



PROSPECTS OF THE IMPLEMENTATION OF GREEN STRUCTURES FOR CLIMATE CHANGE MITIGATION AND POST-WAR DEVELOPMENT OF UKRAINE



Tetiana Tkachenko, Dr Hab., professor, senior researcher, head of the department of environmental protection technologies and labour safety, academician of the Academy of Technical Sciences of Ukraine and the Academy of Construction of Ukraine, member of the national technical standardization committee TC-82 "Environmental safety", the International Association of University Ecologists and the International Society of Geometry and Graphics, known in Ukraine and far beyond its borders as an expert and popularizer in the field of green construction and green standards. Constantly participates in international projects and grant programs, teaches in training courses under the auspices of the UN

UP TO 90% OF BUILDINGS WERE DESTROYED BY HOSTILITIES

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m.Irpin New buildings

Residential complex Flamingo



Residential complex on Gaidar street

Photos with "Monitoring map from LUN City" <https://misto.lun.ua/>

Residential complex Irpinski Lyuky



Frame of the film "Destroyed houses in Vyshgorod district, Kyiv region 06/23/2022"

<https://www.youtube.com/watch?v=xhGI9rR4NF0>

m. Bucha

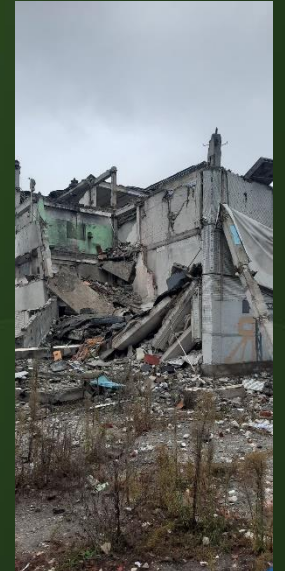


The photowitharticles"TragedyinBuchi:in townstarteddemolishdestroyedhouses". <https://www.dsnews.ua/ukr/politics/tragediya-v-buchi-urmist-pochali-znositi-zruiinovani-budinki-25072022-463209>

UP TO 90% OF BUILDINGS WERE DESTROYED BY HOSTILITIES

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On 26 October 2022, at 03:00 a.m., a missile destroyed the building of the Druzhkov Housing and Communal Professional College of DonNACEA (Kramatorsk), which was renovated with EU funds in 2021.



VIOLATED INFRASTRUCTURE

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By the war, the road infrastructure was significantly destroyed.
Losses exceeded 900 billion UAH for 06 May 2022



Photo and data from the article "Due to the war, the road infrastructure was damaged for more than 900 billion UAH - "Ukravtodor".

<https://www.radiosvoboda.org/a/new-s-ukravtodor-pro-zbytky/31837340.html>

Restoration rainwater drainage on highways needs huge emissions to the environment and large expenses

AND MORE THAN 175 MILLION TONS OF GREENHOUSE GASES ARE EMITTED

5

<https://www.politico.eu/article/russia-carrie-out-missile-strike-ukrainian-shopping-center-say-zelenskyy/>



How much greenhouse gases and heat will be released to treat the military waste and destroyed buildings?



DEVELOPMENT IS ON TIME

The main problems:



High energy efficiency and environmental friendliness;



shortage funds

A solution that satisfies both conflicting requirements is green structures - a combination of structures and living plants

The data from the article "Two years of full-scale war resulted in the release of 175 million tons of greenhouse gases. The consequences will be felt by different countries"

https://lb.ua/society/2024/06/13/618538_dva_roki_pov_nomasshtabnoi_viyeni.html

GREEN STRUCTURES –

A PROSPECTIVE TECHNOLOGY OF CLIMATE CHANGE MITIGATION:

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Increase the energy efficiency – decreasing greenhouse gases and heat emissions at energy generation;

Mitigation of urban heat islands – elimination of overheating cities and towns;

Capturing the rainwater from highways and urban areas – increase of transport reliability with less greenhouse gases and heat emissions, avoidance of flooding of basements – less waste and repairing;

Sequestration of carbon dioxide – less greenhouse gases;

Urban agriculture – optimised logistics to decrease greenhouse gases and heat emissions of transport;

GREEN STRUCTURES – A PROSPECTIVE TECHNOLOGY FOR PEOPLE AND ENVIRONMENT

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Increase the energy efficiency – overcoming energy poverty and strengthening energy independence of countries;

Capturing the rainwater from highways and urban areas – stable transport, safety in basement rooms and underground passes;

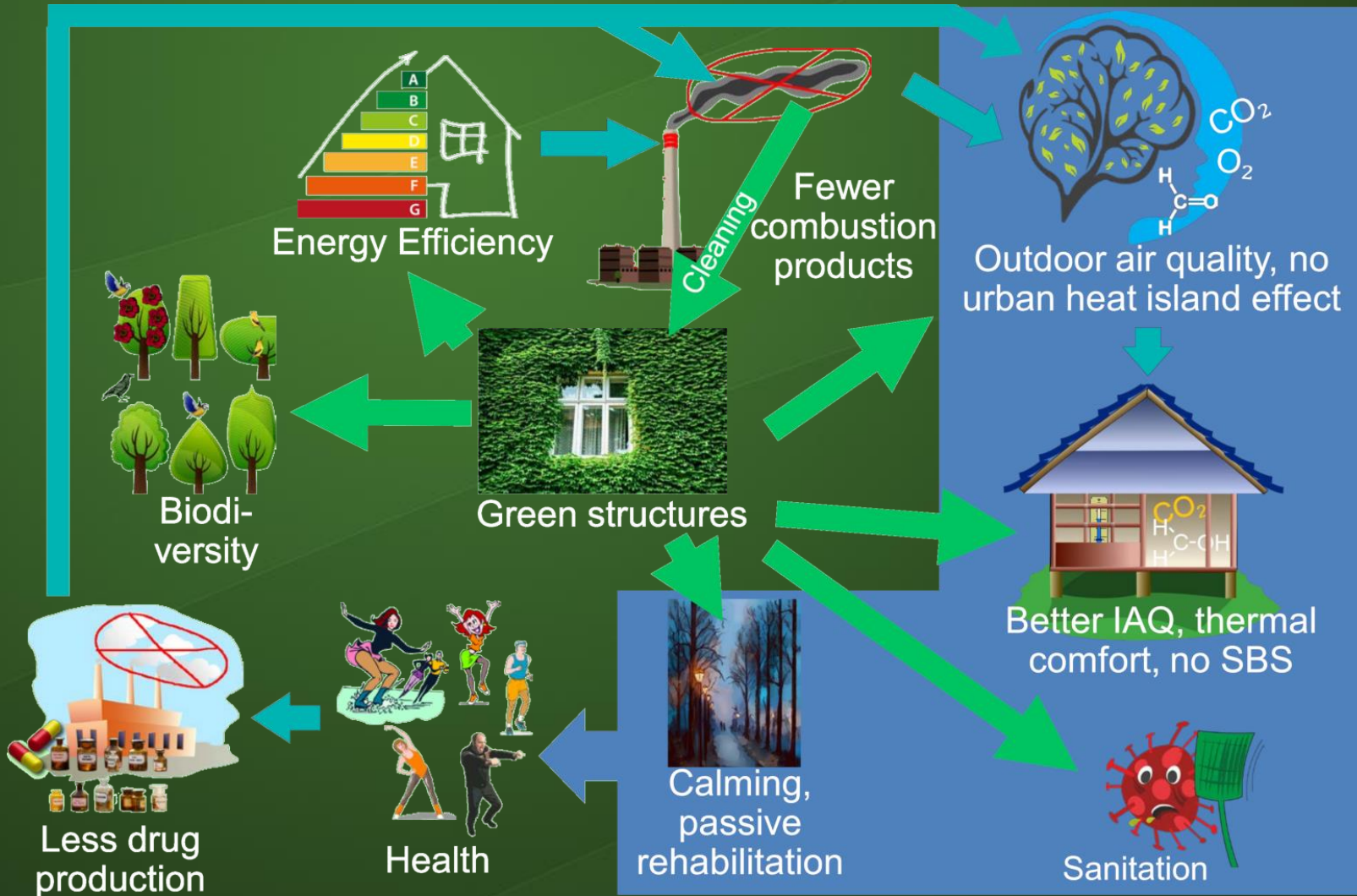
Noise absorption – calmness;

