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CZECH TECHNICAL UNIVERSITY IN PRAGUE

CIRCULAR GREEN ROOFS: UTILIZING RECYCLED MATERIALS AND TREATED GREYWATER

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27.6.2023

CZECH TECHNICAL UNIVERSITY IN PRAGUE

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UCEEB

- Multidisciplinary workplace
- Located in Buštehrad (close to Prague)
- abbreviated **UCEEB**
- Architecture and the Environment

UNIVERSITY
CENTRE FOR ENERGY
EFFICIENT BUILDINGS
CTU IN PRAGUE

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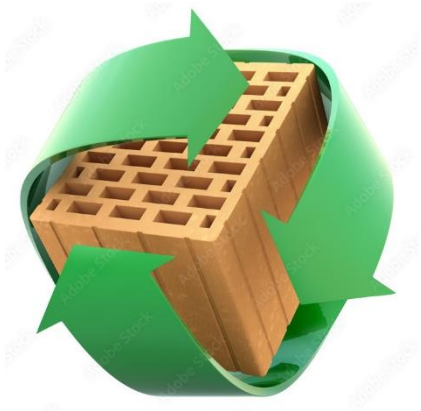
TWO INTERSECTING TOPICS

Utilization of recycled materials in green roof substrate



Onsite nature-based wastewater treatment

GR SUBSTRATE - CURRENT SITUATION

- Large quantity of primary materials
- Energy-intensive materials
- Current composition of green roof substrates
  - Lightweight Aggregates: Expanded clay, perlite, pumice, Vermiculite
  - Organic: Peat
- Only utilization of primary brick production

- Potential for improvement –> utilization of recycled materials

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OUR VISION

- Substrate for green roofs based on recycled materials preserving or improving the properties of currently available substrates
- Utilizing the large amounts of waste our society produce today
- Reducing the ecological impact of green roof substrate production

Primary material extraction

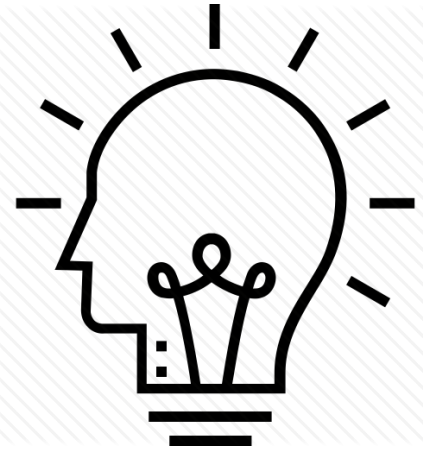
Demolition waste

Sewage sludge

UTILIZATION OF RECYCLED MATERIALS IN GREEN ROOF

- Barriers
  - Hazardous substances in recyclate
  - Variability of recyclate composition
  - Insufficient level of sorting (bricks, concrete, other)
  - Legislation limitation

- Potential
  - Cheap and available material
  - Need to utilize waste materials
  - Replacement of primary materials
  - Good water retention properties



RECYCLED MATERIALS USED IN THIS STUDY

Recycled demolition bricks

- Recycled crushed demolition waste – bricks
- Separated waste

Carbochar („biochar“)

- Pyrolysed sewage sludge
- Waste from wastewater treatment

SUBSTRATE BASED ON RECYCLED MATERIALS

- A new type of „biochar“ from the sewage sludge

Recycled brick | Peat/ Compost | Expanded clay | Carbochar /„Biochar“ | Crushed marl

37.5 % 0 and 9.5 % vol. %

Comparison of substrate	Biochar substrate	Optigreen E light	ACRE light
WHC [%]	41,6	min 35	35-55
Bulk density dry [kg/m³]	822	min 750	480–900
Bulk density at WHC [kg/m³]	1238	max 1450	900–1400
pH	6,5 - 7,0	6,0-8,0	6,5-8,5

Substrates based on recyclate

With „biochar“ Without „biochar“

✓ 16 substrate mixtures prepared and tested in laboratory

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EXPERIMENTAL GR - CITY OF TŘEŠŤ

- Apparent positive effect of carbochar admixture

09/2020

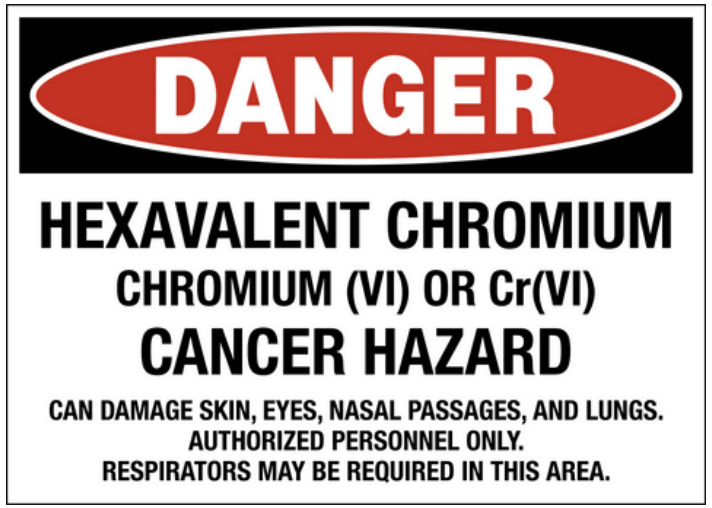
11/2020

05/2021

11/2022

DEALING WITH HAZARDOUS SUBSTANCE LOADS

- Carbochar meets the Legislation limitation - successfully registered
- **Problem of high chromium content in recyclate**
- Legislative restrictions on total amount of heavy metals
  - Chrome VI high risk (minimum proportion in mixture)
  - Chrome III much less toxic (major proportion)



