even with the help from the government. To meet the goals of reducing our consumption, firstly we have to adopt the new strategy of creating "net zero" homes and retrofitting existing buildings to new standards. And to make it much more affordable, especially in developing countries, the solution might be in vertical gardening, which can work as a standalone insulator for an apartment, as well as a thermal damper with a city-scale use. This feature can insure the stability of the grid, exponentially reduce our reliance on fossil fuels and most importantly – create a comfortable and cost-effective environment inside ever-growing urban areas.

ANALYSIS OF PREVIOUS RESEARCH

Vertical gardening was mostly considered as a good aesthetic choice for creating fresh, memorable and unique design for facades of new buildings. Only recently it has come to attention by many world architects as a cheap and easily implementable solution for renovation of old buildings and designing new ones.

By analyzing existing research, we can differentiate the key factors in adopting vertical gardening as the main strategy for reaching our global net-zero goals:

– The effectiveness of vertical gardening as an insulator and its comparison with the standard insulations.

– The effect of widespread use of vertical gardening on the urban "heat island" effect and its economic benefits

– Mid- and long-term benefits of reducing energy consumption of residential buildings on the economy.

GOALS

This work emphasizes on the benefits of using vertical gardening with or instead of standard insulation by analyzing world`s energy consumption patterns and the experience of using vertical gardening around the world. One of the objectives is to offer a viable solution to the problem of existing housing and create a pattern of how to retrofit new technology to old buildings.

RESULTS AND DISCUSSION

As it was previously mentioned, urbanization grows exponentially, as more people from rural areas are moving to the cities, and the demand for affordable housing meets the supply of both old and newly built apartment blocks. Today, some 56% of the world's population – 4.4 billion inhabitants – live in cities. This trend is expected to continue, with the urban population more than doubling its current size by 2050, at which point nearly 7 of 10 people will live in cities. [2] And as of now, people mostly live in apartment buildings or single-family homes that are almost half a century old. A substantial share of the stock in Europe is older than 50 years with many buildings in use today that are hundreds of years old. More than 40% of our residential building have been constructed before the 1960s when energy building regulations were very limited. [3] By comparison, in the US home construction has decreased by 55% nationwide with almost 3 million people born in 2020 and only 912 thousand single-family homes built [4].

The demand for housing is only growing and with it grows the consumption. Global energy demand grew by 2.9% in 2018 and in a business as usual scenario, by 2040 global energy consumption will reach 740 million terajoules – equivalent to an additional 30 percent growth [1]. And if we take into account, that most of this energy is used just for heating and cooling, we can understand how much money and resources can be saved by insulation alone.

Different insulators provide different R-value, which is a measurement of how

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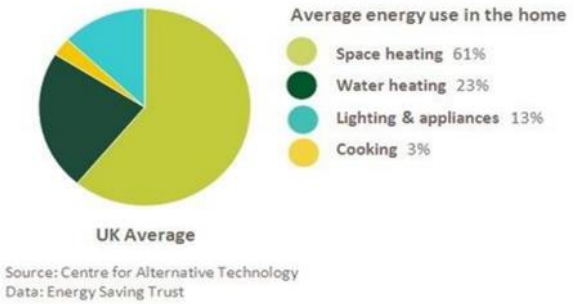

Fig. 1. Average energy consumption by UK household [5]

resistant the material is to heat flow. Materials with a higher R-value are more effective at insulating than those with a lower R-value. And all of those have different prices for installation. Some common types of thermal insulation and their approximate costs (in US dollars) are included in table 1.

And it's important to note that the thicker the insulation, the better it reduces heat flow [6].

In this case, the main advantage of vertical gardening is that it requires less expenses on installation as with time, the module that covers 4 square feet of space can expand to 8–12 square feet, simply due to the growth of installed plants. The thickness of that vegetation cover will grow as well, creating more pockets of air inside of it, which greatly reduces heat-loss. The only downsides to it would be the need for creating an additional irrigation system for the modules and that the expected effects of the insulation would depend on the speed of growth of the used plants.