Improvement indoor air quality (IAQ) – healthy environment by cleaning from pollution, dust, pathogenic microorganisms, viruses, and oxygen saturation, avoiding sick building syndrome (SBS);

Improvement of the environmental friendliness – cleaning air in settlements, improvement of biodiversity, the organization of biota migration routes deep into densely built-up areas, etc;

Passive post-war rehabilitation thanks to the maximum approaching the environment to the natural one, which lowers stress levels and soothes

GREEN STRUCTURES AND THEIR POSITIVE EFFECTS

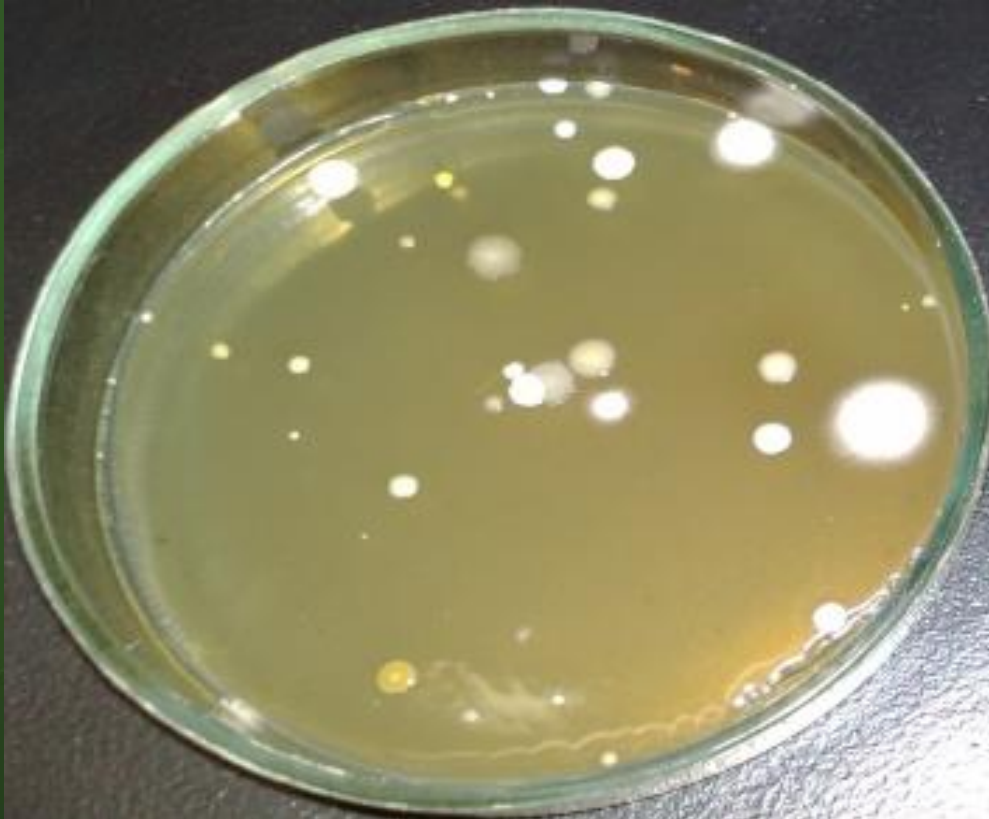


IMPROVING INDOOR AIR QUALITY

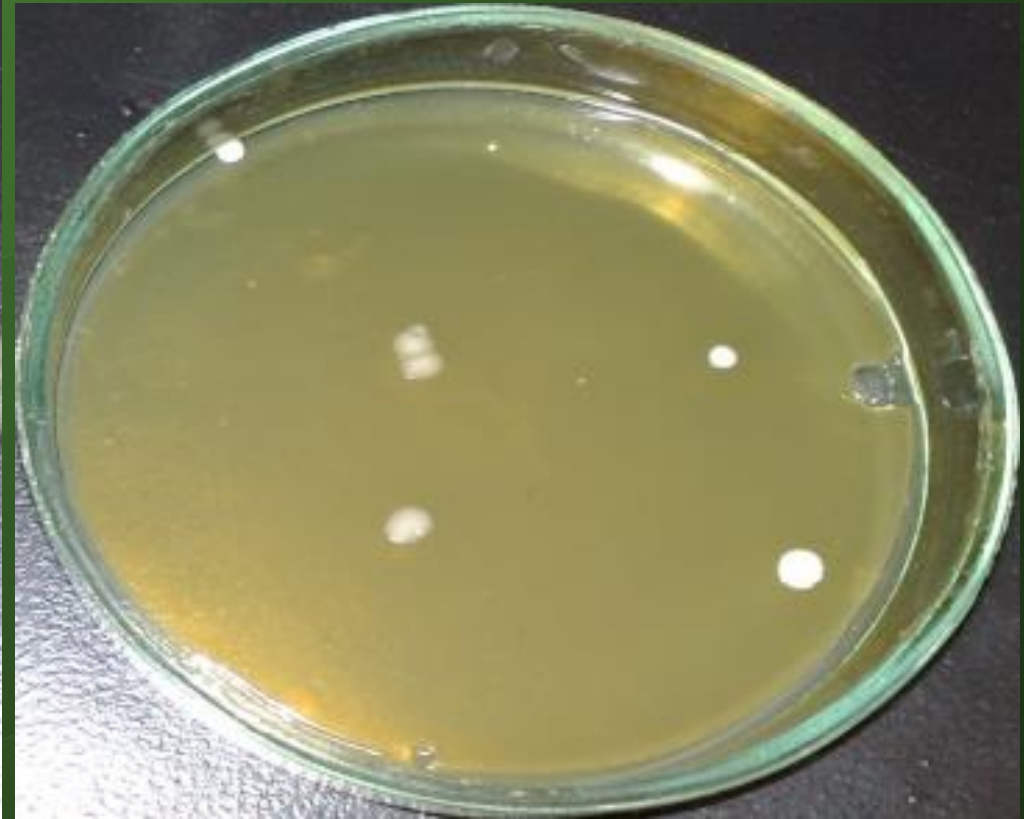
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Plants of green structures sanitize and cleaning the air.

Sedimentation from a
room without plants



Sedimentation from a
room with plants



HISTORY OF GREENING

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ELITE CLASS

Gardens of Semiramis



Villa Mysterias, Pompeii



ECONOMY CLASS

Faroe Islands



Karl Rabits building
(XIX century)



Gundertwasser House 1983-86.



Old yard in Odessa



GREENING FOR MASKING

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HITLER'S BET IN GERLOZHE POLAND



INNOVATIVE EXAMPLES, EU: greening of tram tracks

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Tramwaje Warszawskie announced (<https://tw.waw.pl/zielone-tory-w-centrum-warszawy/>) that they are starting a new landscaping program. Its feature is the use of a new way of landscaping, without rebuilding the existing tram tracks with crushed stone ballast. To do this, the crushed stone will be cleaned, layers of drainage and substrate will be placed on top, and a rather undemanding plant will be planted - *Sedum* (*crassula*). Two sections in the city center have already been landscaped - between placem Zawiszy a Żelazną, and the second between rondem ONZ a dworcem Warszawa Centralna. After landscaping, Warsaw will have 28 kilometers of landscaped tracks

Tram track
Częstochowa (<https://czestochowa.wyborcza.pl/czestochowa/7,150461,27502037,wielki-powrot-tramwajow-nowa-stara-linia-krok-po-kroku-co.html>, <https://bi.img.pl/im/41/39/1a/z27498049IHR,Do-konca-miesiaca-beda-trwaly-testy-nowego-torowis.jpg>)
The first green tram track with a length of 350 m in the city center of Częstochowa