- An option is to dilute the recyclate with standard substrate materials
  - not ideal solution
- Better solution in progress - will be published later

LARGE-SCALE SUBSTRATE APPLICATION

- Temporary solution to the Chromium – Dilution / Limited amount of recyclate
- First large-scale substrate application in Karvina –project ARV
- Significant reduction in recyclate content due to substrate use before the actual registration

Recycled brick	Compost	Expanded clay	Carbochar	Crushed marl	
8.5 %	15.1 %	44.1 %	9.5 %	22.9 %	vol. %

Registration number: GA no. 101036723
Provider: European Commission - Horizon 2020
Solver: Ing. Robert Wawerka, Ph.D.
Start: 01.01. 2022
End: 31.12. 2025
Partners: Norwegian University of Science and Technology, Architects Council of Europe, Technical University of Denmark, Danfoss AS, ENFOR AS, Project Zero, EURAC Research, SINTEF, Palma City Council, IBAVI, Catalonia Institute for Energy Research, METROVACESA, University of Applied Sciences Utrecht , Housing Europe, Buro de Haan, Center Denmark/EU Digital Innovation Hub Sønderborg Andelsboligforening, Green Digital Finance Alliance, Stichting Bo-Ex '91, RC Panels, Utrecht University, Municipality of Utrecht, Bos Installatiewerken BV, iWELL, MEX Architects BV, Mitros Stichting Portaal, Municipality of Karvina, Dolomiti Energia Habitech, University of Trento, Politecnico of Turindi Torino, Oslobygg KF, NanoPower, AIGUASOL

The ARV project's vision is to contribute to the rapid and widespread deployment of Climate Positive Circular Communities (CPCCs) where people thrive and prosper for generations.
The overall goal is to demonstrate and validate attractive, durable and affordable solutions for CPCC that will significantly accelerate deep energy renovations and the implementation of energy and climate measures in the construction and energy industries.
To achieve this goal, the ARV project will use a new concept consisting of a combination of 3 conceptual pillars, 6 demonstration projects and 9 thematic areas.
The three conceptual pillars are integration, circularity and simplicity. Integration in ARV means connecting people, buildings and energy systems through multi-stakeholder co-creation and the use of innovative digital tools. Circularity in ARV means a systematic way of addressing the circular economy through the automated use of LCAs, digital logbooks and material banks. Simplicity in ARV means that solutions are easy to understand and use for all stakeholders, from manufacturers to end users.
These 6 demonstrations are urban regeneration projects in 6 locations across Europe:

Oslo in Norway
Sønderborg in Denmark
Karviná in the Czech Republic
Utrecht in the Netherlands
Palma de Mallorca in Spain
Trento in Italy

[ARV - CLIMATE POSITIVE CIRCULAR COMMUNITIES (CPCC)]

SUBSTRATE REGISTRATION

- Substrate certification in the Czech Republic
- Target material composition for registration

reCihli 20	Expanded clay	Crushed marl	Compost	Brick recyclate	Karbochar
vol. %	70.3	6.5	3.6	11.2	8.3
wt. %	55	10	5	20	10

GREEN ROOF – BACKGROUND

Benefits

- Cooling effect, thermal insulation
- Microclimate improvement
- UHI reduction
- Runoff reduction
- Biodiversity
- Esthetics
- Hydro-insulation protection

Limits

- Full cooling effect only when water available
- Primary material consumption (mentioned before)

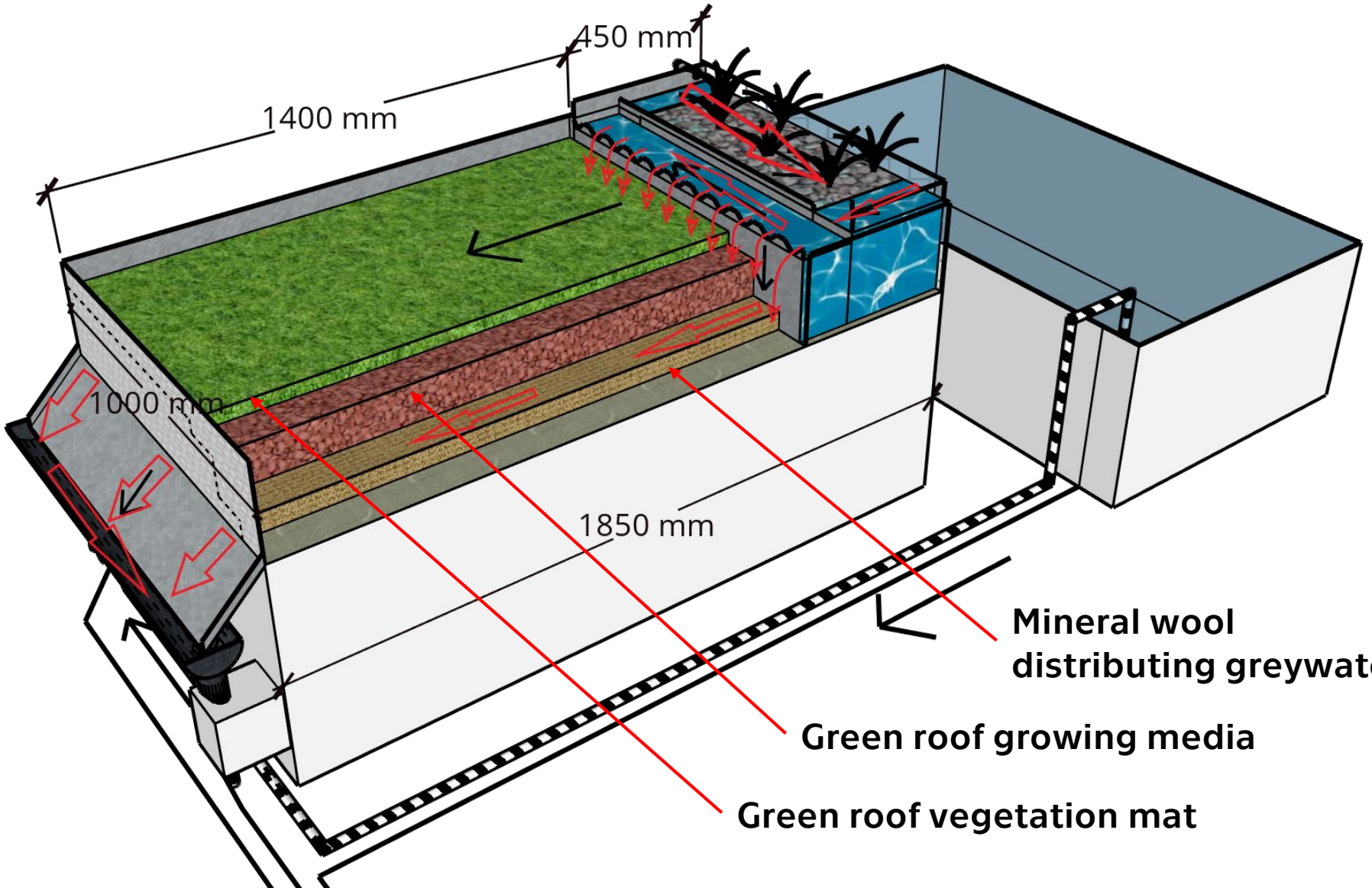
THE GOAL

- Verify the performance of the novel concept of combination of constructed wetland and extensive green roof irrigated with pre-treated grey water.

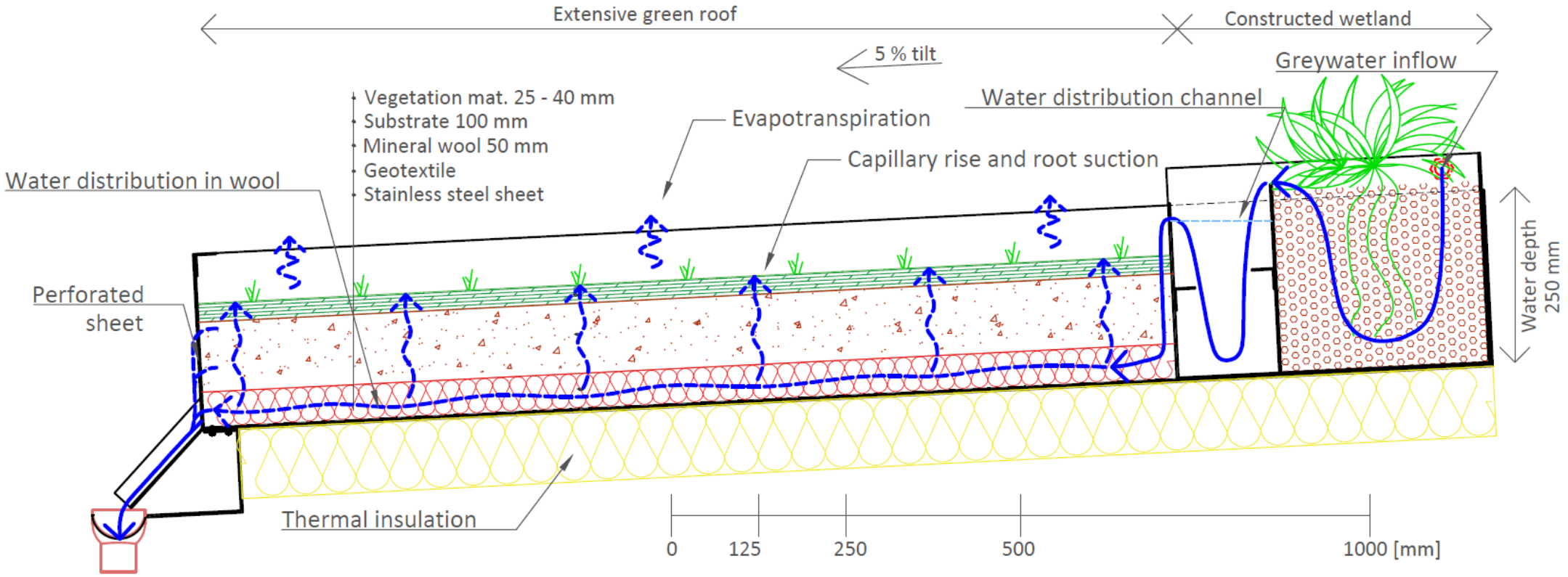
HYBRID GREEN ROOF – IRRIGATION WATER SOLUTION

Principle of Hybrid GR

1. Grey water pumped into the constructed wetland
2. Water treatment in constructed wetland
3. Overflow to a green roof
4. Infiltration to the bottom layer of mineral wool
5. Mineral wool acts as water distribution
6. Plant growth on the green roof and thus increased cooling effect

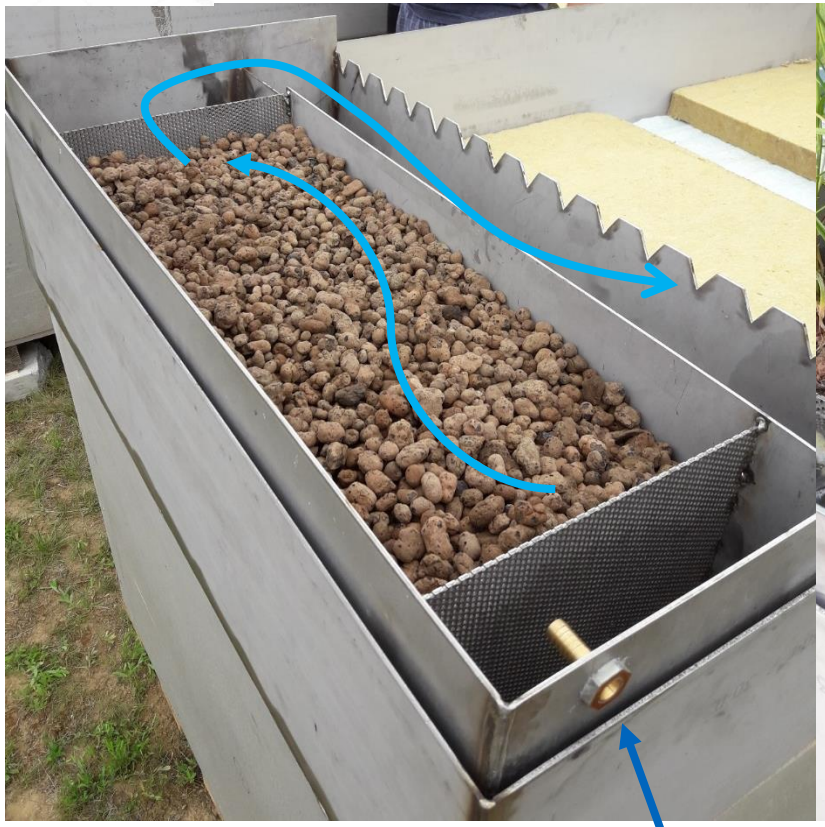


WATER FLOW IN THE HYBRID GREEN ROOF



CONSTRUCTED WETLAND

Distribution canal



Before planting

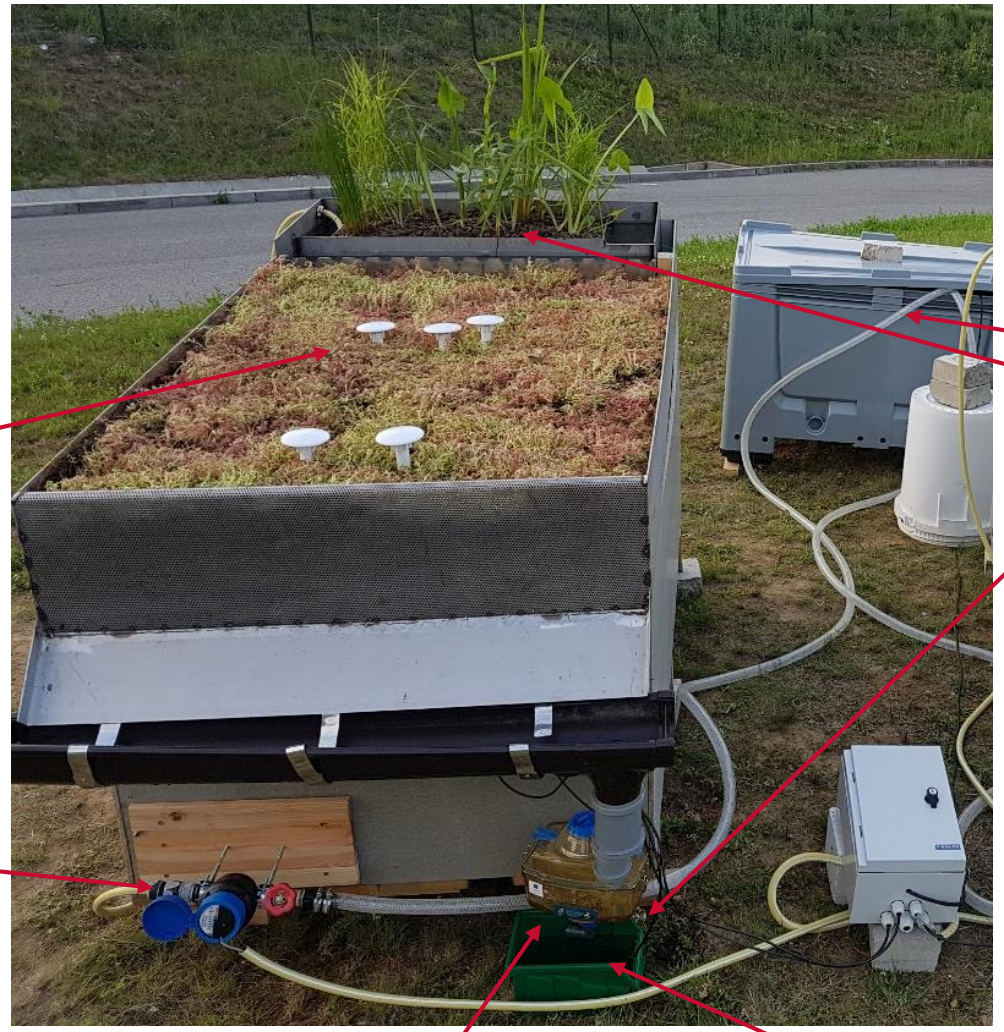