But both these problems can be easily solved by creating a self-sustained gravitational irrigation, as it was used in «One Central Park», which saves around 30% of energy on cooling with all its vegetation [7], as well as by using the fast growing and temperature resilient plants like Lonicera sempervirens, that can grow at the rate of 5 meters per year and can withstand the temperature deviations from –15°C to +30°C [8]. This can be a cost effective way of improving old housing, as the facades can be easily covered with plants and multistory buildings could benefit from it by saving on the installation and sewage maintenance. [9] The other key benefit of using vertical gardening is the effect it has on the urban «heat island» effect.

Fig. 2. One Central Park, Sydney

Structures such as buildings, roads, and other infrastructure absorb and re-emit the sun's heat more than natural landscapes such as forests and water bodies. This leads to a growing ambient temperature inside the cities, which causes significant damage to the health of people and vegetation inside the city. For the most populated cities (that is, the top 5%), the effects of urban heat islands add 1.72°C, 2.08°C and 2.35°C to the temperature increase due to global climate change in 2015, 2050 and 2100, respectively. These estimates are 0.70°C, 0.84°C and 0.93°C for the median cities. About 20% of these cities could experience a total warming higher than 4°C in 2050 and about 25% could warm more than 7°C by the end of this century. [10] This can affect the economy

Table 1

Some common types of thermal insulation and their approximate costs (in US dollars)

Material	Price (per square foot)	R – Value (per inch)
Fiberglass batting	$0.50 to $1.00	3.5–3.7 [15]
Cellulose	$0.50 to $1.00	3.2-3.8 [15]
Foam	$1.00 to $2.00	6.5-7 [16]
Mineral wool	$1.00 to $2.00	4.2 [17]
Radiant barriers	$0.50 to $1.00	Don`t has it`s own, as it only refracts temperature [18]
Aerogel	$2.00 to $5.00	10.3 [19]
Cork	$1.50 to $3.00	3.6 – 4.2 [20]

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at scale, as higher temperature increases demand for cooling, which in turn demands more energy. This can affect lives of every individual, as immense heat may reduce their productivity at best and lead to serious damage to health at worst.

To mitigate this effect, it is required to use new materials, which reflect solar radiation instead of absorbing it. But this in turn requires additional expenses on adapting the existing facades to new standards, excluding the apparent need for insulation. And vertical gardening can provide both, and insure the low heat transfer of the building as well as mitigating the heat absorption, as plants use all this solar heat for the photosynthesis. And if it's used at scale it creates a cascade effect on the overall environment.

Most importantly, mitigating the «heat island» effect can greatly reduce our electricity consumption pattern. For an average household (in Melbourne, Australia), the temperature reduction of 1.15°C in the city can save $37 per year, which is not much, but at scale it can lead to the millions of dollars saved for each city. [11] Not only that, but vertical gardening has a direct effect on the city's water management. The modules, as well as the plants themselves can accumulate the rainwater, which in turn helps to relieve the sewage systems in times of massive rainfalls. Studies show that 25 square foot (2.3 square meter) greenwall systems retain on average 2.5 gallons (9.4 liters) of water a day. [12] These numbers can differ drastically with use of bigger plants (like Parthenocissus tricuspidata 'Veitchii' or Lonicera sempervirens).

With those vertical systems, cities can reduce the pressure on the sewage systems, as more water would evaporate and stay in a more natural environment. This provides additional savings, as processing of sewage water can cost from $3 to $5 per 1 liter to the city [13] in US and around €168 per inhabitant in EU [14].

Fig. 3. Lonciera sempervirens used as a decoration and in vertical gardening

Fig. 4. Using Parthenocissus tricuspidata 'Veitchii' for vertical gardening in Kyiv

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CONCLUSIONS

The cost effectiveness of using vertical gardening for insulation can be described as a mid- and long-term investment, which can positively affect the overall economic behavior of every city. Benefits for single-family houses are not as drastic, as with densely populated areas, but they still provide the proper thermal isolation and rainwater management to consider it as a viable alternative to the classic insulation. For the cities it is paramount to use his technology, as urban areas will continue to expand. It is necessary to accumulate research on which strategy to use for each country, as we have to take into account the climate parameters of each nation as well as their cultural heritage and economical structure. For different climates we have to use different plants for them to provide the best insulation and to be as maintenance-free as possible.

As we discussed previously, with increased population the demand for electricity will increase as well, which leads to bigger consumption of fossil fuels, which affects the global temperature of the planet, which leads to the amplification of urban «heat island» effect. This cycle has to be stopped or at least slowed, and adopting renewable energy would not work as a standalone solution. We have to change our perception of the urban landscape in order to improve our environment as well as our economies.

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АНОТАЦІЯ

Литвин Б.Б., Косик О.І. Використання вертикального озеленення для покращення теплоізоляції у міських умовах.

Мета *роботи – підкреслити важливість теплоізоляції в умовах сучасного міста і запропонувати більш природну альтернативу існуючим матеріалам. Постійне зростання міського населення призводить до збільшення попиту на житло. Молодь переїжджає до міст у пошуках нових можливостей, що призводить до збільшення споживання енергії, яке має прямий негативний вплив на навколишнє середовище. Цей нескінченний цикл здебільшого стосується ефективності. Поліпшення теплових властивостей кожного будинку дасть змогу створити економічно ефективну систему, придатну для використання у всьому існуючому житлі, і цим ми досягнемо значного відсотка економії коштів на опалення та охолодження, а також зменшимо залежність від викопного палива, що, своєю чергою, дасть змогу значно більше заощадити на інфраструктурі, спеціальному обладнанні та субсидіях для цієї галузі.*

У цьому дослідженні застосовано комплексну ***методологію*** *шляхом аналізу існуючих робіт щодо ефекту міського «теплового острова» та його пом'якшення, а також даних щодо створення більш сталих систем управління водними ресурсами та прикладів використання вертикального озеленення в будівництві як для новозбудованого, так і для вже існуючого житла.*

Результати *дослідження ілюструють значне поліпшення теплоізоляції, якого можна досягти шляхом інтеграції вертикального озеленення у міські структури. Завдяки поєднанню експериментальних даних та існуючих реалізацій було виявлено, що наявність вертикальних садів призводить до помітного підвищення теплоізоляції. Ці результати підкреслюють потенціал включення вертикальних садів як сталого рішення для поліпшення теплових характеристик міських будівель.*

Наукова новизна *цього дослідження робить внесок у наукову літературу, пропонуючи новий погляд на роль вертикального озеленення у міській теплоізоляції. Визначення оптимальних видів і конфігурацій рослин для конкретних міських умов додає новий вимір до сталого міського дизайну, підкреслюючи важливість зеленої інфраструктури у вирішенні сучасних екологічних проблем.*

Практичне значення *цього дослідження є важливим для архітекторів, містобудівників та політиків. Результати дослідження дають практичні рекомендації щодо використання вертикального озеленення як сталої стратегії для зменшення споживання енергії, модернізації існуючих будівель відповідно до критеріїв сталого житла та пом'якшення ефекту міського «теплового острова».*

Ключові слова: вертикальне озеленення, міський острів тепла, ізоляція, енергозбереження, модернізація.

ВІДОМОСТІ ПРО АВТОРІВ:

Литвин Богдан Богданович*, бакалавр, Київський національний університет імені Тараса Шевченка, Київ, Україна, e-mail: lytvynbogdan164@gmail.com, orcid: 0009-0007-8405-7555*

Косик Оксана Іванівна*, кандидат біологічних наук, доцент, Київський національний університет імені Тараса Шевченка, Київ, Україна, e-mail: o_kosyk@knu.ua, orcid: 0000-0003-0873-3180*

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