DRAINAGE OF EXCESS WATER FROM THE HIGHWAY

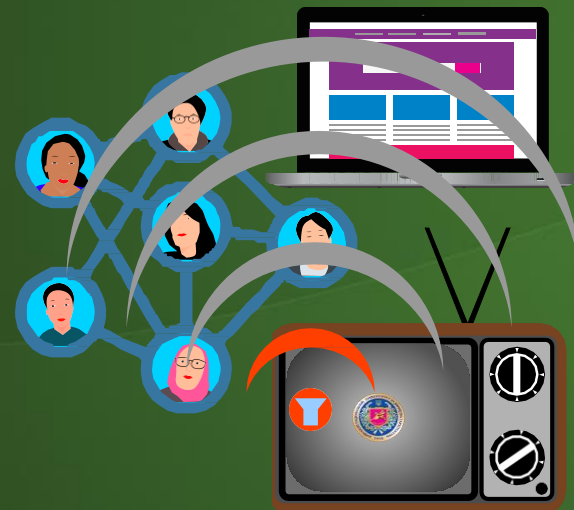
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Warsaw, Poland

REASONS OF NOT ENOUGH DISSEMINATION IN UKRAINE

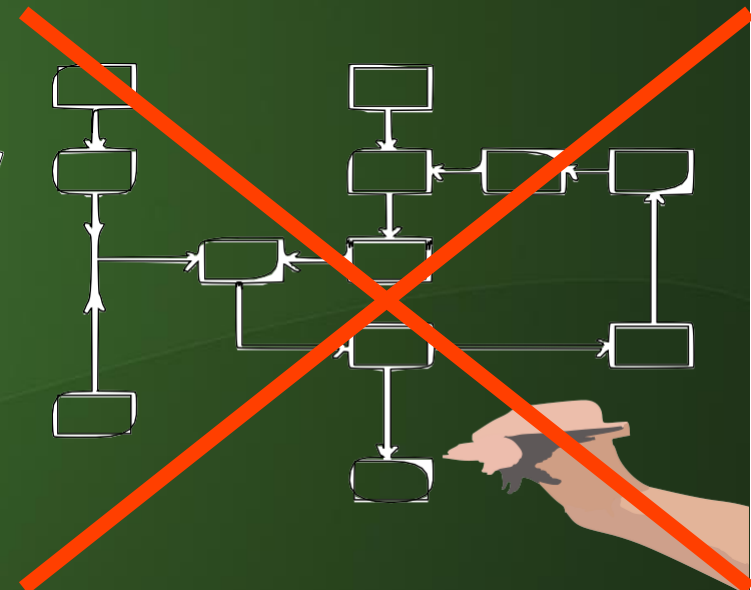
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Insufficient information



Insufficient normative base



Non-systematic implementation

Instead, the world's leading cities are actively greening their buildings by agitation building owners for greening, requirements for greening of new construction sites, granting from the budget, etc.

Our developments and research results, in particular the projects of DSTU "Green Structures. Guidelines" and "Methods of determining thermotechnical and gas exchange characteristics of vegetation layers", "Environmental criteria and method for life cycle assessment at the design and construction stages", etc., allow to scientifically ground and systematically implement green structures to achieve maximum efficiency.

CLASSES OF BUILDINGS

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Opinion:

*Green structures
are very expensive
and used only for
buildings of
premium class*

Green roofs, terraces and walls
for expensive buildings or with state support

**Hanging gardens of
Semiramis, reconstruction
of F. Krishen**



**Author's green
roof**



Vertical and vertical-horizontal landscaping
for buildings of every classes, minimal
expenses, may be performed at exploitation

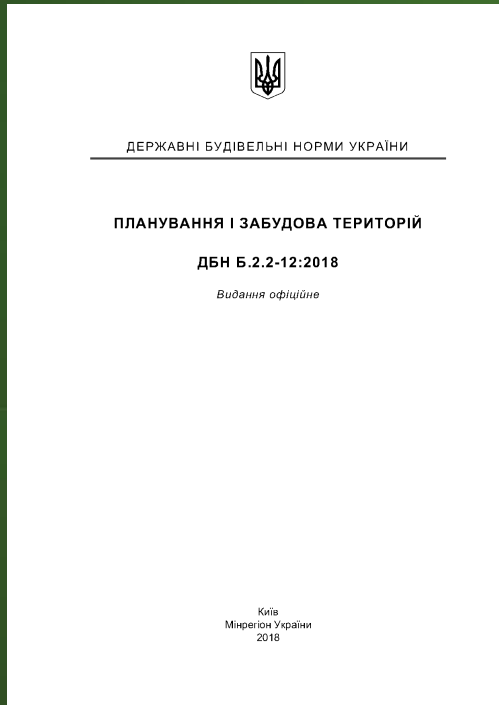
Vertical-horizontal greening of
small architectural forms,
Podil, Kyiv



Surviving vertical greening damaged by a missile,
Lukyanivka, Kyiv



DBN B.2.2-12:2018 Planning and development of territories



6.2.6 In the territories of residential, public, resort and recreational buildings, facilities should be provided:

- ✓ general landscaping of areas (trees, shrubs, lawns, flower beds);
- ✓ planar landscaping (roofs, inter-rail tramways, golf courses);
- ✓ vertical greening of buildings and structures (facades, balconies, noise barriers);
- ✓ renewable greening (disturbed areas, ravines, slopes).

8.2.6 На територіях житлової, громадської, курортної та рекреаційної забудови слід передбачати засоби:

- загального озеленення ділянок (дерева, чагарники, газони, квітники),
- площинного озеленення (дахів, міжрейкових трамвайних полотен, гольф-полів);
- вертикального озеленення будинків і споруд (фасадів, балконів, шумозахисних стінок);
- відновлюваного озеленення (порушених ділянок, ярів, схилів).



**RESEARCH RESULTS
IN KYIV NATIONAL
UNIVERSITY OF CONSTRUCTION AND
ARCHITECTURE,
WHICH ALLOW TO CREATE THE
NORMATIVE BASE FOR
A NEW WORLD LEVEL IN PRINCIPLE**

SEQUESTRATION OF CO₂ FROM HIGHWAYS

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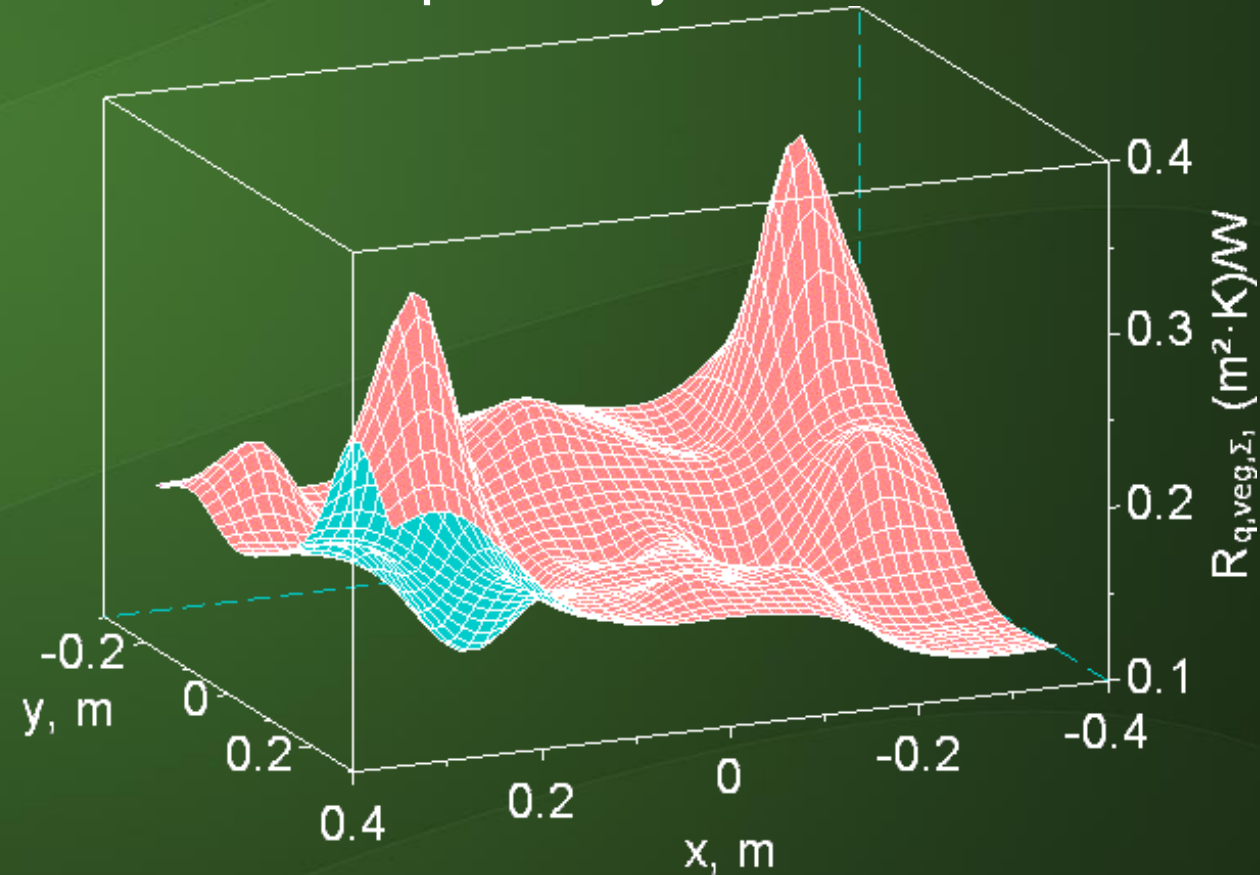
ROYAL TOWER, Kyiv

The area of green spaces is about 180 m². It was established that the area of woody plants absorbs 3.769 kg/(m²·year), and 1 hm² of tree plantations per year absorbs the emission from the highway in 19.8 days. The total absorption effect from trees and grass is 5.461 kg/(m²·year), and 1 hm² absorbs highway emissions for 28.7 days per year.



ADDITIONAL THERMAL INSULATION 19

The experimental method is created and the research is performed on the thermal resistance of plant layers

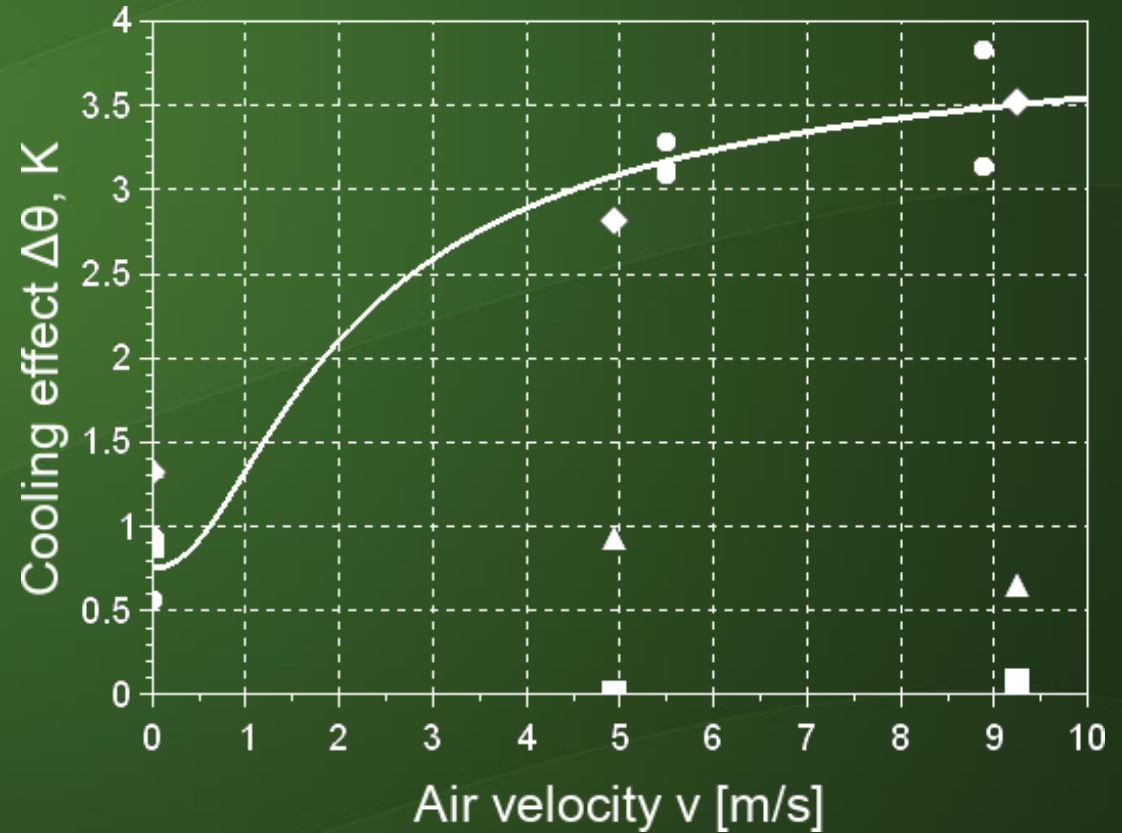


This allows to calculate energy savings for air conditioning, as well as heating in the spring-autumn period

COOLING EFFECT

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The clear definition of the effect as the temperature difference between ambiance and under the plant layer is issued.

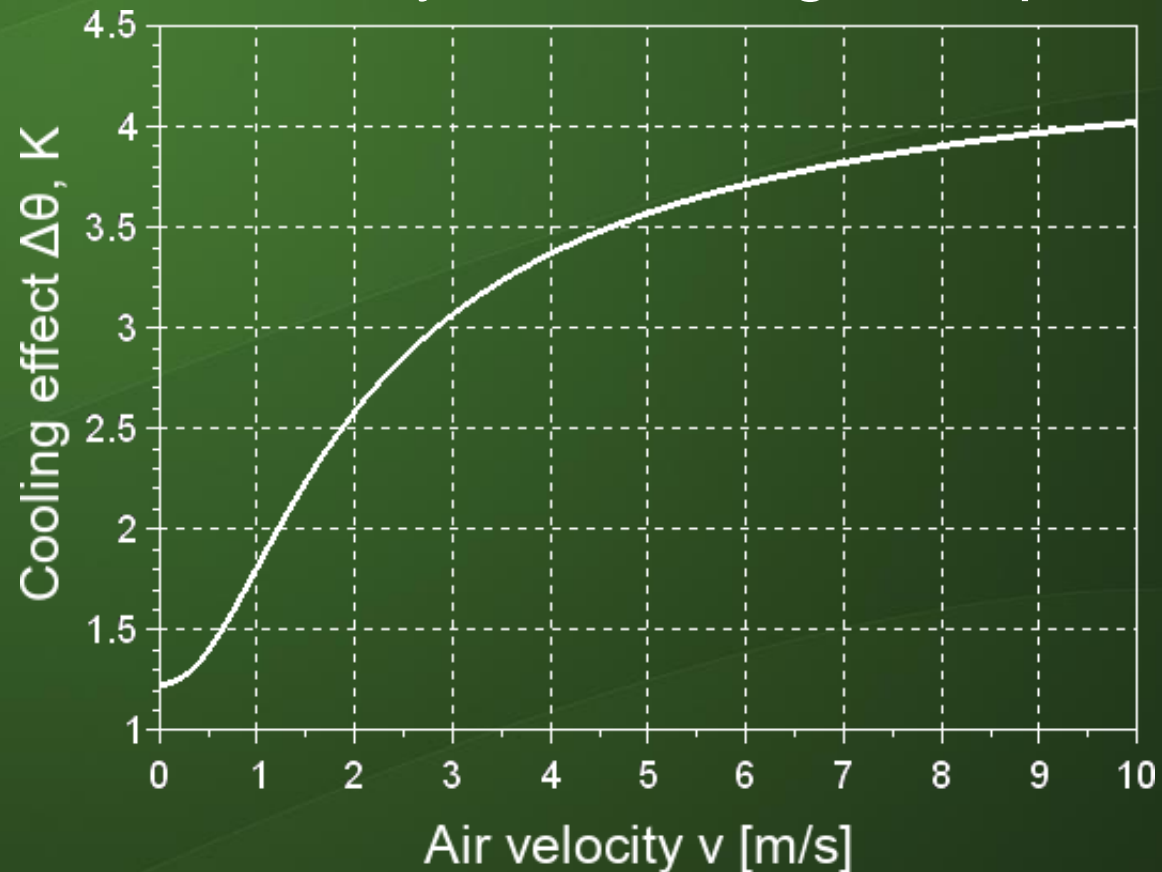


This allows determining the energy savings for air conditioning or the effect of passive air conditioning

COOLING EFFECT

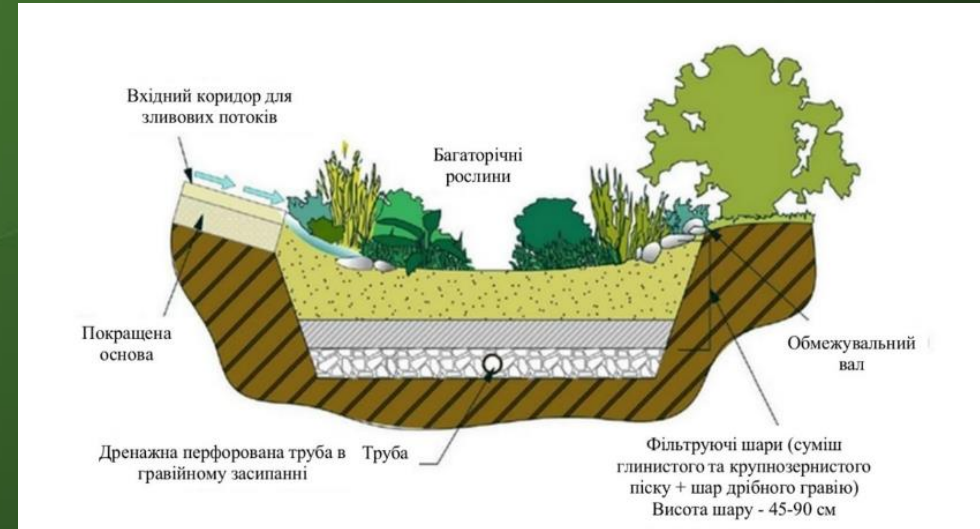
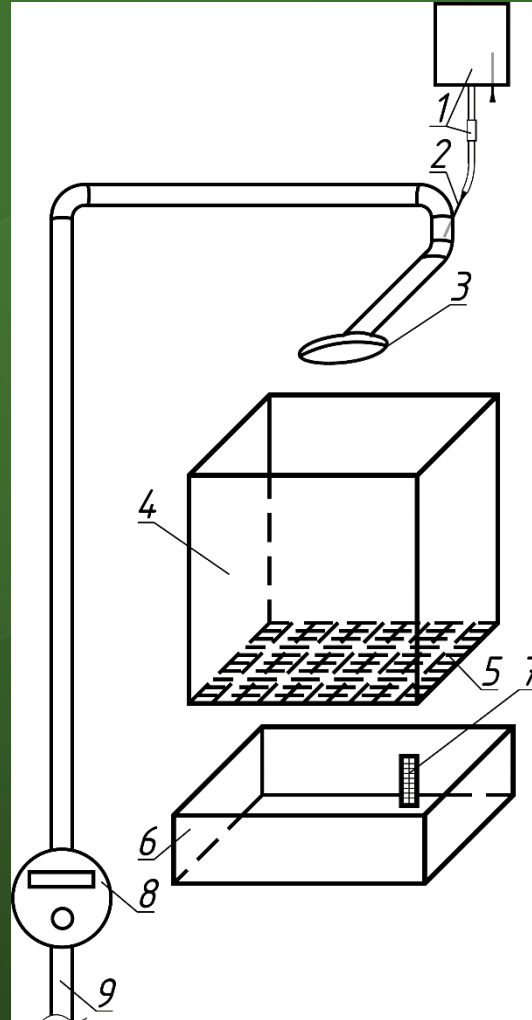
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Greening with *Parthenocissus quinquefolia* is more effective than with grass (*Lolium perenne*). Such greening requires minimal costs and can be carried out at any time during the operation of the building



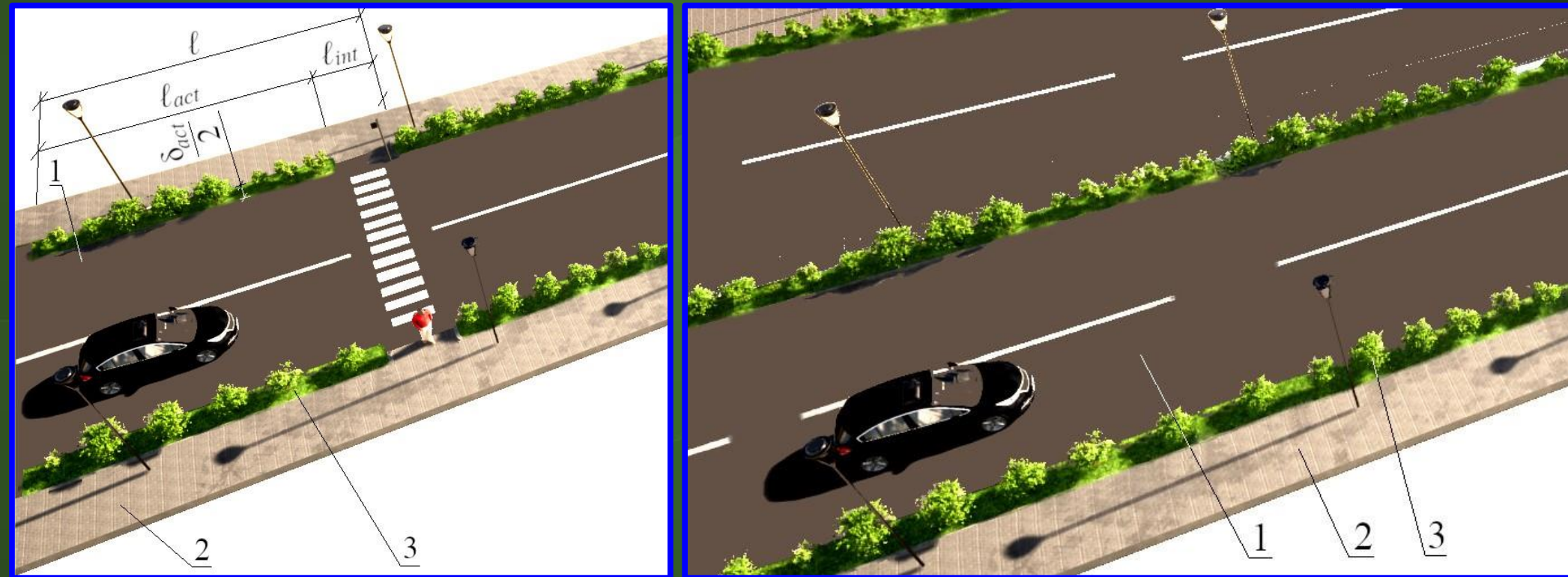
CATCHING AND FILTRATION OF RAINWATER

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RAIN-GARDENS BANDS

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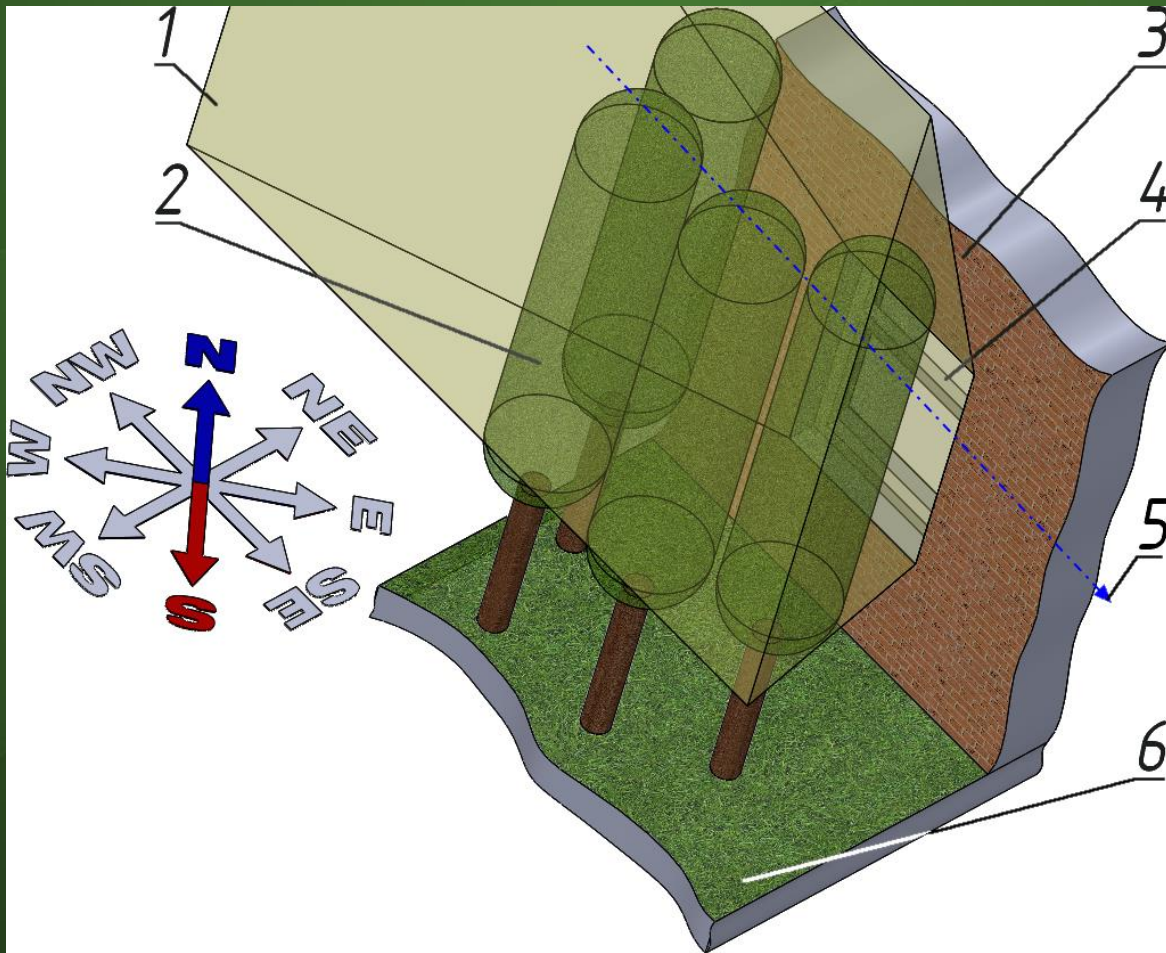


1 – roadway; 2 – pavement; 3 – rain-garden band.

For Kyiv, the width δ_{act} doesn't exceed 11% of the road width

AUTOMATIC SOLAR PROTECTION CONTROL BY DECIDUOUS PLANTS

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- 1 – figure to be filled;
- 2 – plants;
- 3 – wall;
- 4 – window,
- 5 – the direction of the sun rays;
- 6 - green terrace.

ORGANIZATION OF BIOTA MIGRATION ROUTES

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ПЕРСПЕКТИВНІ ЗОНИ ВВЕДЕННЯ «ЗЕЛЕНИХ
КОНСТРУКЦІЙ» У МІСЦЯХ ЦЕНТРАЛЬНИХ
МАЛОПОВЕРХОВИХ ЗАБУДОВ
СОЛОМ'ЯНСЬКОГО РАЙОНУ
МІСТА КИЄВА



Plot No. 1 – an industrial area with a nine-story building. "Orlyatko" park and the territories of educational institutions are nearby.

Plot No. 2 has two parks - "Sputnyk" and "Youth" - gathering places for birds that will be able to find new homes on "green roofs".

Plot No. 3 near the private sector, two parks (Solomyansky Landscape Forest Park and Protasiv Yar Park).

Plot No. 4 is very densely built-up.

Plot No. 5 borders the private residential sector and has the park "Vidradny", the park of the "Prestige" lyceum and the green area of the Medmistechna. The building is 5-storey, rather compact in the area of Novokaravaev Dachy.

The condition for the creation of bird migration routes is the limiting of the distance between "green" structures.

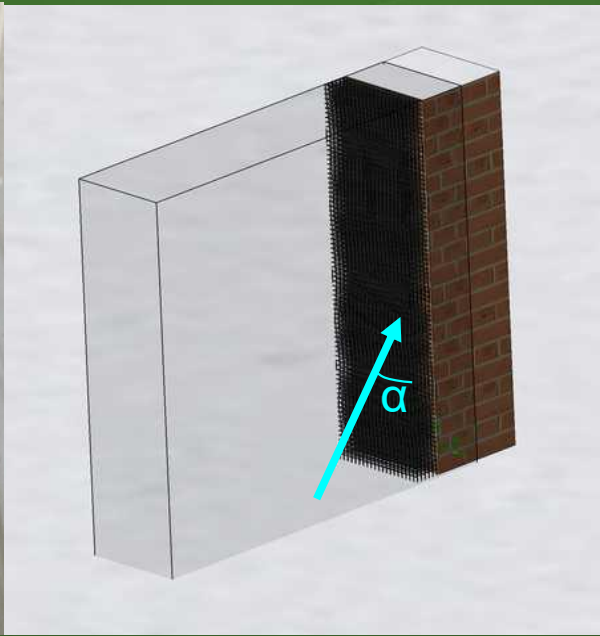
Solomianskyi district, Kyiv

LATEST RESEARCH – SIMULATION OF THE THERMAL RESISTANCE OF VERTICAL FACADE GREENING IN THE COLD PERIOD OF THE YEAR

*Greening of walls, Kyiv,
Pechersky district*



*Three-dimensional model of
a building fragment*



The results

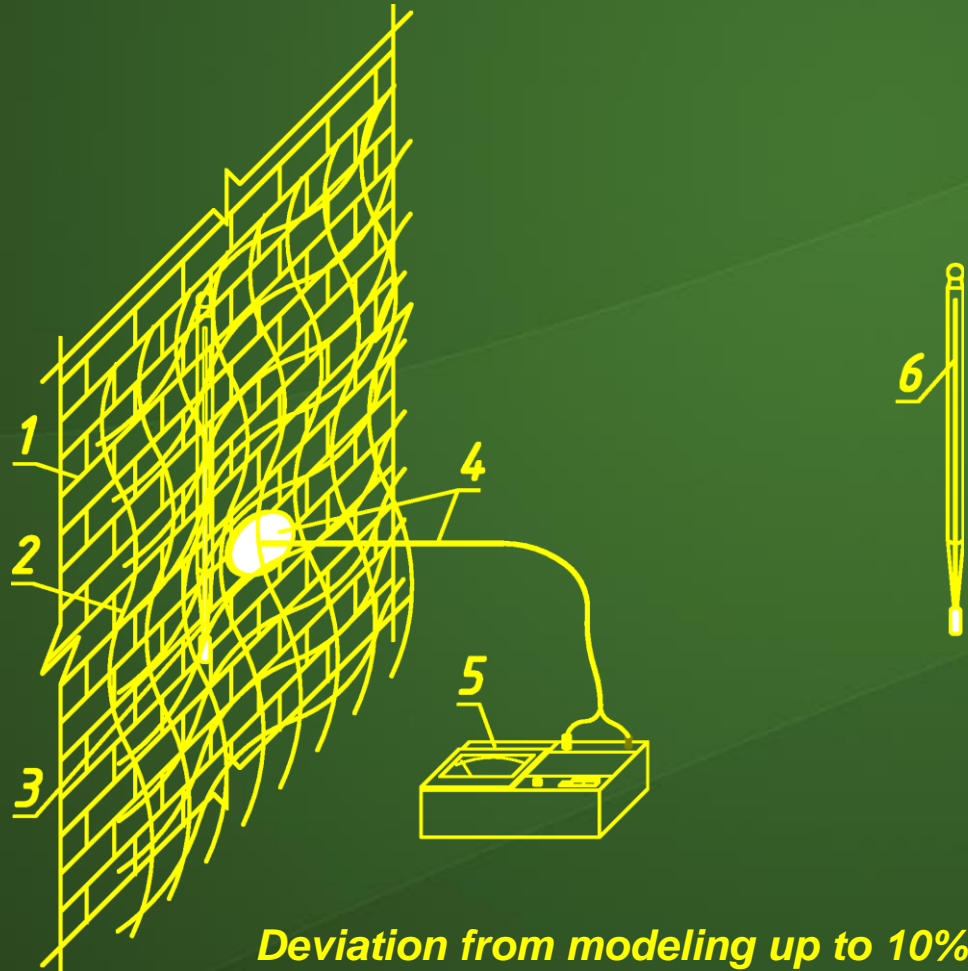
Wind direction	Wind speed, m/s	Heat transfer resistance, m ² ·K/W
Calm	Calm	0.71
Runs into the facade	2	0.12
Runs into the facade	5	0.09
At an angle of 45°	2	0.077
At an angle of 45°	5	0.035
Estimated external heat transfer		1/23 = 0.043

$$\alpha = \pi/2, R = (\delta/260) \cdot (420\nu + 2.97)^{-0.3147}, \text{ m}^2\text{K/W};$$

$$\alpha = \pi/4, R = (\delta/260) \cdot (7.52\nu + 1,453)^{-0.9147}, \text{ m}^2\text{K/W}$$

FIELD STUDIES OF VERTICAL GREENING WITHOUT LEAVES

Scheme of the study



Carrying out the experiment



- 1 – wall;
- 2 – plants;
- 3 – thermometer under the plant layer;
- 4 – thermal flow sensor;
- 5 – thermal flow meter;
- 6 – thermometer in the environment

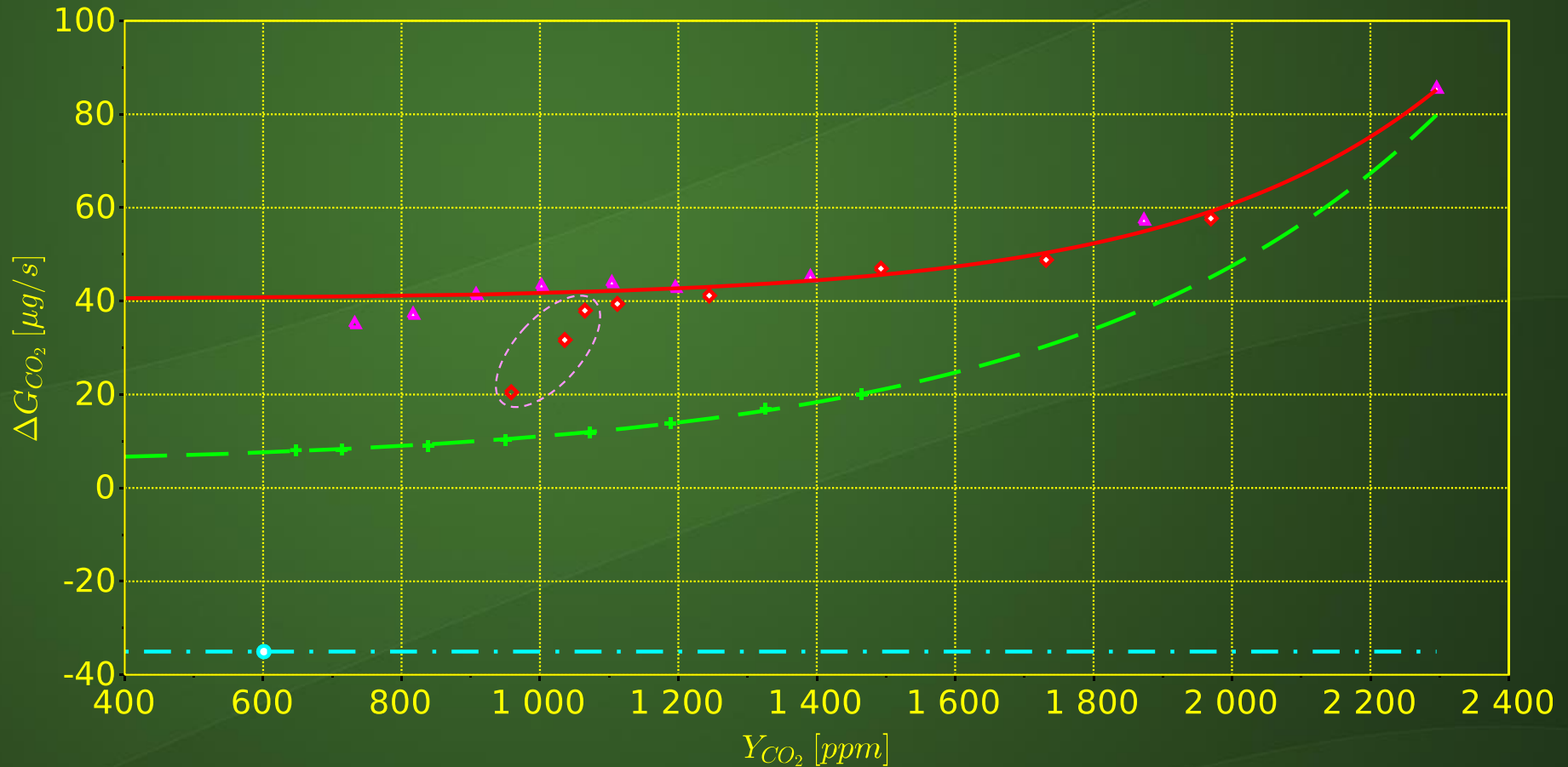
COMPENSATION OF AIR POLLUTION

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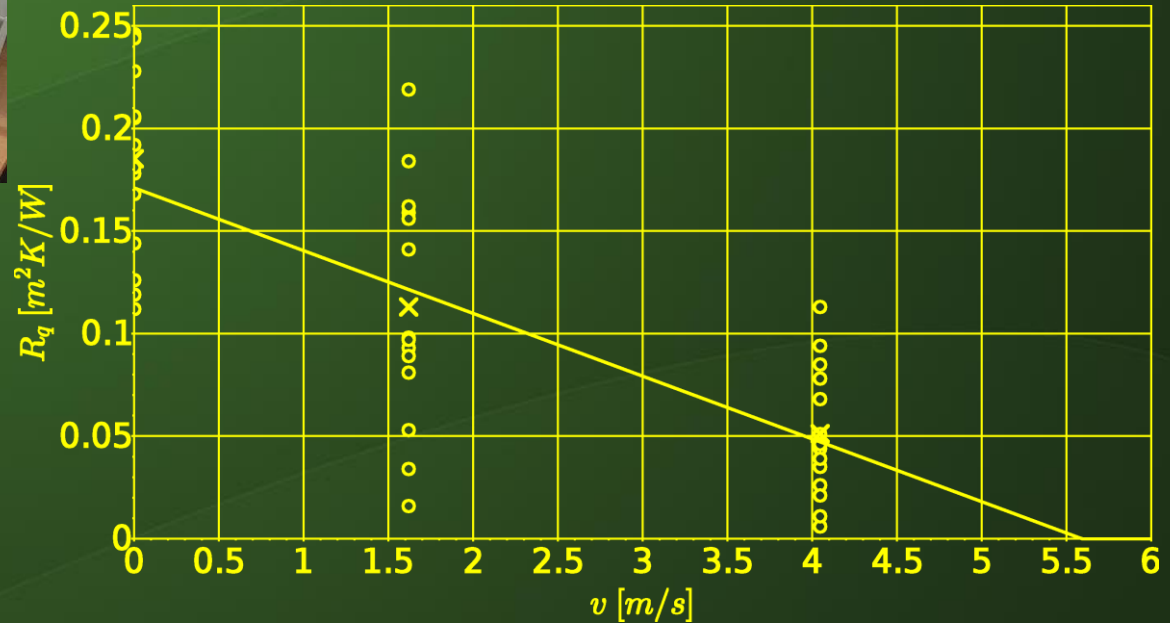
COMPENSATION OF AIR POLLUTION

29



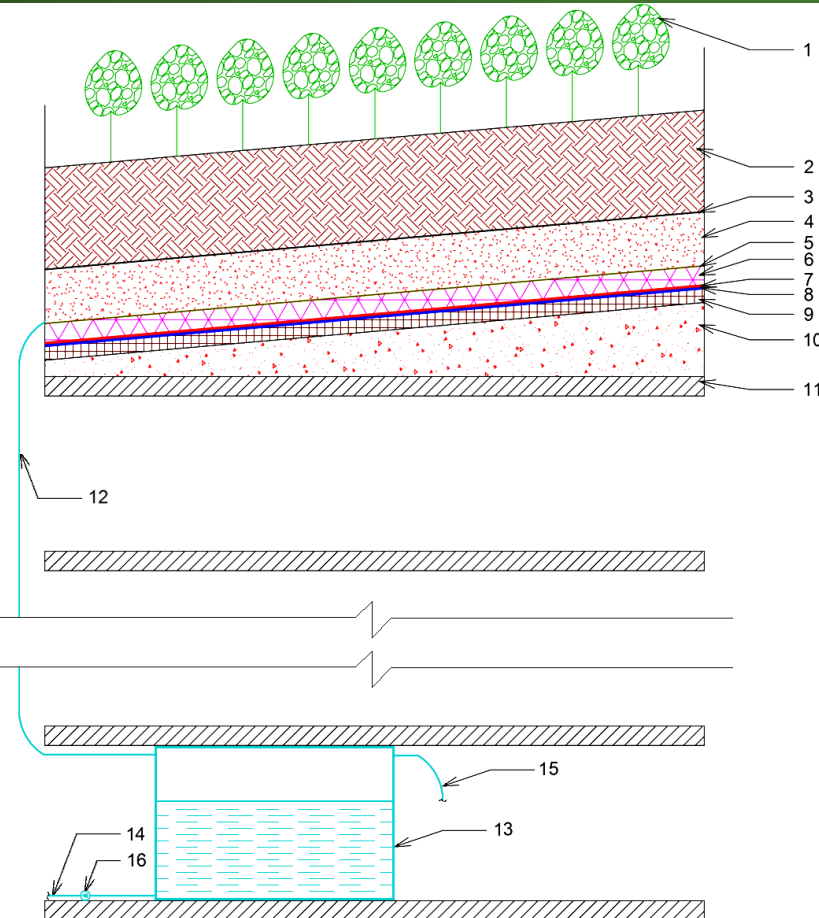
research data: \circ (breath); $+$ 6872 ftk; \triangle 20236 ftk; \diamond 31136 ftk
approximation: $-.-$ - 0 (breathing); $- - -$ - 6872 ftk; $- - -$ - 14766.35 ftk
 $- - -$ - plants have exhausted their photosynthetic capabilities and need recovery in the dark

STUDY OF THERMAL RESISTANCE OF HORIZONTAL GREENING 30

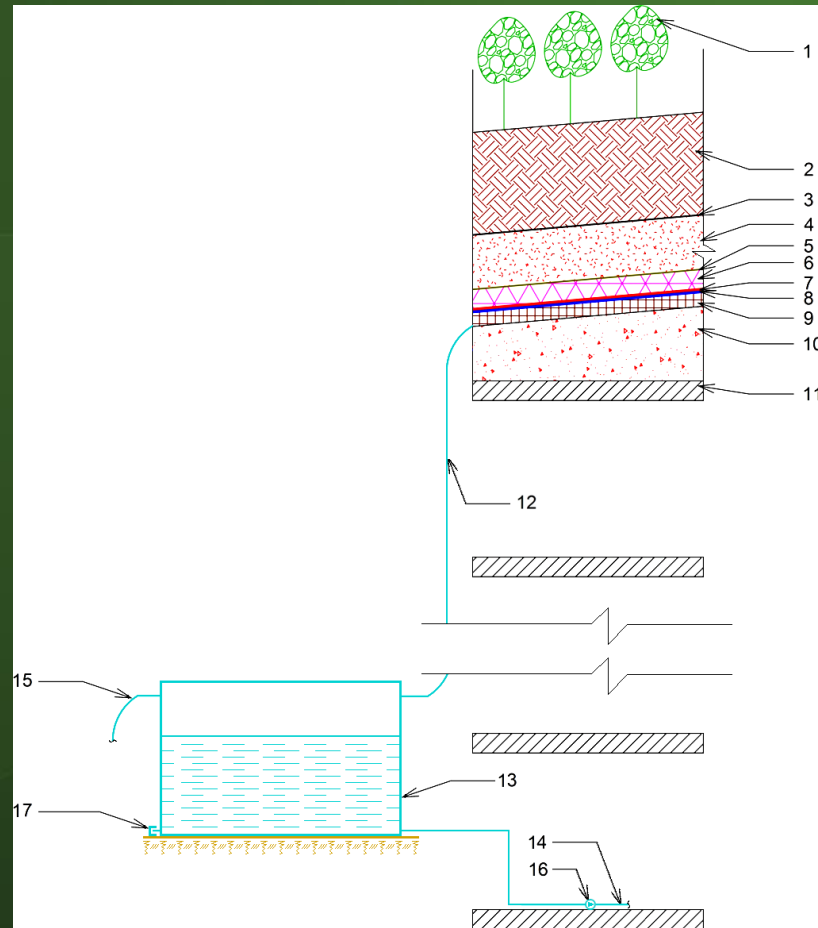


IMPROVEMENT OF INVERTED GREEN ROOF TECHNOLOGY FROM DOMESTIC MATERIALS

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IMPROVEMENT OF INVERTED "GREEN ROOF" TECHNOLOGY FROM DOMESTIC MATERIALS ³²



- 1 – plants; 2 – substrate;
3 – filter layer made of thermobonded geotextile; 4 – expanded clay drainage; 5 – barrier for roots made of fiberglass;
6 – insulation from extruded polystyrene foam
7 – vapor barrier (vapor barrier film UkrSpan);
8 – Euroruberoid waterproofing; 9 – reinforced cement–sand screed;
10 – slope–forming layer of expanded clay; 11 – support base – reinforced concrete floor slab; 12 – spillway;
13 – water storage tank; 14 – to the technical water supply system (flushing toilets, cleaning, washing, watering); 15 – overflow line to the drainage system; 16 – pump; 17 is a recommended blocked pipe for future tanks

GREEN ROOF PROJECT ON KYIV NATIONAL UNIVERSITY OF CONSTRUCTION AND ARCHITECTURE

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APPROVED

WE ALSO HAVE RECOMMENDATIONS:

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- ✓ on the assortment of plants for different climatic conditions based on the mathematical model of plant development according to the Tumanov scale based on the data of many years of observations of green roofs, as well as software for the selection of plants for most cities of the world in Copernicus CDS Toolbox
- ✓ on selecting substrate for growing various types of plants on intensive and extensive roofs
- ✓ regarding the masking of civil and military facilities with green constructions

Green structures are promising biotechnology for climate change mitigation, post-war recovery and further sustainable development of Ukraine to overcome energy poverty, improve health, achieve energy independence, compensate for the negative impact of hostilities on the environment and passive post-war rehabilitation;

the spread of green structures requires, on the one hand, the formation of public opinion through the mass-media, and on the other hand, a well-systematized national regulatory framework, which, taking into account original research, can become the best in the world;

green structures are intended for the entire spectrum of construction, not just for elite buildings.



THANK YOU FOR YOUR ATTENTION



Tetiana TKACHENKO, Dr Hab., professor, senior researcher, Head of the Department of Environmental Protection Technology and Labour Safety, Kyiv National University of Construction and Architecture, a member of the Technical committee for standardization TC 82 "Environmental Protection", member of workgroups for Ukrainian standards including standardisation of green structures, academician of the Academy of Technical Sciences of Ukraine and the Academy of Construction of Ukraine, member of the International Association of University Ecologists and the International Society for Geometry and Graphics, known in Ukraine and far beyond its borders expert in the fields of green construction, green structures, green standards etc. She constantly participates in international projects and grant programs, teaches in training courses under the UN support

Phone/Viber/Telegram: +380673533877. Phone +380665299136

E-Mail: tkachenkoknuba@gmail.com, tkachenko.tm@knuba.edu.ua