After planting

Grey water inflow

CONSTRUCTED WETLAND

Every day, the water from the wetland (14% of the volume) is displaced by another batch of 10 l of fresh grey water.

THE EXPERIMENTAL SET-UP: SENSORS



Temperature and Humidity

Water chemical properties
-storage tank GW
-wetland
-outflow

Inflow

Outflow

Conductivity of outflow

+ weather data

THE EXPERIMENTAL SET-UP: OVERVIEW

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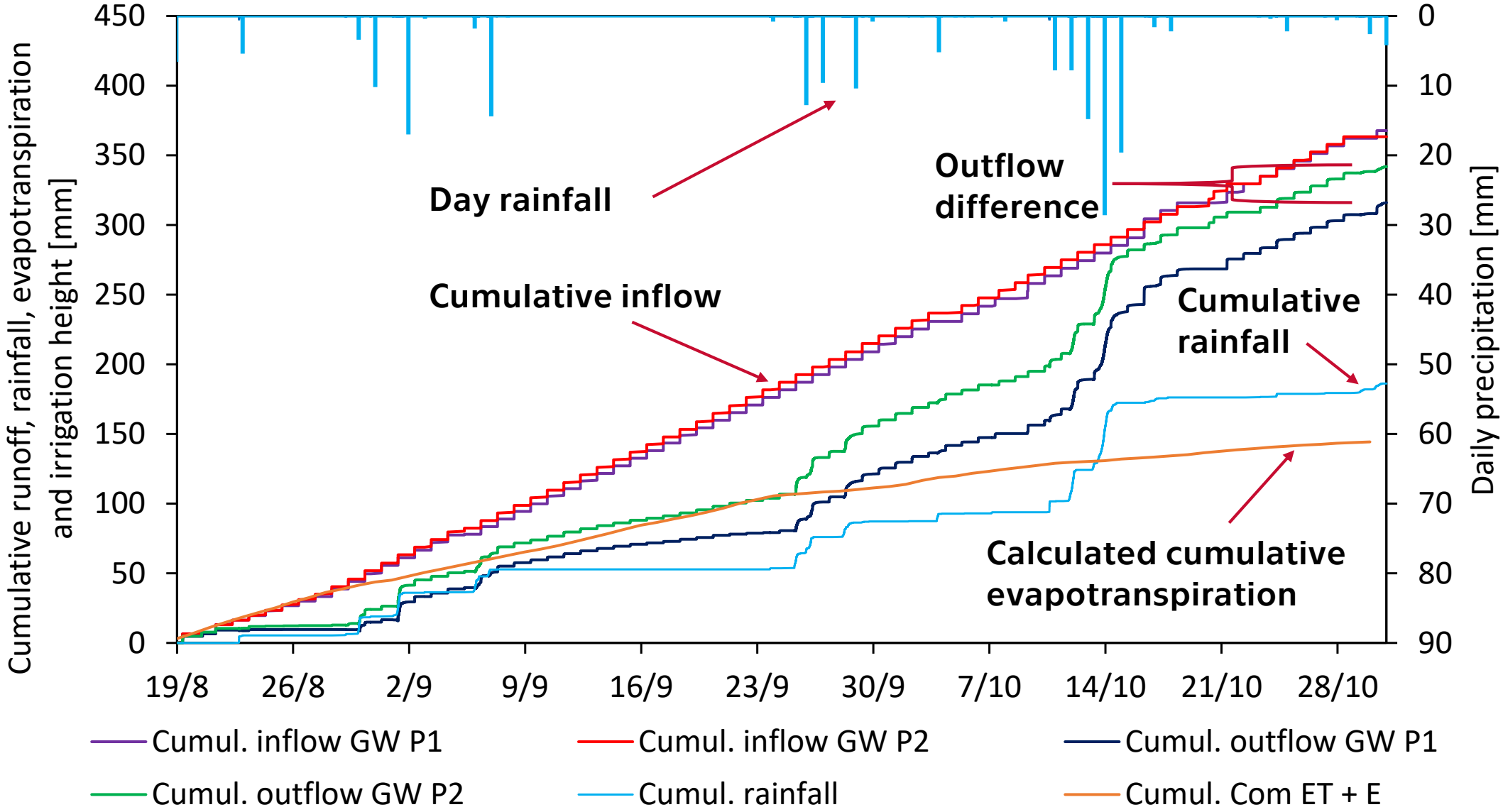
AdMaS®

Two selected substrates tested in open-air experiment – test beds of hybrid green roof

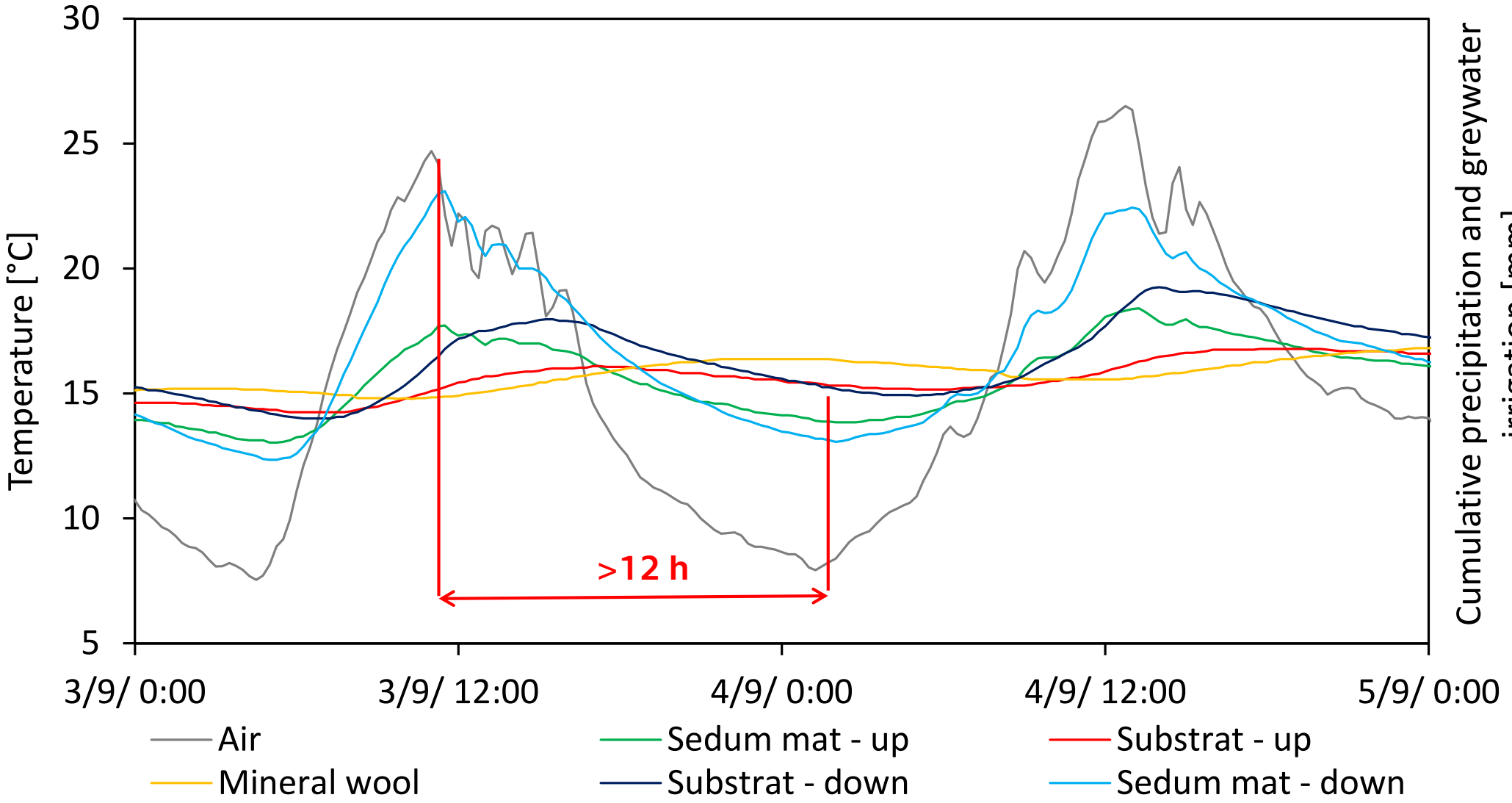
Identical treatment and monitoring schemes of the beds

Difference only in the substrate used

RESULTS: WATER BALANCE

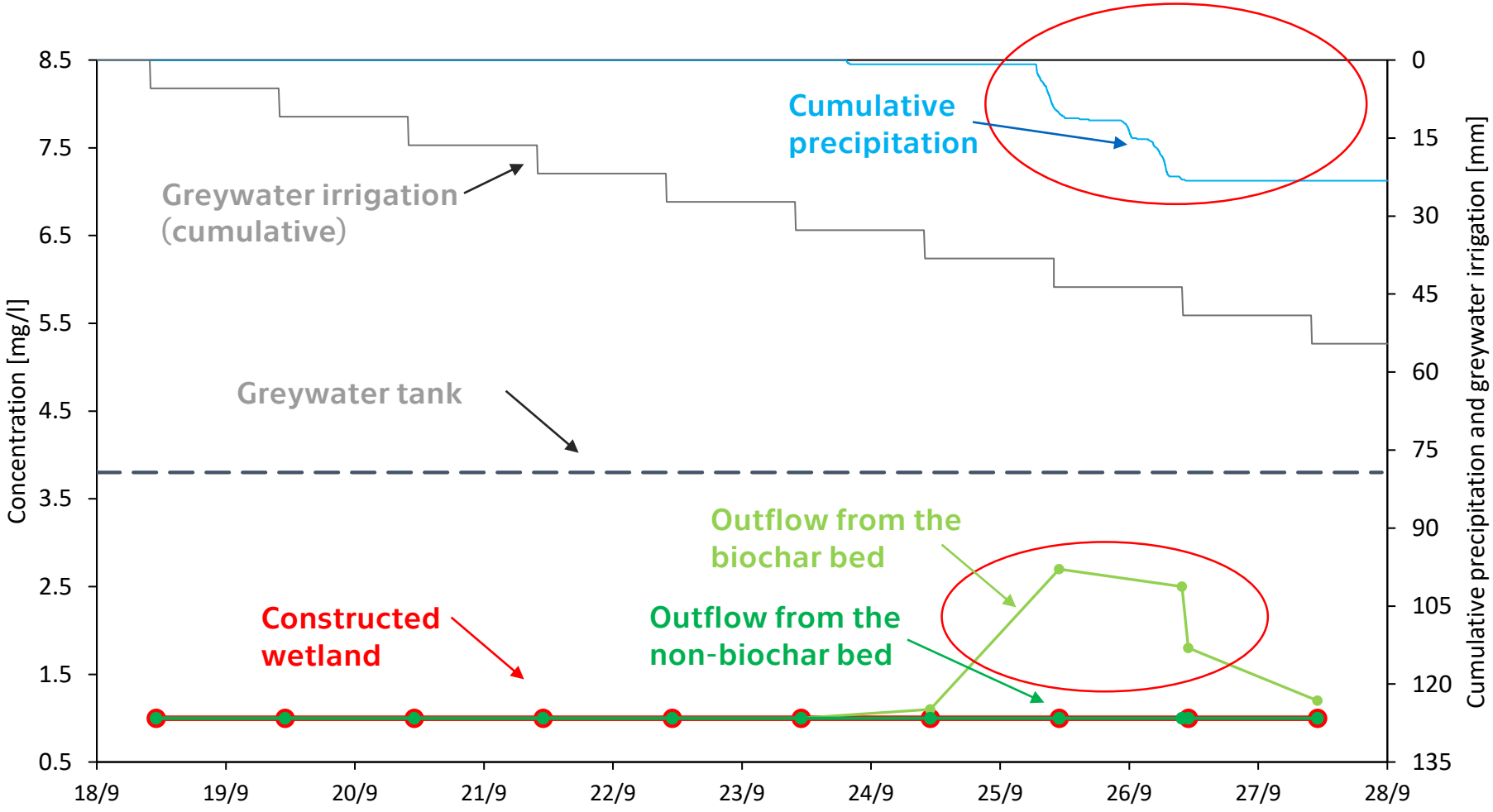


RESULTS: TYPICAL COURSE OF DAILY TEMPERATURE



CHEMICAL ANALYZES RESULTS

- Significant response of **total nitrogen** concentrations to precipitation



- Similar response for orthophosphates

VEGETATION GROWTH

First season

28.8.2020
Biochar substrate P1 non-biochar substrate P2

Difference after 2.5 months after installation

30.10.2020
Biochar substrate P1 non-biochar substrate P2

Difference after 4.5 months after installation

VEGETATION GROWTH

Second and third season

31.8.2021
Biochar substrate P1 non-biochar substrate P2

Difference after 14.5 months after installation

28.8.2022
Biochar substrate P1 non-biochar substrate P2

Difference after 26.5 months after installation

VEGETATION GROWTH

Fourth season

26.4.2023

Biochar substrate P1

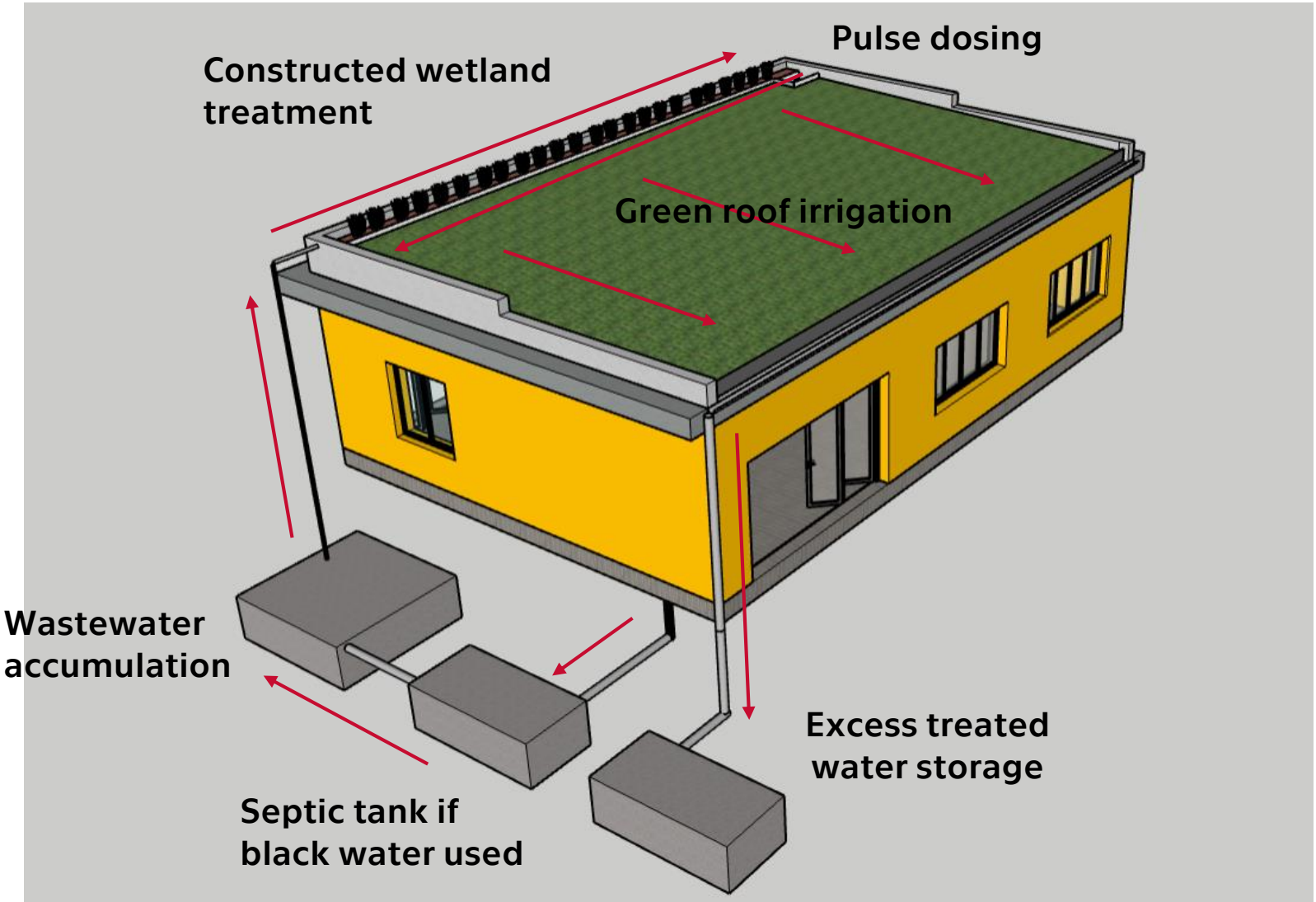
non-biochar substrate P2

Difference after 32 months after installation

Journal article:

Petreje, M., Sněhota, M., Chorazy, T., Novotný, M., Rybová, B., Hečková, P., 2023. Performance study of an innovative concept of hybrid constructed wetland-extensive green roof with growing media amended with recycled materials. J. Environ. Manage. 331, 117151.
https://doi.org/10.1016/j.jenvman.2022.117151

EXAMPLE USE OF HYBRID GREEN ROOF



SketchUp 3D model HGR

CONCLUSIONS

- Substrate with recycled materials is suitable for vegetation growth
- The properties of the substrate with recycled materials similar to commercial options.
- Nutrient rich sewage sludge carbochar increases vegetation activity and thus evapotranspiration
- Hybrid constructed wetland - extensive green roof was developed and tested
- The constructed wetland effectively removes N and P nutrients from greywater
- In response to the precipitation, nutrients are leached from the biochar
- The irrigation of the greywater did not have a negative effect

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THANK YOU FOR YOUR ATTENTION

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