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Executive Summary

This report profiles task 2.7 of the GrowGreen programme in reference to a Wuhan Research Exchange (31-64) that seeks to understand the idea and use of the 'sponge city' concept. It has been led by Manchester City Council in partnership with the University of Manchester, Wuhan DRC and Wuhan University. Wroclaw University of Environmental and Life Sciences, University Polytechnic Valencia and the Technical University of Catalonia are also engaged with wider aspects of the project and attended some of the webinars in this part of the programme.

This project used GrowGreen as the platform to enable an exchange of knowledge, lessons learned and best practice between the 6 EU cities involved in the project (Manchester, Brest, Modena, Valencia, Wroclaw and Zadar) and Wuhan. The project has focused on Wuhan's involvement in China's dynamic and expansive 'Sponge Cities' programme. This seeks to provide sustainable solutions to reducing waterlogging and improving water quality in cities susceptible to flooding. The project has sought to create an exchange between the cities and influence them on developing similar schemes in Europe.

The nature and depth of the exchange between Wuhan and the 6 EU cities has been different to the exchange between the 6 EU cities on other parts of GrowGreen due to budget and logistical constraints of working with a Chinese partner city. However, effort has been made to maximise collaboration as far as possible within the boundaries of the GrowGreen project. The challenges brought about by the Covid-19 pandemic has also had an effect in reducing in-person meetings and having to move to a webinar approach. The webinars though have still provided useful knowledge-sharing and active engagement.

This report describes the impact of the 'Sponge Cities' projects in China, and more specifically in Wuhan, and the lessons learned that can be replicated by other cities who want to develop a "Sponge Cities strategy" as part of their overall approach to climate change adaptation and mitigation. 'Sponge Cities' is a concept where, in seeking to mitigate the impacts of excessive surface water and river flooding, construction projects that can help soak up water or channel it more safely are devised. China is a global leader in such technology and Wuhan is one of the most impressive examples to consider. The concept is beginning to develop in Europe, but not at the same rapid speed as in China. The information exchange is aimed to provide the EU with strategies that can enhance take-up of such methods across the continent.

The report is structured around the following themes:

- A background to how the Sponge Cities concept developed in China with reference to core research papers describing the development of the policy.
- The Sponge Cities Programme in Wuhan – an overview of how the policy was developed in Wuhan, how extensive it has become, and some of the core benefits of the scheme. These benefits include the practical reduction of waterlogging and significant financial reductions in developing such projects in comparison with conventional construction methods.
- An overview of a formal visit to Wuhan by a Manchester delegation in November 2018 who were shown some of the city's sponge projects and the way it has helped reduce waterlogging and the impacts of flooding.

- How the project has assisted Wuhan in knowledge exchange and engaging in wider discussion between China and the European Union.
- Wuhan / Manchester Impact – an overview of how Manchester has developed its own sponge city projects following the visit to Wuhan. This centres on the development of the *West Gorton Sponge Park* as an EU funded demonstrator project, its use in successor projects like Mayfield Park and Victoria North Riverside, the development of Manchester's "Our rivers, Our city" strategy; and presentations from the University of Manchester to other GrowGreen Cities.
- Impact on the other GrowGreen cities – some examples of how the understanding of the sponge city concept has been used by the other member cities. One of the common features that comes across in this section is how considering 'sponge solutions' is becoming more common parlance in creating a sustainable and climate resilient green space – a highly effective Nature Based Solution (NBS).
- Throughout the report the negative impact of the Covid-19 pandemic is noted. It would have been beneficial to have undertaken at least one in-person return visit to Wuhan beyond the one that was held in November 2018, which would have also involved the other members of GrowGreen beyond Manchester. The stringent measures on containing the virus in China has made that impossible to undertake.
- Instead, a number of informative webinars have been held including a November 2020 'Wuhan Sponge Cities Programme' event, a January 2022 'Digitalisation of Sponge Cities' webinar seeking to support Wuhan on data management collection, a UK Government Foreign and Commonwealth Office 'Introduction to the Sponge City' webinar that was advertised to a wider range of cities beyond the core GrowGreen members and a virtual presentation about the impact of the Sponge City programme in Wuhan at the GrowGreen final conference in Brest, France in November 2022.
- The conclusion considers what has been the impact on GrowGreen cities of a greater understanding of the Wuhan sponge city concept, as well as how it has fed into wider discussion between EU and Chinese cities across other areas of climate change and developing nature-based solutions.
- Annexes list the attendees at Sponge City webinars, the engagement between the EU and China in this policy area and a bibliography of relevant literature.

1. Introduction

Within the EU's Smart and Sustainable Cities call (H2020-SCC-2016-2017), there have been a number of EU/ China collaborations on the topic of nature-based solutions (see Annex 2 for further detail on such initiatives). The knowledge exchange programme between Wuhan and the six GrowGreen Cities of Manchester, Valencia, Wroclaw, Brest, Zadar and Modena is one of these collaborations. It is focussed specifically on the "sponge cities" approach adopted in Wuhan to reduce flood risk and improve water quality.

Manchester City Council has a longstanding formal sister city arrangement with several cities around the world. This includes Wuhan, a city of around 11 million residents within the Hubei province of Central China. Manchester's sister city link with Wuhan dates from 1986. In 2016, the Council and Wuhan signed a Memorandum of Understanding (MoU) on climate change collaboration. Climate change has been one of the main areas of cooperation between the two cities and has been continuously included in each Cooperation Action Plan between the two cities in 2018, 2019-2021 and the latest in 2021-2023.

As a result, Wuhan was invited to be a partner on the GrowGreen project, and Manchester, with the other project cities, have been cooperating and sharing experiences with Wuhan via delegation visits and co-hosting webinars, including a site visit to Wuhan in November 2018 by GrowGreen delegates from the city.

This has enabled GrowGreen to be a platform to enable exchange of knowledge, lessons learned and best practice between the partners and Wuhan. The Covid-19 pandemic has precluded more in-person visits and created some challenge in developing this work programme in the way it was originally envisaged. However, many of the learning points from Wuhan's approach to creating 'Sponge City' have been adopted in projects developed in Manchester, as well as being actively shared with the other members of GrowGreen.

This report considers how the Sponge City policy and approach developed in China, and how it has been actively developed in the city of Wuhan. It also outlines some active and practical uses of the approach in Manchester, how Wuhan has responded to feedback to its approach, and how it has influenced the approach of some of the other GrowGreen members.

2. China's Sponge City Programme

With China's remarkable industrialisation and modernisation over the past three decades, there has been a huge shift in its population from agricultural areas to urban towns and cities. China's urbanisation has been rapid with the share of the population living in cities growing from just 19% in 1980 to around 65% by 2021. Between 2000 and 2014, China alone accounted for 32% of all urban land expansion globally: its built-up area has increased from 7,438 km^2 in 1981 to 52,102 km^2 in 2015, and it continues to increase rapidly.

In all of China's large cities, drainage of water is a huge logistical challenge and often does not meet national flood-prevention safety standards. As a result, up to 80% of storm water in Chinese cities becomes urban runoff, polluting bodies of water by drawing off pesticides and fertilisers from fields, and garbage and human waste from urban waste systems, and feeding this into rivers and streams, creating a public health and environmental crisis.

With climate change bringing much more frequent extreme rainfall events, this exposure is only increasing. As such, China has made responding to urban water management challenges a national priority and the central government is seeking to progress "from the traditional sector based, engineering oriented paradigm to a nature-based, holistic approach". In doing so, it is promoting changes to traditional infrastructure, for example: absorptive roads and permeable pavements; the implementation and expansion of green infrastructure, such as rain gardens, parks and wetlands; and built environment measures such as green roofs and rainwater reuse facilities. The key design feature of this new paradigm – known as the "Sponge City" – is "blending natural features and the city together as seamlessly as possible".

The construction of sponge cities uses a low-impact development concept to naturally absorb, store and purify rainwater to prevent urban flooding, improve water storage and discharge capacity, enhance water quality and alleviate heat island effects. The "sponge city" concept was given formal national endorsement when Chinese President Xi Jinping declared at the Central Government Conference on Urbanisation in 2013 that cities should "act like sponges".

China's national government has put in place an implementation framework that enables lower levels of government to adopt sponge city measures. This includes establishing basic laws and regulations, and compulsory standards and targets, and providing support in the form of technical guidelines, direct funding and favourable financing instruments. The sharing of successful examples from other cities, accompanied by financial and technical support from national government, has built enthusiasm for the concept in lower levels of government and in non-pilot cities. Preliminary estimates suggest a huge total investment of CNY 10 trillion (US$1.38 trillion) in sponge measures across 100,000 km^2 nationwide.

In 2015, the State Council of China issued a guideline on Promoting the Construction of Sponge Cities, enabling urban areas and infrastructures, like parks, streets and buildings, to "act like sponges"[1].

The guideline sets a formal target of 20% of the urban area being constructed to meet the sponge city standards by 2020. This figure should rise to 80% by 2030 to absorb and utilise 70% of rainfall in situ. To meet the targets, six measures are used with the aim to minimise the impact of urban development and construction on the environment:

- infiltration
- retention
- storage
- purification
- utilisation
- drainage

These measures also run alongside three guiding principles: the ecology and natural cycle

- guide and develop through planning
- governmental guidance and social participation

[1] The State Council of China. (2015). Guideline on Promoting the Construction of Sponge Cities: www.gov.cn/zhengce/content/2015-10/16/content_10228.htm (In Chinese) & http://english.www.gov.cn/policies/latest_releases/2015/10/16/content_281475212984264.htm

Municipal governments are required to follow the guidelines and establish a sponge city work plan. The construction of sponge cities applies to both new urban districts and any renovations undertaken in existing districts. Guided by the Ministry of Housing and Urban-Rural Development, the Ministry of Finance and the Ministry of Water Resources, the Sponge City pilot programme selected 16 pilot cities in 2015, including Wuhan, followed by another 14 pilot cities in 2016.

To support the construction of sponge cities, the national government offers funds for pilot cities for the initial three year from CNY 400 million (EUR 55.4 million) to CNY 600 million (EUR 83.1 million). The municipality is encouraged to fundraise and establish collaboratives to the share risks and benefits between the government and social capital (i.e., investment capital from private enterprises and state-owned companies). This allows the market to play a role in the allocation of resources. For example, a public-private partnership (PPP) and franchising are ways to encourage participation in the investment, construction and management of sponge cities. PPP can reduce the expenditure on construction and relieve fiscal pressure for the government as well as introducing innovative designs and operation management.

The Ministry of Housing and Urban-Rural Development (MHURD) published a catalogue of technology and products that can be applied in sponge city construction. The catalogue lists technologies, such as stormwater collection and reuse, and products, such as permeable pavements and rainwater infiltration pipes. Technical consulting companies, including private companies, state-owned companies and universities, are also included in the catalogue[2].

The evaluation focuses on seven indices:

- use and management of funds
- collaboration between government and social capital
- cost compensation and guarantee mechanism
- quantity of outputs
- quality of outputs
- project benefits
- technology application

[2] The Ministry of Housing and Urban-Rural Development. (2016).The Catalogue of Advanced Applicable Technology and Products in Sponge City Construction. http://www.jzlj.org.cn/Item/Show.asp?m=1&d=5368 (Chinese)

Figure 1 Chinas Sponge City Pilot Programme

3. Wuhan – A Sponge city

Wuhan is the capital city of the Hubei Province, and it is the most populous city in central China at 11.21 million inhabitants (2019 figures). Water accounts for a quarter of Wuhan's total territory, resulting in it being known as the "River City" or the "city of hundreds of lakes"[3]. 8.5 million residents occupy around 8,500 km2 of land on the Jianghan floodplain, where the Yangtze and Han rivers meet. Abundant water resources have driven the city's development, but the resulting urbanisation has exacerbated flooding and increased water pollution. Of the city's 11 rivers, four did not meet prescribed water quality standards as of 2014. In July 2016, Wuhan was hit by torrential rains. More than 600 millimetres of rain fell on the city within a week[4].

Wuhan has developed the sponge city concept and become a leading example of a nature-based approach for increasing urban resilience to climate change. Wuhan has initiated 389 separate sponge city projects covering 38.5 square kilometres (km2) of the city, including urban gardens, parks and green space designed to allow water to infiltrate during regular precipitation and to direct water away from urban areas during flooding. Other projects

[3] Grow Green – An Overview of the Chinese Sponge City Programme and its implementation in Wuhan, January 2021 https://growgreenproject.eu/wp-content/uploads/2021/01/Sponge-City-Programme-in-Wuhan-China.pdf

[4] www.researchgate.net/publication/339973440_Building_Climate_Resilience_and_Water_Security_in_Cities_Lessons_from_the_sponge_city_of_Wuhan_China

include artificial lakes that draw water away from populated areas and water channels that can safely handle large volumes of water during flooding.

This diagram outlines how Wuhan has developed these projects dependent on the impacts of each activity:

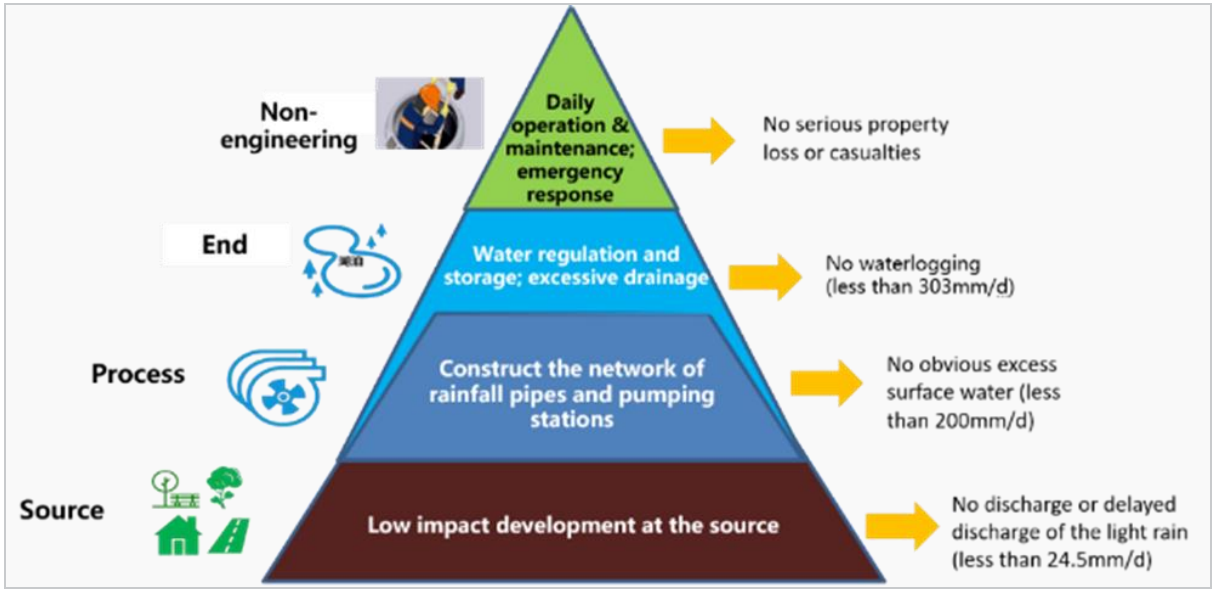


Figure 2 Wuhan's Sponge City project management process

It is important to note that the Wuhan sponge city programme is not a construction project that exists separately from other urban plans, but is interdependent with them, especially the Wuhan Comprehensive Planning and its ecological planning framework. It also requires the cooperation of different departments, such as water affairs, landscape and road traffic, to be planned and implemented.

As part of developing this process, city officials developed the Wuhan sponge city construction index system to set the goals and target the values for sponge projects. As the four categories of technical performance evaluation for comprehensive water management (water ecology, water environment, water resources, water safety) were recommended by the national government, Wuhan has adjusted the indexes according to its municipal context. These indexes are the core indicators of sponge performance and waterlogging prevention and later become the standard reference for the design of sponge infrastructures in Wuhan.

Index Type	No.	Index Name	Catagory	Index Value		Notes
				2020	2030	
Water Ecology	1	Water retention rate of natural lakes	Concept	100%	100%	
	2	Volume capture ratio of annual rainfall	Concept	20% area reach standards	80% area reach standards	Zoning by construction
	3	Proportion of natural shoreline of rivers and lakes	Measure	≥50%	≥80%	
Water Environment	4	Proportion of water bodies meeting quality standards	Target	80%, and no black and odorous water	95%, and no water below grade 5 (V standard)	
	5	Reduction of non-point source pollution in the upper part of watersheds	Measure	≥50% (Calculate by TSS*)	≥50% (Calculate by TSS)	
	6	Number of combined sewer overflows	Measure	≥10 times/year	≥10 times/year	Mixed flow outlets
Water Resources	7	Utilization rate of rainfall resources	Measure	Consumption of rainfall is not less than 5% of tap water	Consumption of rainfall is not less than 5% of tap water	Introductory
	8	Utilization rate of regenerated wastewater	Measure	≥20%	≥20%	Introductory
Water Safety	9	Flood control standard	Target	Resist 200-year storm event	Resist 200-year storm event	
	10	Waterlogging control standard	Target	Resist 20-year storm event	Resist 50-year storm event, 100-year storm event for key areas or facilities	
	11	Rate of discharge pumping station meeting standards	Measure	85%	100%	
	12	Levee compliance rate to the standard length	Measure	100% for the main levee, 90% for back levee	100% for the main levee and back levee	
	13	Rate of stormwater main pipes (canals) meeting standards	Measure	70%	95%	
	14	Proportion of permeable hardened pavement in new projects	Measure	≥40%	≥40%	

Figure 3 Wuhan construction index system

In designing projects that will develop effective ways to soak up excess water, Wuhan has developed a series of nature-based solutions and more traditional 'grey' solutions in its sponge infrastructure. These include:

Nature based solutions -

- Rain gardens
- Green roofs
- Grass swales
- Bio-retention facilities
- Depressed green spaces
- Vegetation buffer zones

Grey solutions -

- Permeable pavements
- Infiltration basins
- Infiltration trenches
- Rainwater storage modules
- Artificial soil infiltration facilities

Wuhan's nature-based approach to resilience was calculated to be more than CNY 4 billion (almost US$550 million) cheaper than upgrading the city's drainage system. There were also significant co-benefits, including improved local air quality, biodiversity and conservation benefits, health and lifestyle benefits, and increased land value.

The city of Wuhan was selected as a recipient of pilot funding for the national government's Sponge City Programme. As a provincial capital city, it received CNY 500 million (US$68.9 million) annually between 2015 and 2017, and the municipal government pledged an additional CNY 10.2 billion (approximately US$1.41 billion) of public funds into its sponge city construction. The municipal government identified the reduction of waterlogging, the control of water pollution and rainwater collection as priority investment areas under the programme.

Pilot projects like those in Wuhan are providing practical examples of how the sponge city concept can be applied. A paper developed by the Collation of Urban Transitions[5] documents a number of examples of the work undertaken in Wuhan. Amongst a number of case studies it documents is the redevelopment of what was once Asia's largest refuse landfill site, the sponge city infrastructure in the Wuhan Garden Expo Park. The redevelopment is seen as an exemplary example of low-carbon transition. Completed in 2015, the park covers 30 km^2 of public green space. Of the rainwater that falls there, 70% is collected by rainwater gardens, which are home to more than 400 plant species, saving the municipality CNY 1.5 million (US$206,800) every year in watering costs.

Another exemplary case study is the creation of the Yangtze River Beach Park. This is a large "low-carbon" park that has been developed to showcase the potential of sponge city and green architecture design. A substantial scheme, it has included the planting of 45,000 trees, 325 km^2 of shrubbery and 390 km^2 of grass. This has allowed for the creation of a substantial amount of leisure facilities including new football pitches and swimming pools and increased the value of the local land by almost two thirds. Its climate benefits are also impressive, with the temperature in the park around 3 degrees cooler than in the city, and 725 carbon tonnes being sequestered annually. Both the Wuhan Garden Expo Park and the city's popular Yangtze River Beach Park have been recognised as an award-winning showcase of international good practice and they are emblematic of the wider benefits that sponge city projects are having in Wuhan and other cities worldwide.

Figure 4 shows this case study in pictorial form:

[5] www.researchgate.net/publication/339973440_Building_Climate_Resilience_and_Water_Security_in_Cities_Lessons_from_the_sponge_city_of_Wuhan_China

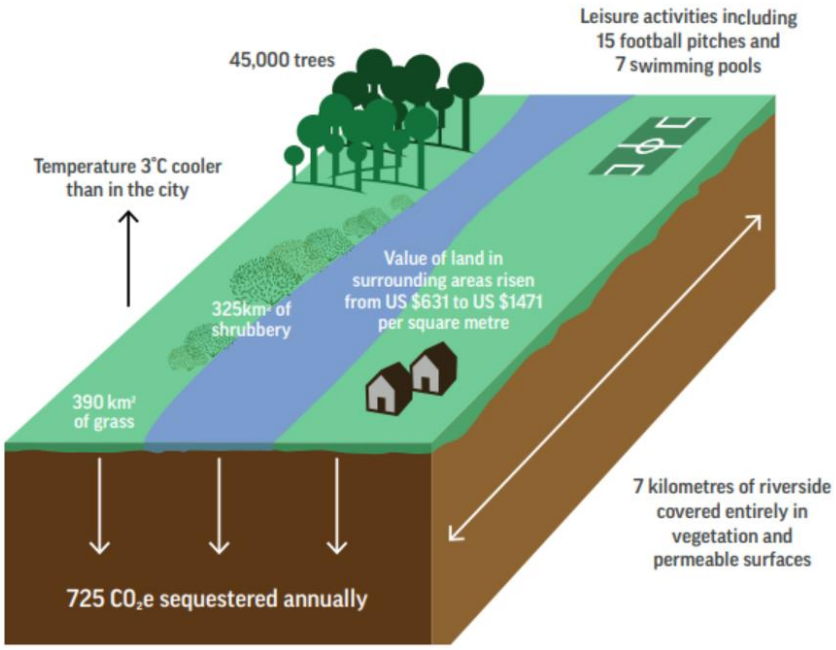


Figure 4 The Yangtze River Bank project

Before the Sponge City Programme, Wuhan's core river defences consisted primarily of walls lining the riverbanks. Now, the city is embracing the protective qualities of nature by expanding parkland, vegetation, green buildings and permeable pavements. Across the board, these are reducing waterlogging, improving the quality of the available land and having a positive impact on carbon emission reduction for Wuhan.

Overall, these sponge interventions – such as artificial waterbodies, permeable pavements, green roofs and walls, and the expansion of parkland – have increased the city's rainwater capacity by a third and created a pleasant living environment for residents. The intention is that by 2030, around 800 km^2 of the city will be sponge city enabled.

The true benefits of the Sponge City concept in Wuhan is particularly evident in recent figures from how the city has dealt with recent heavy rain in comparison to previous event. In the summer of 2020, Wuhan suffered from multiple rounds of intense precipitation. The daily precipitation rate hit a height of 472.3mm. Yet, compared to a similar storm event in 2016:

- The number of waterlogging points reduced from 162 to just 30.
- The maximum duration of waterlogging shortened from 1 month to 6 hours.
- The size area of waterlogging points was significantly reduced.
- The sponge measure greatly alleviated the impact of waterlogging on traffic and the public.

Such benefits are multifarious – less economic damage to repair, less housing and buildings flooding creating social and wellbeing dividends, and traffic flowing more easily throughout the city. Above all, the city is more protected into the medium and longer term to the impacts of climate change.

To sum up, four key areas have been delivered in the Wuhan Sponge City Programme:

1. Applying a whole-process management in waterlogging prevention.

2. Integrating sponge projects in Wuhan Comprehensive Planning with the collaboration of different city departments.

3. Developing localized strategies and technical standards.

4. Establishing a fund-raising mechanism and attracting social participation for risk- and benefit sharing.

A much more detailed assessment of the Wuhan Sponge City programme was developed for the GrowGreen programme by Yunyue Peng and Kate Reilly of the IUCN European Regional Office. It can be fully accessed on the GrowGreen website - https://growgreenproject.eu/wp-content/uploads/2021/01/Sponge-City-Programme-in-Wuhan-China.pdf.

4. Manchester Delegation to Wuhan – November 2018

In November 2018, representatives of the GrowGreen Project from Manchester visited Wuhan to get first-hand experience and a greater understanding of its 'Sponge Cities' project. They fed back their assessment of the projects in a number of webinars to other GrowGreen members and cities around Europe interested in understanding more of the 'Sponge City' concept.

Those attending from Manchester included:

- Professor James Rothwell – The University of Manchester
- Dr Adam Barker – The University of Manchester
- Jonny Sadler – Director of Manchester Climate Change Agency
- Dave Barlow - Green infrastructure & Biodiversity Lead, Manchester City Council

The Wuhan officers that hosted the visit informed the Manchester delegation, that with the city surrounded by water (25% of the area of the city is water), flooding remains an ongoing and major problem the city has had to endure. Given this, the 'Sponge City' concept is an obvious good fit for Wuhan. Officers told the Manchester delegation that water quantity and water quality were the focus of activity and since 2015 around 40km^2 of Wuhan has been 'sponge city enabled'.

In total they explained that they had created 288 demonstration projects to date across a number of areas, including:

- Retrofitting and new development
- Looking at surface water flooding and river flooding projects
- Including quite small projects (<10m^2) to very large ones (>5km^2)

By 2030, they explained that the drive from central government and the local city aims to have constructed around 800km^2 of 'sponge city enabled' infrastructure across Wuhan, as noted above.

The representatives from the GrowGreen Project in Wuhan in November 2018

Some of the schemes the delegation were shown in Wuhan included:

An example of a swale (swales are shallow, broad and vegetated channels designed to store and/or convey runoff and remove pollutants) near residential housing in Wuhan

A planted swale taking part runoff in Wuhan

An example of permeable paving in Wuhan

Tree pits taking runoff of water from roads

A rain garden taking footpath runoff

One of the information boards in Wuhan explaining the sponge city concept to the public

One of the environmental monitoring stations capturing water quantity and water quality data – they are situated at 108 locations across the city

The Manchester delegation also discussed with the Wuhan delegates the detail of a cost analysis conducted by the University of Leeds[6] of Wuhan's sponge city projects. This showed that the use of sponge measures with a focus on nature-based solutions in Wuhan sponge city demonstration areas have saved around CNY 4 billion (EUR 509 million) compared to the conventional approach to upgrade the drainage system based on grey infrastructure. This clearly reveals the true potential of nature-based solutions to European cities.

Many of the ideas shown to the Manchester delegation were incorporated into the West Gorton Sponge Park demonstrator project in the east of the city, and in the Mayfield Park

[6] Lucy Oates, Liping DAI, Andrew Sudmant, and Andy Gouldson. (2020). Building Climate Resilience and Water Security in Cities: Lessons from the sponge city of Wuhan, China. Coalition for Urban Transitions. London, UK, and Washington, DC: https://urbantransitions.global/wpcontent/uploads/2020/03/Building-climate-resilience-and-water-security-in-cities-lessons-from-theSponge-City-of-Wuhan-China-final.pdf

developed as the city's first new part in a century. The knowledge exchange also influenced some of the content in Manchester's 'Our Rivers, Our City' strategy. They were also shared with the other members of the GrowGreen group in a number of webinars. Further details on some of its applications are outlined in section 7 below.

5. Wuhan as an Observer

Whilst it is evident that Wuhan is a leader in the sponge city thinking and developments, its participation in GrowGreen has also offered it opportunities to learn from its wider work.

As a partner in the project, Wuhan DRC has benefited from all the communication channels being offered by GrowGreen to provide information about the progress of the Sponge City projects and wider areas of the project. These include:

- The GrowGreen website and social media.
- The GrowGreen newsletter.
- Other NBS EU funded projects such as ThinkNature, Connecting Nature, Naturvation Nature4cities.
- Participation and representation in conferences related to Climate Change and NBS such as UNFCCC COP, World Forum on Natural Capital, Resilient Cities, Adaptation Futures, ICLEI World Congress and the Convention on Biological Diversity Conference for Cities and Subnational Governments.
- Global and European networks that GrowGreen partners are part of such as ICLEI (Local Governments for Sustainability), EuroCities , the Climate KIC and IUCNs Global Water Programme.

The project has also provided a number of opportunities for knowledge exchange across partners that could benefit by Wuhan DRC. These include:

- Development of an EU-China NBS platform.
- Opportunity to collaborate in scientific research related to NBS with the University of Manchester.
- Opportunity for visits to other Front Runner Cities demonstration projects in Valencia, Wroclaw and Manchester.
- Access to GrowGreen collaborative data platform, reports and information.
- The GrowGreen training programme also provided access to tools, frameworks and methodologies relevant to designing and implementing nature-based solutions in collaboration with stakeholders. Of particular interest is the cross-city citizen engagement programme developed to enable citizens to understand and contribute towards the delivery of NBS projects in their communities. As part of the training programme case studies from leading cities, such as Wuhan, is being presented for learning and exchange to other cities across Europe and further afield.

Other areas where Wuhan has benefited include:

- It has seen a strengthening of the MOU between Wuhan and Manchester to create meaningful and useful discussion on climate change issues of concern to both cities.

- Through the webinars held, it has had the opportunity not just to interact with GrowGreen members, but with major cities from around Europe.
- It has extended networking opportunities, for example, between the University of Manchester and Wuhan University.
- There has been useful knowledge exchange and skill sharing of how European cities develop technical solutions and stakeholder engagement differently to the Chinese experience. The examples of 'bottom up' engagement will be of particular interest to Wuhan.

6. Replication Lessons to Develop a Sponge Cities Strategy

There are a number of important lessons from Wuhan's approach on creating a sponge city that are applicable to the members of GrowGreen, as well as European cities in general, if they are to replicate the benefits of such an approach.

These include:

- The Wuhan Sponge City Programme has generated a range of social and environmental benefits to the city beyond the reduction of flooding and waterlogging. These included a reduction in carbon emissions, an improvement in public health and wellbeing, enhanced natural cooling and improved biodiversity conservation. GrowGreen cities should look to emphasise these wider benefits when developing sponge infrastructure schemes.
- Wuhan's successful approach was made possible by putting in place a detailed implementation framework, focused and centred through a national government policy-led approach, which incentivised and enabled lower levels of government to adopt sponge city measures. