Results from the COST Action Circular City

Günter Langergraber & Nataša Atanasova

Workshop

C2C-CC / Circular City - DONE - WHAT's NEXT?

19 September 2022

VIA University College, Aarhus, Denmark

Challenges

Cities worldwide are **facing a number of challenges** including resource depletion, climate change and degradation of ecosystems.

If cities do not **adapt their current infrastructure and resource management**, they will not be able to cope with these challenges.

Nature-Based Solutions (NBS) are one element that can help to achieve this transition.

The future of our cities?

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Trailer "Green Cities extension for game Cities Skylines"

Reality 1

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Bosco Verticale, Milano

Reality 2 - examples from Vienna

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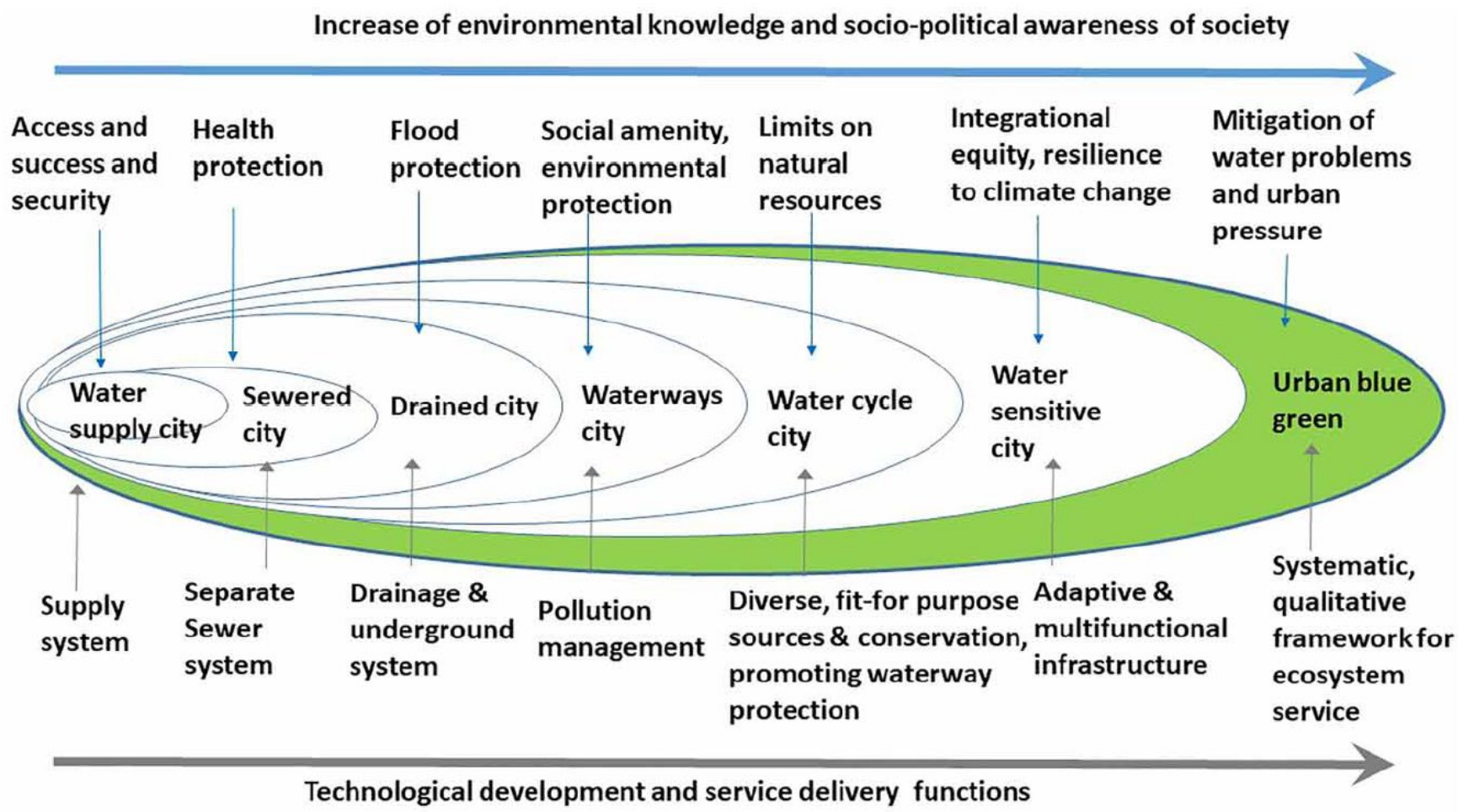
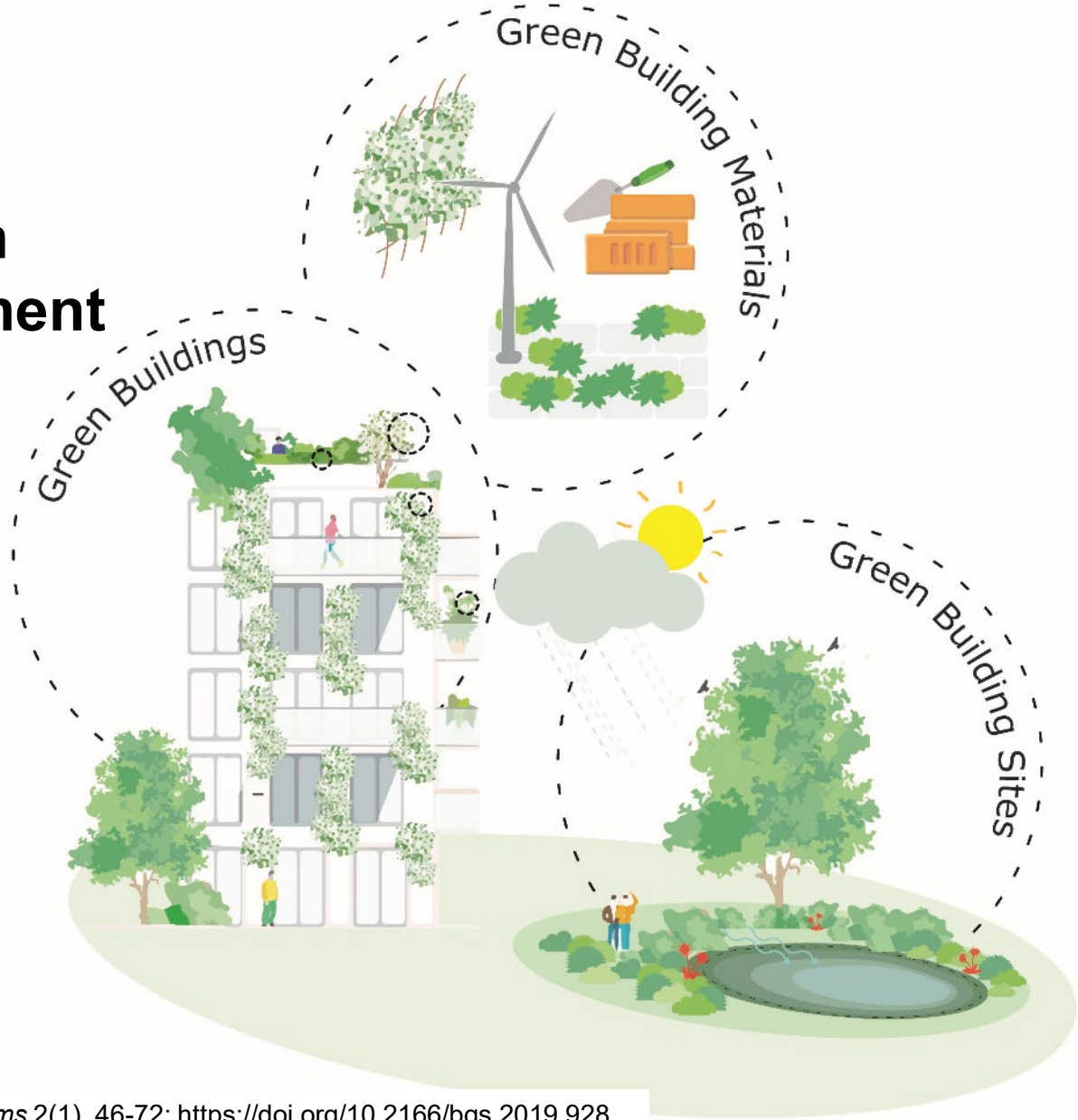
Water in cities

Oral et al., 2020, *Blue-Green Systems* 2(1), 112-136; doi: 10.2166/bgs.2020.932.



Scales of NBS implementation in the built environment



Pearlmutter et al., 2020, *Blue-Green Systems* 2(1), 46-72; https://doi.org/10.2166/bgs.2019.928.

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COST Action CA17133 Circular City

Implementing nature based solutions for creating a resourceful circular city

Duration

22 Oct 2018 – 21 Apr 2023

Chair: Günter Langergraber, BOKU University Vienna

Co-Chair: Nataša Atanasova, University of Ljubljana

COST Action Circular City

Video

- https://www.youtube.com/watch?v=R3NXLb-W1pg

What is a COST Action?

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- COST is the longest-running (since 1971) European framework supporting trans-national cooperation among researchers, engineers and scholars across Europe.
- COST funds pan-European, **bottom-up** networks across all science and technology fields.
- COST **does not fund research** itself.
- COST provides support for networking activities such as **meetings, workshops, conferences, training schools, short-term scientific missions** (STSMs) and dissemination activities.

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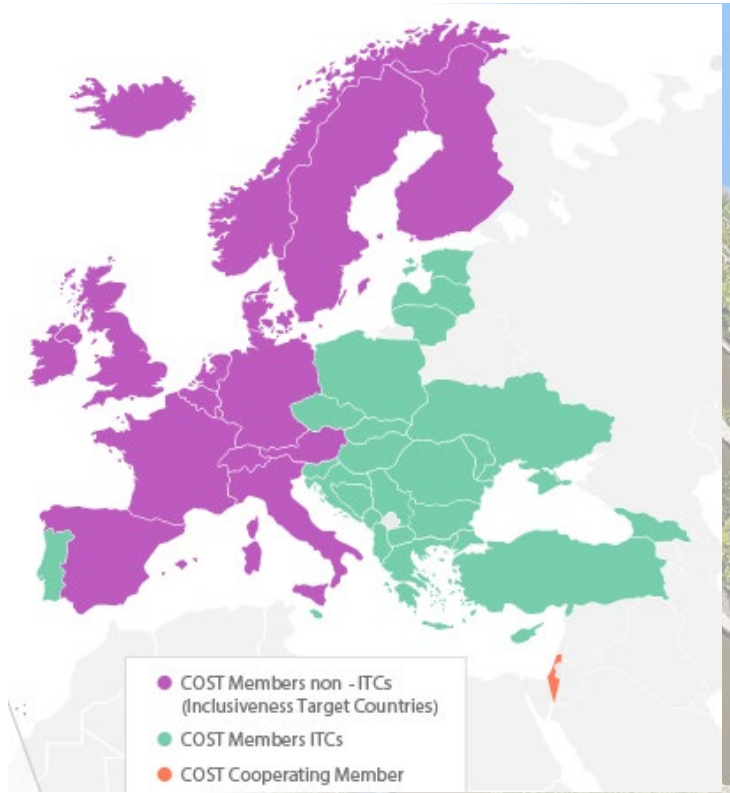
The network

All COST countries participating!

- **EU 27 + UK**
- **EU Candidates and Potential Candidates**
  - Albania, Bosnia and Herzegovina, Moldova, Montenegro, North Macedonia, Serbia, Turkey
- **Other countries**
  - Iceland, Norway, Switzerland, Ukraine, Georgia
- **COST Cooperating Member**
  - Israel

+ (former) MC Observers from

- Armenia, Colombia, Taiwan, Russia, Tunisia



plus > 470 interested persons

→ network of > 640 persons
→ > 300 persons participated in our workshops
→ incl. EU-funded project on NBS and/or CE

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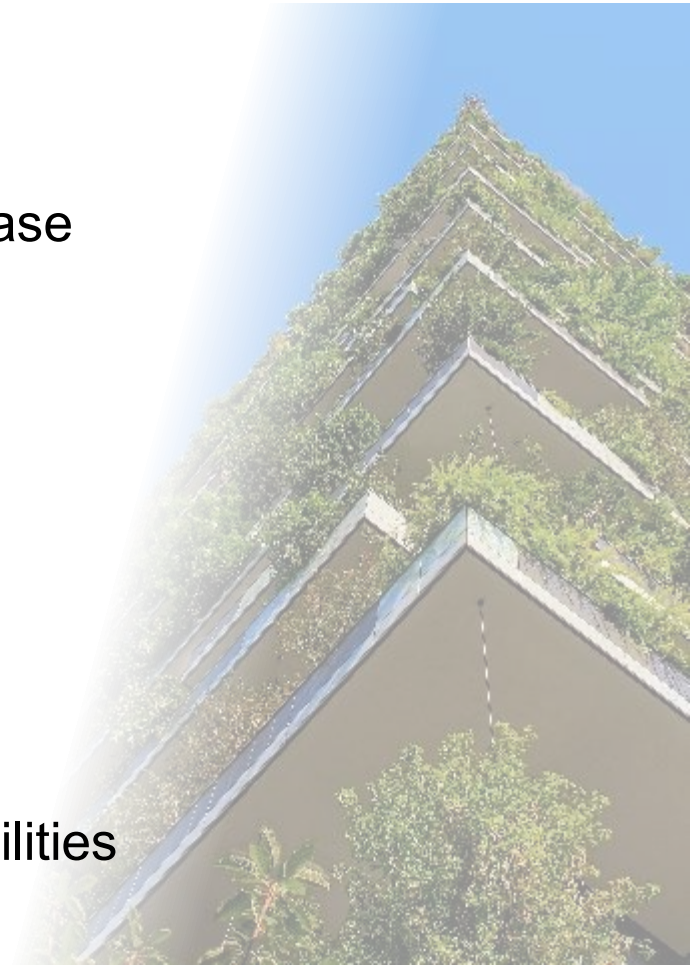
Activities

Circular City @ Klimatorium, Lemvig

COST Action Circular City

Main deliverables

- ✓ Report on the state of the art and existing case studies
- ✓ Catalogue of potential solutions for providing/recovering resources with NBS.
- ▪ Guideline on combined NBS and CE possibilities within the urban environment



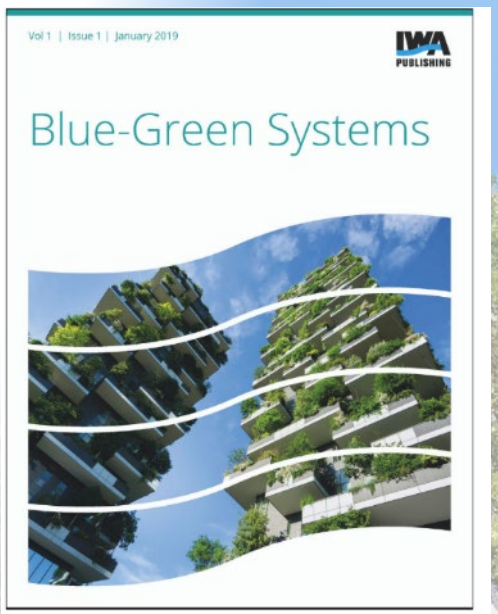
COST Action Circular City

Main deliverables

- ✓ Report on the state of the art and existing case studies

  → Special issue in the IWAP Open-Access online journal *Blue-Green Systems*

- ✓ Catalogue of potential solutions for providing/recovering resources with NBS.



- Guideline on combined NBS and CE possibilities within the urban environment

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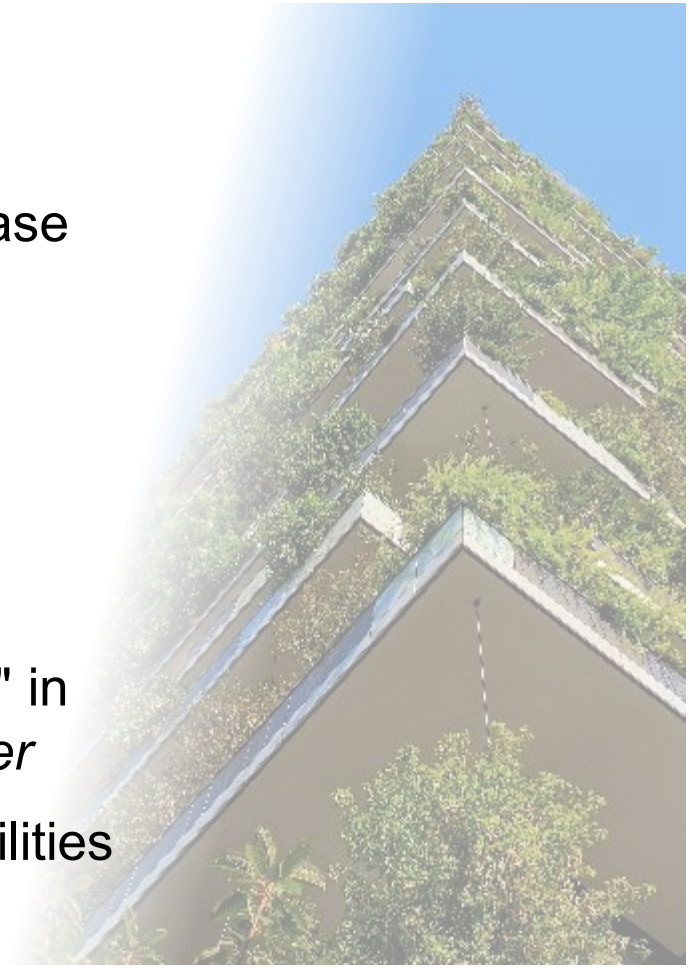
Main deliverables



- ✓ Report on the state of the art and existing case studies

  → Special issue in the IWAP Open-Access online journal *Blue-Green Systems*

- ✓ Catalogue of potential solutions for providing/recovering resources with NBS.

  → Special issue "*Water and Circular Cities*" in the MDPI Open-Access online journal *Water*

- ▪ Guideline on combined NBS and CE possibilities within the urban environment

Nature-Based Solutions (NBS)

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Definition

NBS are defined as **concepts that bring nature into cities** and those that are **derived from nature**.

NBS address societal challenges and enable resource recovery, climate mitigation and adaptation challenges, human well-being, ecosystem restoration and/or improved biodiversity status, within the urban ecosystems. As such, within this definition we achieve resource recovery **using organisms** (e.g. microbes, algae, plants, insects, and worms) **as the principal agents**. However, physical and chemical processes can be included for recovery of resources (as discussed in WG3 Resource Recovery), as they may be needed for supporting and enhancing the performance of NBS.

Langergraber et al. (2020) Implementing nature-based solutions for creating a resourceful circular city. *Blue-Green Systems* 2(1), 173-185; doi: 10.2166/bgs.2020.933.

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Framework

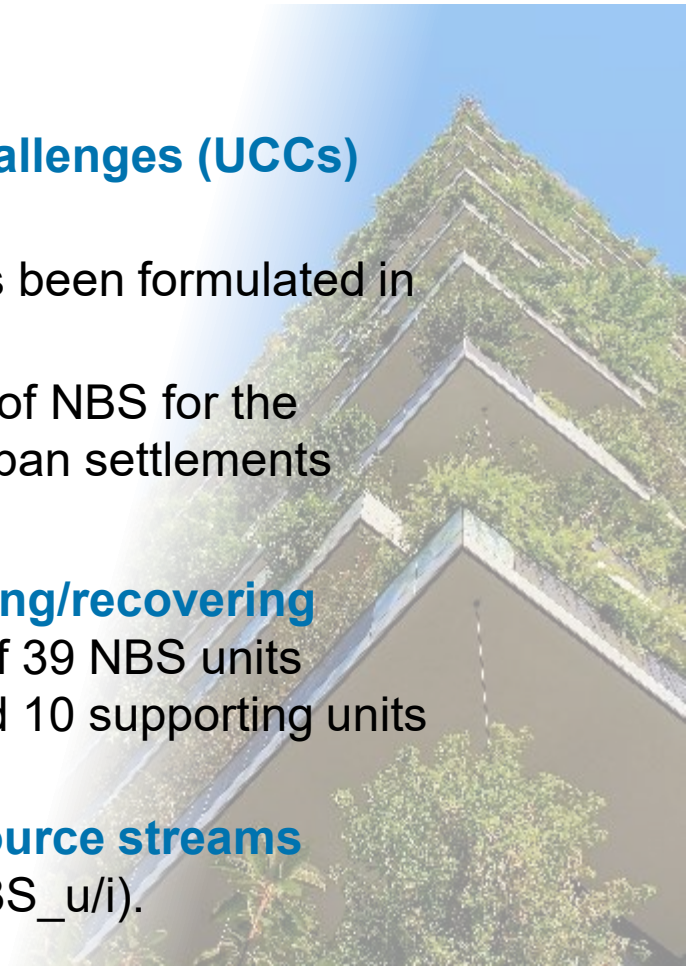
➔ Was developed in a series of virtual workshops

➔ Framework for addressing **Urban Circularity Challenges (UCCs)** with Nature-based Solutions (NBS).

- UCCs have been defined and framework has been formulated in Atanasova et al. (2021)
- Framework aimed at mainstreaming the use of NBS for the enhancement of resource management in urban settlements

➔ Framework includes:

1. The **catalogue of technologies for providing/recovering resources with NBS** that comprises a set of 39 NBS units (NBS_u), 12 NBS interventions (NBS_i), and 10 supporting units (S_u),
2. the **analysis of input and output (I/O) resource streams** required for NBS units and interventions (NBS_u/i).



Nature-Based Solutions (NBS)

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NBS SPATIAL UNITS	NBS TECHNOLOGICAL UNITS	SUPPORTING UNITS	NBS SOIL & RIVER INTERVENTIONS

Food & biomass production

Productive garden (49)
Urban forest (50)
Urban farms and orchards (51)

(44) Aquaculture
(45) Hydroponic and soilless technologies
(46) Organoponic / Bioponic
(47) Aquaponic farming
(48) Photo Bio Reactor

Remediation, Treatment & Recovery

Treatment wetland (21)
Waste stabilisation pond (22)
Anaerobic treatment (26)
(for nutrient, VFA & methane recovery)
Aerobic (post) treatment (27)
(for water recovery)

(S3) Phosphate precipitation
(for P recovery)
(S4) Ammonia stripping
(for N recovery)
(S5) Disinfection
(for water reuse)
(S6) Biochar/Hydrochar
(S7) Solid/liquid separation
(S8) Membrane filtration
(S9) Adsorption
(S10) Advanced Oxidation

(23) Composting
(24) Bioremediation
(25) Phytoremediation

(Public) green space

Green corridors (37)
Green belt (38)
Street trees (39)
Large urban park (40)
Pocket/garden park (41)
Urban meadows (42)
Green transition zones (43)

Vertical Green Systems & Green Roofs

(13) Ground-based green facade
(14) Wall-based green facade
(15) Pot-based green facade
(16) Vegetated pergola
(17) Extensive green roof
(18) Intensive green roof
(19) Semi-intensive green roof
(20) Mobile green and vertical mobile garden

Rainwater management

Infiltration basin (1)
Infiltration trench (2)
Filter strips (3)
Filter drain (4)
(Wet) Retention pond (5)
(Dry) Detention pond (6)
Bioretention cell (7)
Bioswale (8)
Dry swale (9)
Tree pits (10)
Vegetated grid pavement (11)
Riparian buffer (12)

(S1) Rainwater Harvesting
(S2) Detention vaults and tanks

(River) Restoration

(28) River restoration
(29) Floodplain
(30) Diverting and deflecting elements
(31) Reconnection of oxbow lake
(32) Coastal erosion control

Soil and Water Bioengineering

(33) Soil improvement and conservation
(34) Erosion control
(35) Soil reinforcement to improve root cohesion and anchorage
(36) Riverbank engineering

1. Classification
2. Terminology (Name & Synonyms) + Definition
3. Sub-categories

39 NBS units
12 NBS interventions
& 10 Supporting units

Langergraber et al., 2021, *Water* 13, 2355; https://doi.org/10.3390/w13172355.

Urban Circularity Challenges

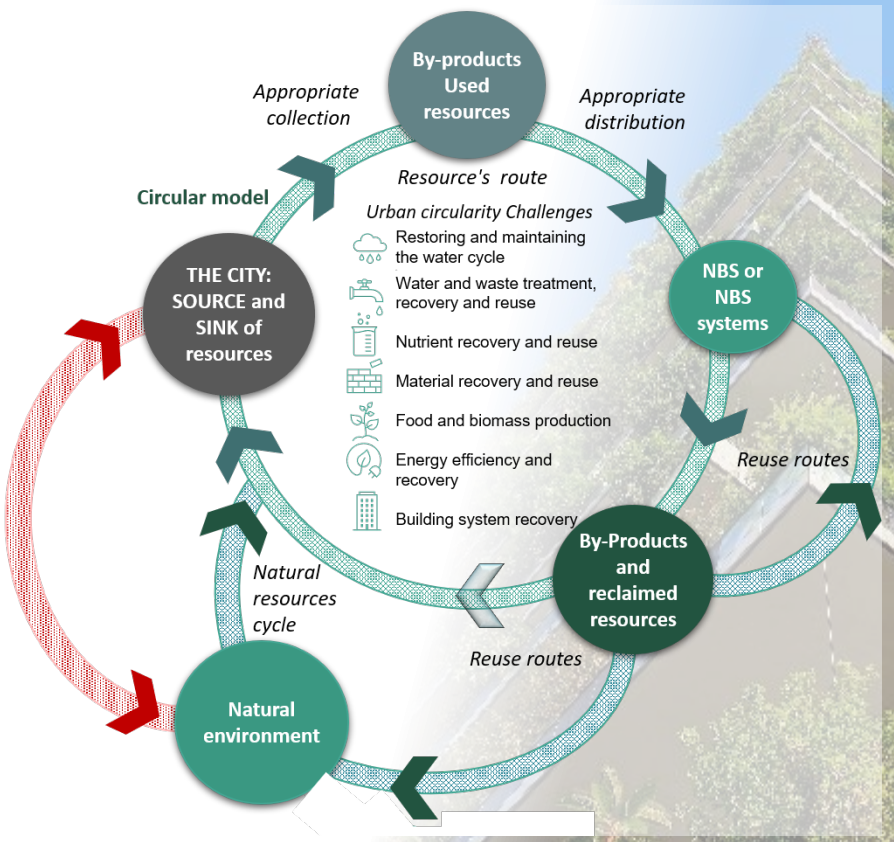
Circular economy: shift from linear to **circular resource management**

Two general challenges:

(1) how to **minimize** linear import and consumption of **new resources**; and

(2) how to **minimize waste** production.

➔ specific **Urban Circularity Challenges** that can be addressed with NBS



Langergraber et al., 2021, *Water* 13, 2355; https://doi.org/10.3390/w13172355.

Urban Circularity Challenges

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Restoring and maintaining the water cycle

Water and waste treatment, recovery and reuse

Nutrient recovery and reuse

Material recovery and reuse

Food and biomass production

Energy efficiency and recovery

Building system recovery

URBAN SECTORS – fields of activities for managing resourses:

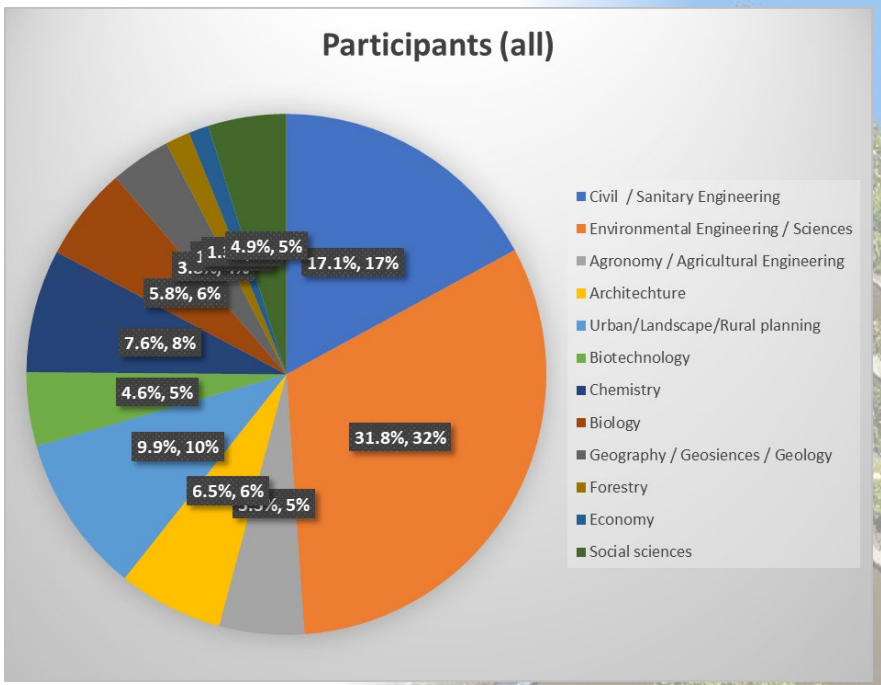
- Urban water management
- Built environment
- Urban farming
- Resource recovery

So, what is the potential of each unit to address resources management in each of the sectors?

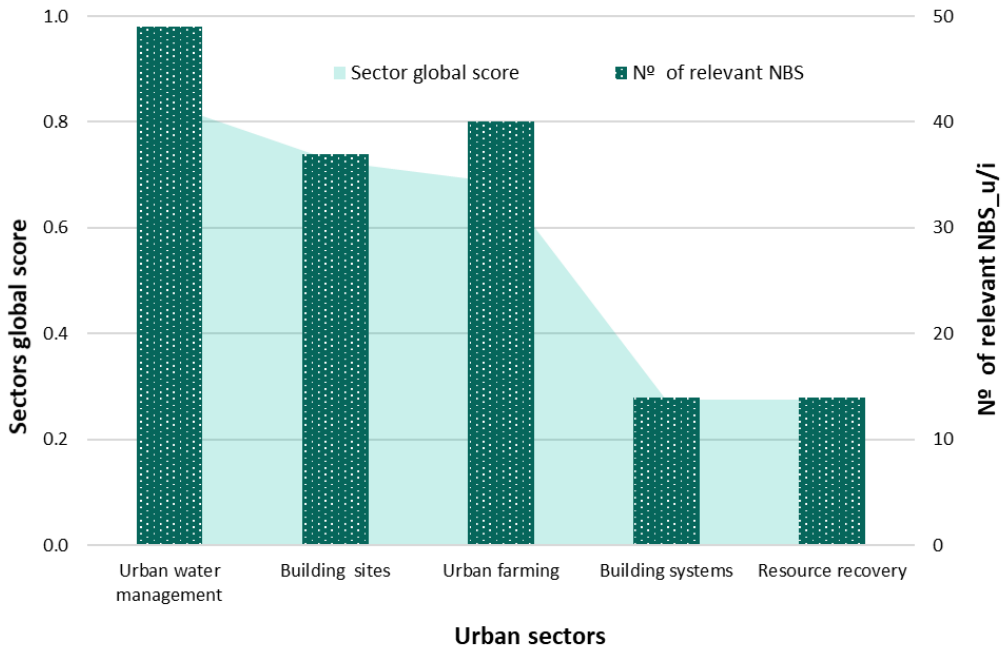
Langergraber et al., 2021, *Water* 13, 2355; https://doi.org/10.3390/w13172355.

Who did the assessment

10 COST workshops, average 71 participants from 28 countries, with different professional background, working in selected urban sectors.



Two interesting results



Only five NBS_u/i were selected as relevant by all sectors:

treatment wetlands, phytoremediation, street trees, large urban parks, and pocket gardens/parks.


water

MDPI

Article

Towards a Cross-Sectoral View of Nature-Based Solutions for Enabling Circular Cities

Guenter Langergraber [1,*], Joana A. C. Castellar [2,3], Theis Raaschou Andersen [4], Maria-Beatrice Andreucci [5], Gösta F. M. Baganz [6,7], Gianluigi Buttiglieri [2,3], Alba Canet-Martí [1], Pedro N. Carvalho [8,9], David C. Finger [10,11], Tjaša Griessler Bulc [12], Ranka Junge [13], Boldizsár Megyesi [14], Dragan Milošević [15], Hasan Volkan Oral [16], David Pearlmutter [17], Rocio Pineda-Martos [18], Bernhard Pucher [1], Eric D. van Hullebusch [19] and Nataša Atanasova [20]

Cross-sectorial view

Keywords on the potential of NBS to address circularity in cities

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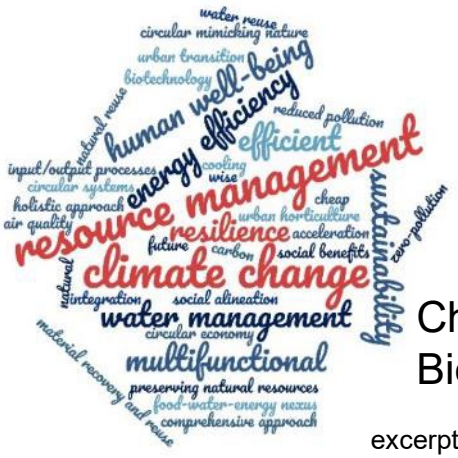
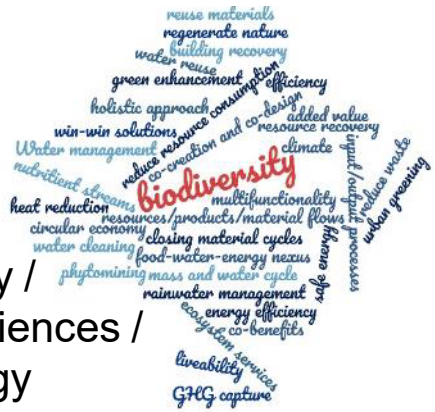
All participants

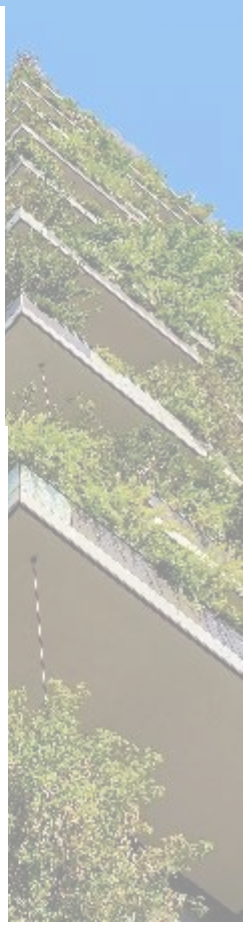
Engineering



Chemistry / Biotechnology



Biology / Geosciences / Geology



excerpt from Langergraber et al., 2021, *Water* 13, 2352; https://doi.org/10.3390/w13172352.

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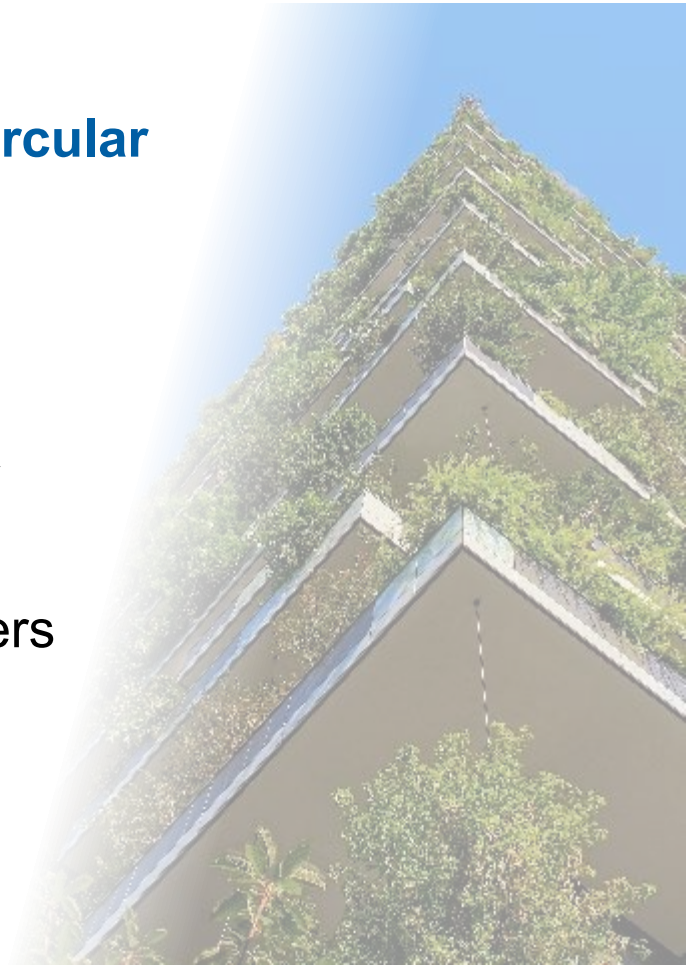
Final deliverable

Guide on how NBS can be used to create Circular Economies

- Web-based tool
- Describe how we can apply our framework
- Explain with selected real cases on how our framework can be implemented
- Different entry points for different stakeholders according to their interest



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NATURE-BASED SOLUTIONS FOR CREATING CIRCULAR CITIES

Partecipation is **free of charge.**

The course is available on **June 27th 2022** on Cap-Net

Download your certificate at the end of the course.

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A circular city is a city that uses its resources (water, air, energy, [illegible] land) several times, in cycles or cascades, turning the city into a productive urban space in order to minimise resource imports and at the same time waste production. A circular city manages to do so by creating regenerative urban spaces, sustainable buildings and prospering communities.

This course provides knowledge on how to create such cities by using nature- based solutions. It comprises knowledge on resources flows and management of these flows in cities, appropriate nature- based solutions for managing resources, implementation aspects and number of worked examples to help understanding this complex domain.

The course is self-based, however some mandatory and voluntary live sessions will be organised at specific dates, one to introduce the course, one after six weeks to have a joint discussion of the first two modules and one after three months to have a final session which will allow to share ideas and have feedback.

The course is organised in four modules. They will consist of short video presentations, reading and **a final quiz at the end of each module.** There will also be recommended literature, videos and webpages for the participants to see more details about specific topics of the course.

The course will provide you with a learning experience that overcomes disciplinary gaps and leads participants to a new level of understanding circularity aspects of resources management in cities with NBS.

4 modules

1. Resources flows and management in cities
2. Presenting nature-based solutions for a circular urban metabolism
3. Design requirements for NBS
4. Implementation of Nature-Based Solutions

Will be open until 15 Nov 2022 !

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First batch:

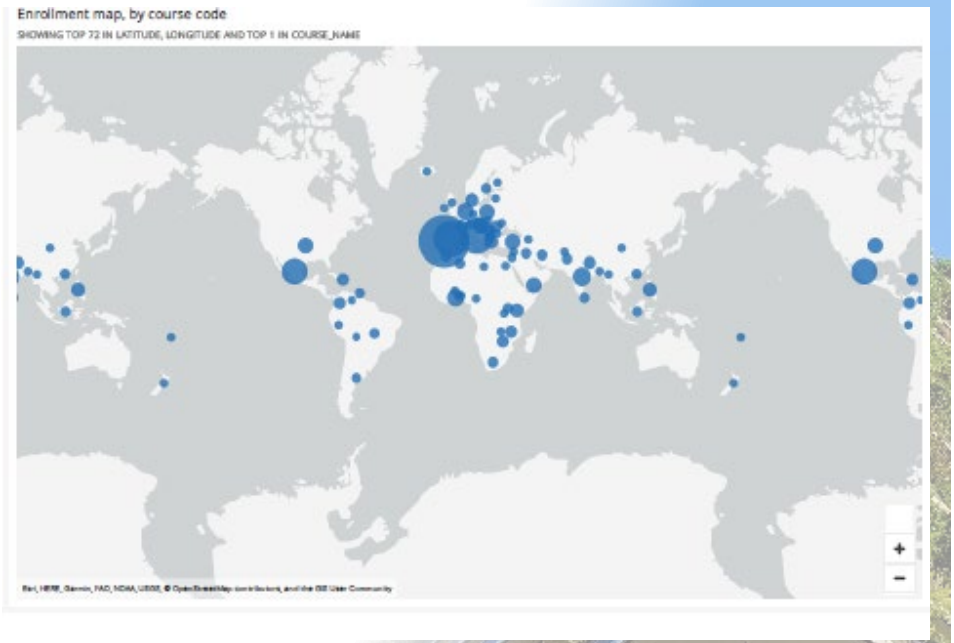
- **404 registered** participants (up to now)
- **49 completed** the course already

On-line course

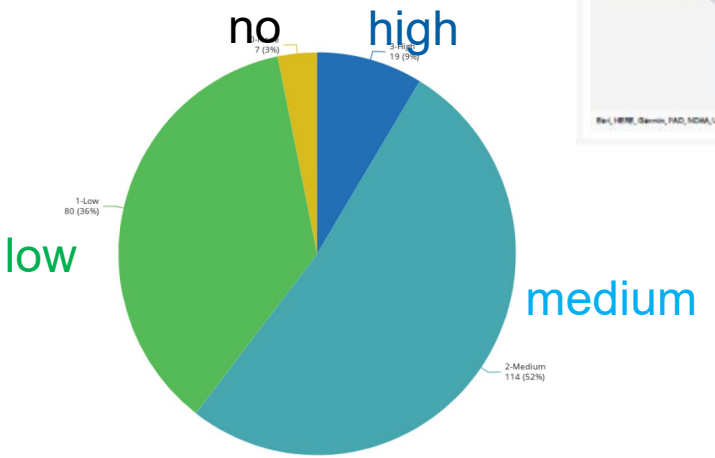
NBS for creating circular cities

Statistics (404 participants)

- 47 % female / 53 % male
- worldwide

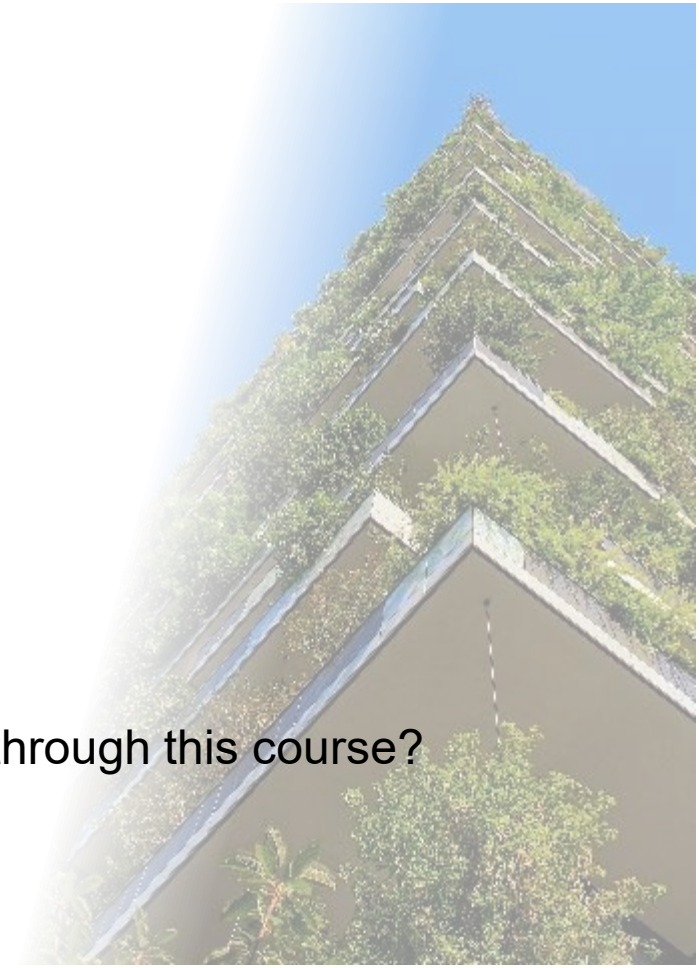


- level of knowledge/expertise before



On-line course

NBS for creating circular cities



Statistics (49 completed):

- How relevant was the course?
  - 18 Extremely relevant
  - 29 Relevant
  - 2 Slightly relevant
- Overall experience
  - 24 Excellent
  - 24 Good
  - 1 Poor
- To what degree did you acquire new knowledge through this course?
  - 12 Extremely high
  - 28 Very high
  - 9 Somewhat high

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Website & Social Media

- https://circular-city.eu/

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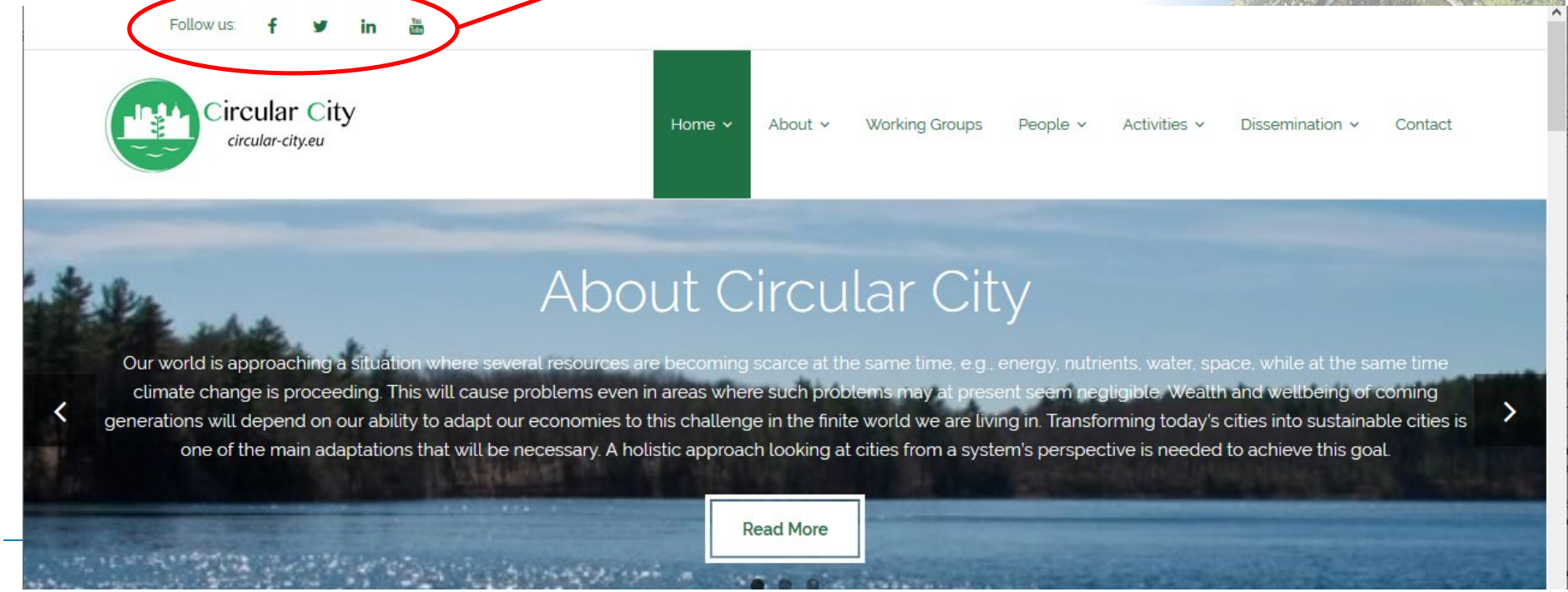
- Instagram
- Twitter
- YouTube



Summary

- Cities have to transform to become more resilient towards existing challenges such as resource depletion, climate change and degradation of ecosystems.
- Nature-based solutions (NBS) provide a range of ecosystem services beneficial for the urban biosphere.
- By adopting the concept of circular economy, benefits of NBS for urban areas can be increased.
- Water is a key element when using NBS in the urban environment.
- A circular flow system using NBS for managing nutrients and resources within the urban biosphere facilitates the transformation towards a more resilient, sustainable and healthy urban environment.
- The COST Action Circular City is currently investigating potential ways how these transformations can take place.

Further reading 1/2

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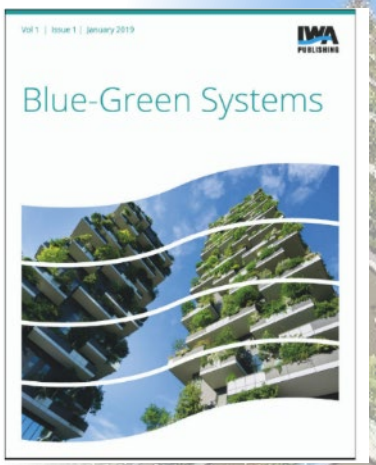
Special issue "*Towards Circular Cities*" in the IWA Publishing Open Access journal *Blue-Green Systems* (> 100 authors from 35 countries)

https://iwaponline.com/bgs/pages/towards_circular_cities_special_issue



- Langergraber et al., 2020, *Blue-Green Systems* 2(1), 173-185 (Introduction)
- Pearlmutter et al., 2020, *Blue-Green Systems* 2(1), 46-72 (WG1 paper)
- Oral et al., 2020, *Blue-Green Systems* 2(1), 112-136 (WG2 paper)
- Kisser et al., 2020, *Blue-Green Systems* 2(1), 138-172 (WG3 paper)
- Skar et al., 2020, *Blue-Green Systems* 2(1), 1-27 (WG4 paper)
- Katsou et al., 2020, *Blue-Green Systems* 2(1), 186-211 (WG5 paper)

Papers towards the framework

- Castellar et al., 2021, NBS in the urban context: terminology, classification and scoring for urban challenges and ecosystem services. *Sci Total Environ* 779, 146237; https://doi.org/10.1016/j.scitotenv.2021.146237
- Atanasova et al., 2021, NBS and Circularity in Cities. *Circular Economy and Sustainability*, https://doi.org/10.1007/s43615-021-0

Further reading 2/2

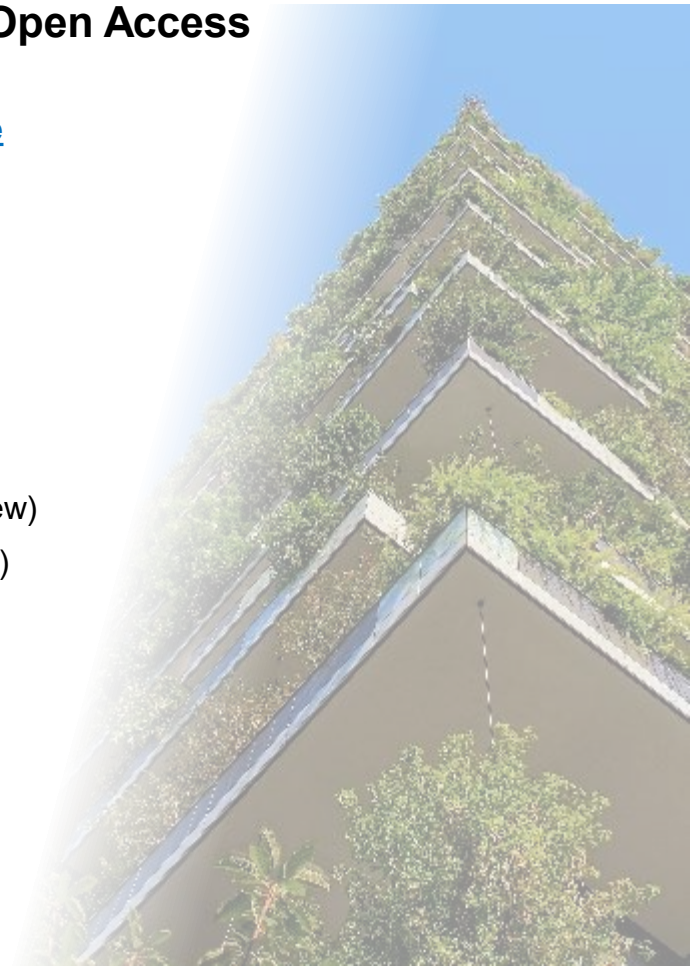
Special issue "*Water and Circular Cities*" in the MDPI Open Access journal *Water*

https://iwaponline.com/bgs/pages/towards_circular_cities_special_issue

Key papers from the COST Action (> 80 authors from 28 countries)

- Langergraber et al., 2021, *Water* 13, 2355 (Introducing the framework)
- Pearlmutter et al., 2021, *Water* 13, 2165 (WG1 perspective)
- Oral et al., 2021, *Water* 13, 3334 (WG2 perspective)
- Van Hullenbusch et al., 2021, *Water* 13, 3153 (WG3 perspective)
- Canet-Marti et al., 2021, *Water* 13, 2565 (WG4 perspective)
- Langergraber et al., 2021, *Water* 13, 2352 (Towards a Cross-Sectoral View)
- Nika et al., *Water* 13, 2198 (Circular Performance Indicators, WG5 paper)

+ other papers from outside the COST Action



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Email: natasa.atanasova@fgg.uni-lj.si
https://www.en.fgg.uni-lj.si/

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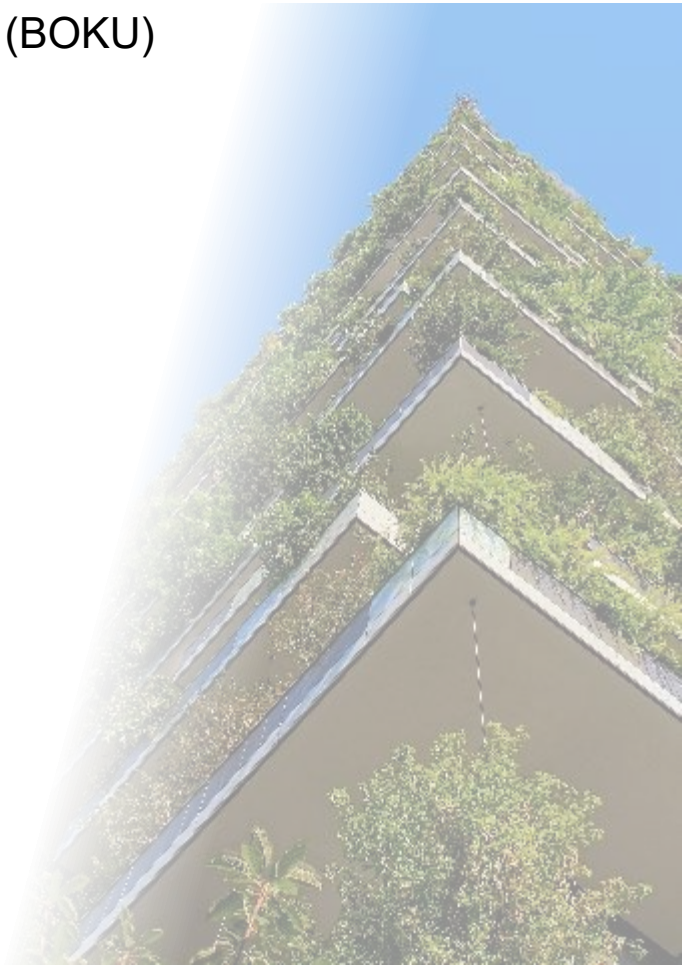

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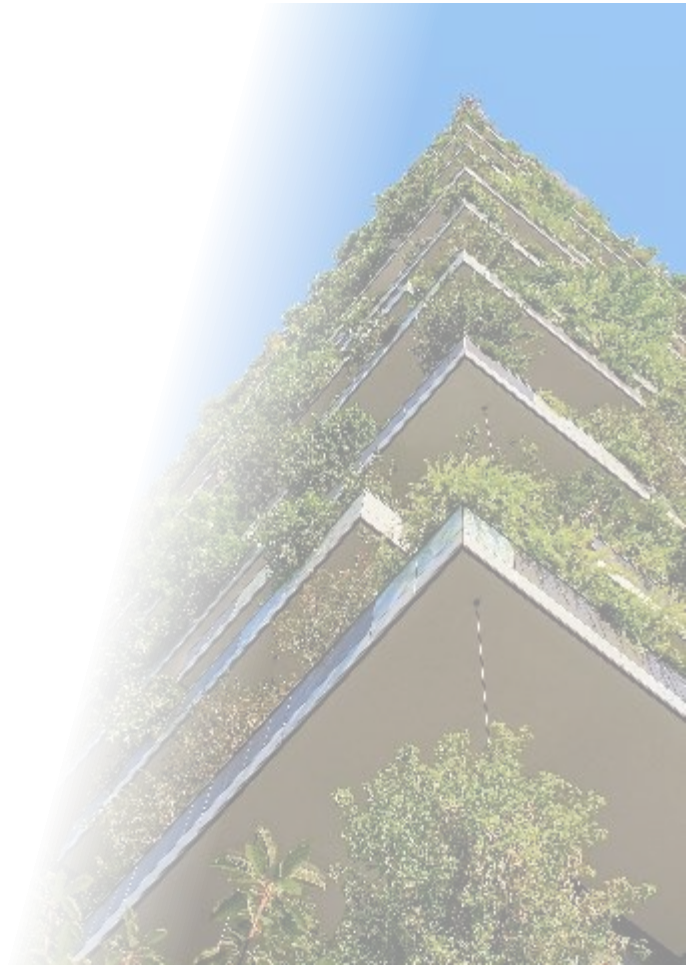

Nature-Based Solutions (NBS)

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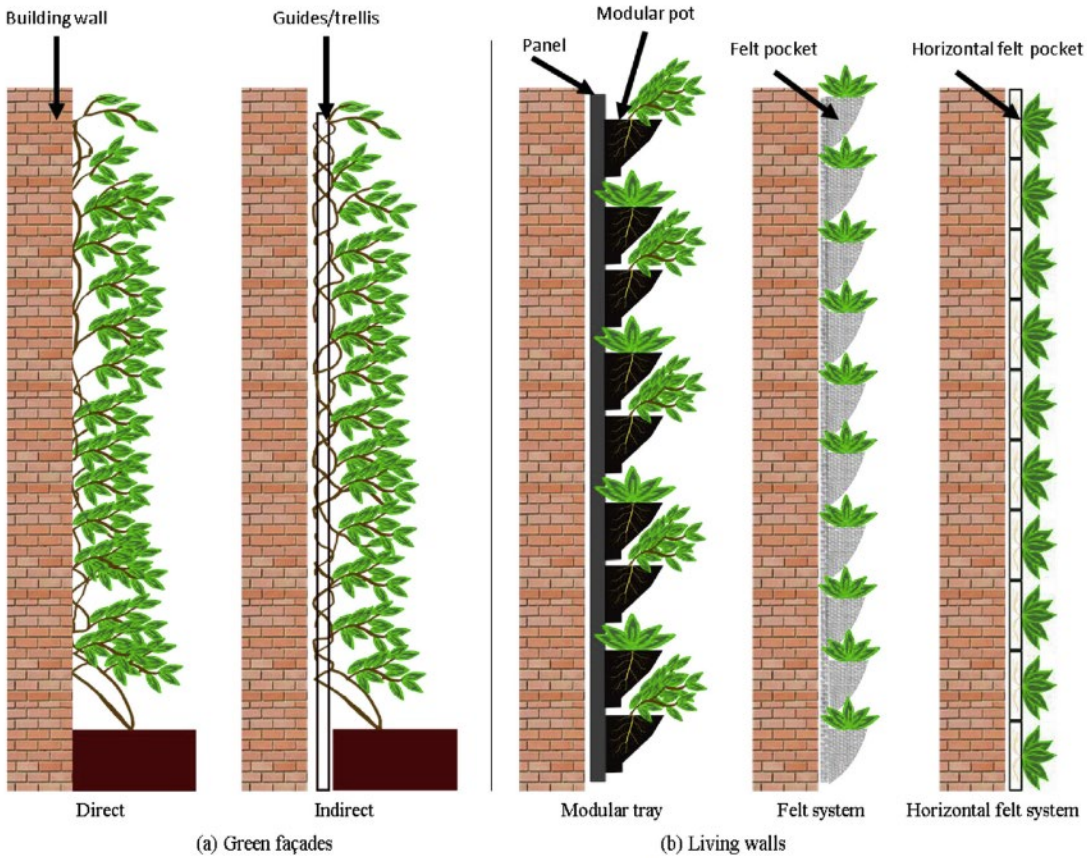
Terminology of e.g. vertical greening systems

Unit / Intervention	Synonyms
Ground-based green facade	**Green facade**; Green facade with climbing plants; Climber green wall; Ground-based green-wall; Green climber wall; Green wall with ground-based greening; Climber plant wall; Ground-Based Green Facade with Climbing Plants; Soil-based green façade
Wall-based green facade	**Green wall**; Hydroponic green facade; Facade-bound greening; Facade bound green wall; living wall; Continuous green wall; Plant wall system; Green façade with vertical panels; Greening vertical panel; Vertical greening panel
Pot-based green facade	**Living wall**; Planter green wall; Planter green facade; Planter boxes; Planter pots; Planter-based green wall; Planted/planting container(s); Pot planted plants; Potted plants; Potted Mobile Garden; Raised bed; container plants

Castellar et al., 2021, *Sci Total Environ* 779, 146237; https://doi.org/10.1016/j.scitotenv.2021.146237
Langergraber et al., 2021, *Water* 13, 2355; https://doi.org/10.3390/w13172355.

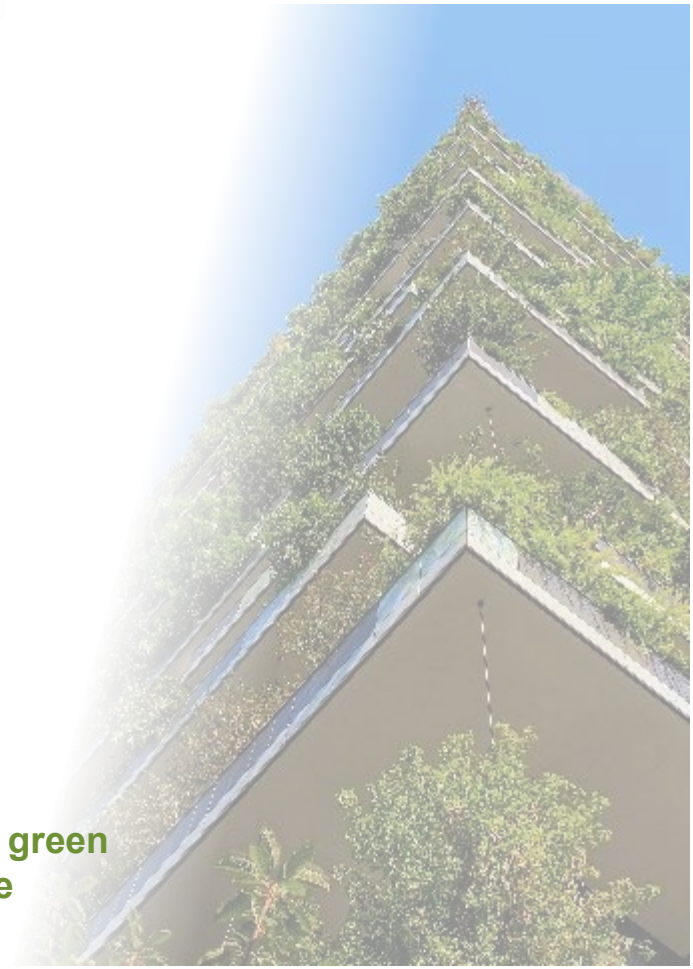
Vertical greening systems



Ground-based green facade

Pot-based green facade

Wall-based green facade



Adapted from Bustami et al., 2018, *Building and Environment* 146, 226–237

Nature-Based Solutions (NBS)

Classification

Usually several **single units / interventions** are implemented together for a **nature-based solution** (NBS).

- **NBS units** (NBS_u)
  - **spatial** units (NBS_su)
  - **technological** units (NBS_tu)
- **NBS interventions** (NBS_i)
  - **river** interventions (NBS_ir)
  - **soil** interventions (NBS_is)
  - **biodiversity** intervention (NBS_ib)
- **Supporting units** (S_u)

Castellar et al., 2021, *Sci Total Environ* 779, 146237; https://doi.org/10.1016/j.scitotenv.2021.146237

Nature-Based Solutions (NBS)

List of NBS units and interventions

Sub-categories	NBS_u	NBS_i	S_u
Rainwater management	12 (tu)	-	2
Vertical Greening Systems & Green Roofs	8 (tu)	-	-
Remediation, Treatment & Recovery	4 (tu)	3 (is)	8
(River) Restoration	-	5 (ir)	-
Soil and Water Bioengineering	-	4 (is)	-
(Public) Green Space	7 (su)	-	-
Food & biomass production	8 (5 tu, 3 su)	-	-
Total	**39** (29 tu, 10 su)	**12**	**10**

Langergraber et al., 2021, *Water* 13, 2355; https://doi.org/10.3390/w13172355.

Nature-Based Solutions (NBS)

#	Unit / Intervention	Synonyms	Descriptions
1	Infiltration basin	Green water storage and infiltration system; Storm basin; Non-permanent infiltration basin; Green water storage and infiltration system; Storm basin; Micro-catchment; The sponge zone (Castellar et al., 2021)	An **Infiltration basin** is a surface storage basin designed for short term temporal water storage by using an existing natural depression in the ground or by creating a new one. After a heavy rain, the water fills up the depression. The water then soaks into the ground or drains to the sewage system. If there is no heavy rainfall, the area is dry and could be used as a green area. Adapted from Castellar et al. (2021).
2	Infiltration trench	Percolation trench	**Infiltration trenches** are laminated systems with fabric-lined excavations atop a fabric-lined reservoir to increase infiltration. Adapted from UACDC (2010).
3	Filter strips	Vegetative filter strips	A **filter strip** is a sloped medium that attenuates stormwater runoff by converting it into sheet flow, and is typically located parallel to an impervious surface such as a parking lot, driveway, or roadway. Furthermore, the adoption of vegetated filter strips is increasing as they have been demonstrated to be effective for trapping runoff and sediment and promoting soil infiltration. Adapted from UACDC (2010) and Pan et al. (2018).
4	Filter drain	Filter trench; Surface sand filter	**Filter drains** are shallow trenches filled with stone/gravel that create temporary subsurface storage for attenuation, conveyance and filtration of surface water runoff. The stone may be contained in a simple trench lined with a geotextile, geomembrane or other impermeable liner, or with a more structural facility such as a concrete trough. Adapted from Ballard et al. (2015).
5	(Wet) Retention pond	(Wet) Retention basin; Wet pond; Wet pool Water Retention ponds; Green retention pond; Extended Retention Basin; Holding pond; Pond; (wet) retention basin (Castellar et al., 2021)	(**Wet) Retention ponds** consist of a permanent lagoon area with landscaped banks and surroundings to provide additional storage capacity during rainfall events. It has the capacity to continuously retain storm water, remove urban pollutants, and improve the quality of both surface runoff and release this at a controlled rate. During dry periods it also holds water. Adapted from Castellar et al. (2021).
:		:	:

In total: 39 NBS units, 12 NBS interventions & 10 Supporting units

excerpt from Langergraber et al., 2021, *Water* 13, 2355; https://doi.org/10.3390/w13172355.

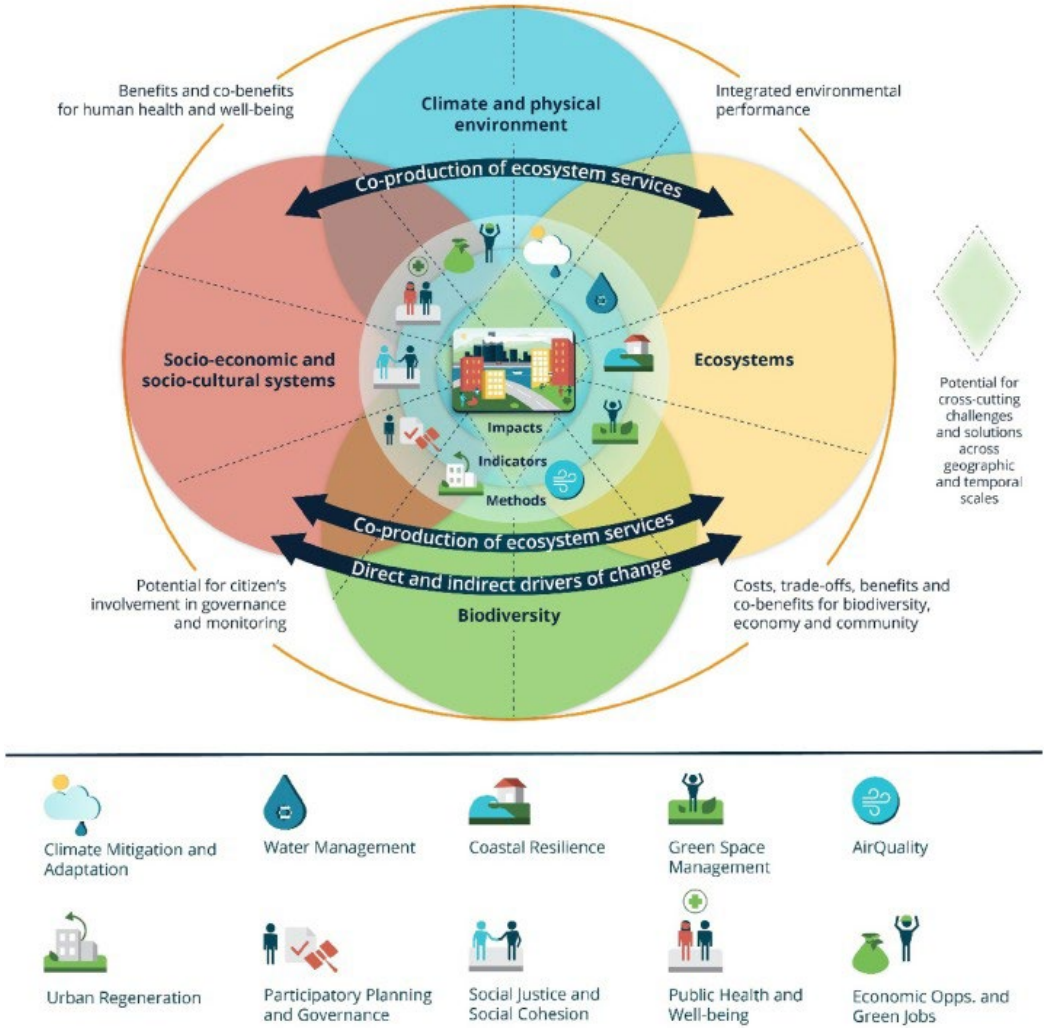
Urban Circularity Challenges

Table 1. Urban Circularity Challenges (UCCs) addressed by NBS units (NBS_u), NBS interventions (NBS_i), and Supporting units (S_u) (● = addressing the challenge; ● = contribution to challenge mitigation; ○ = potential contribution, depending on the design; and as an "empty cell" = not addressing the challenge). NBS_tu = technological units; NBS_su = spatial units; NBS_is = interventions; NBS_ir = river interventions; and S_u = Supporting unit.

Classification	(#) NBS units, NBS interventions, and Supporting units	Urban Circularity Challenge: Restoring and maintaining the water cycle	Water & waste treatment, recovery and reuse	Nutrient recovery and reuse	Material recovery and reuse	Food and biomass production	Energy efficiency and recovery	Building system recovery
Rainwater Management	NBS_tu							
	(1) Infiltration basin	●	●			○	○	
	(2) Infiltration trench	●	○					
	(3) Filter strips	●	●					
	(4) Filter drain	●	●					
	(5) (Wet) Retention pond	●	●		○	○		
	(6) (Dry) Detention pond	●	●					
	(7) Bioretention cell	●	●	●	○	○		●
	(8) Bioswale	●	●			○		
	(9) Dry swale	●	○			○		
	(10) Tree pits	●	●	●		○	●	
	(11) Vegetated grid pavement	●	●			○	●	
	(12) Riparian buffer	●	●	●		●	○	
	S_u							
	(S1) Rainwater harvesting	●	○				●	○
	(S2) Detention vaults and tanks	●	○					●

excerpt from Langergraber et al., 2021, *Water* 13, 2355; https://doi.org/10.3390/w13172355.

NBS and Urban Challenges



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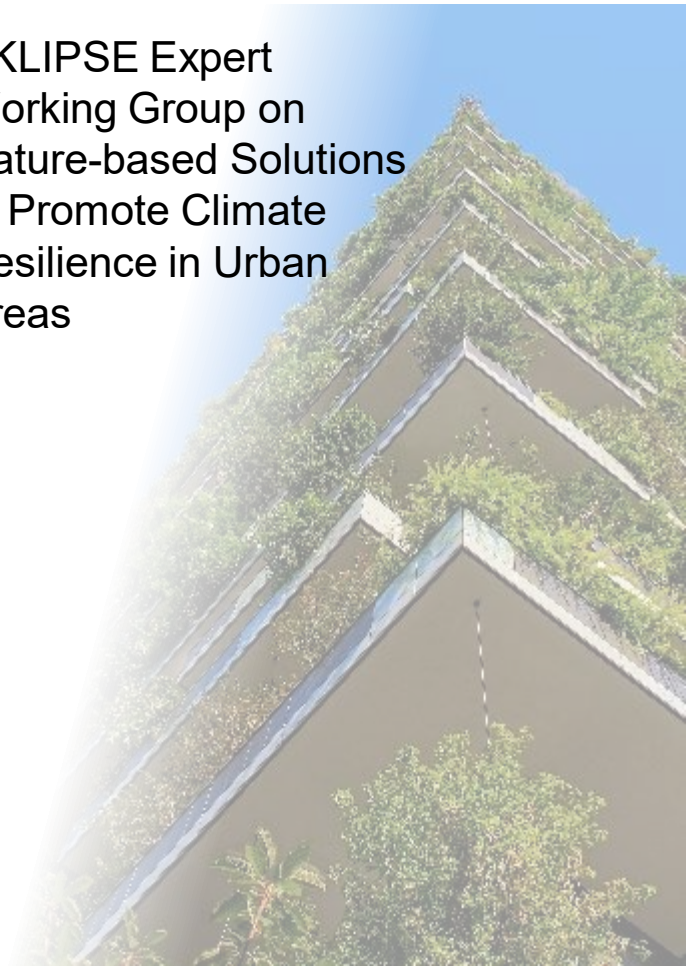

Quantifying the potential of NBS

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		NBS_u (1)	NBS_u (2)	…	NBS_u (i)
Built Environment	SITES	0	0		
	BUILDING	1	0		
	Urban water management	1	1		
	Resources recovery	0	0.5		
	Urban farming	0,5	0,5		
	Global score	0,50	0,4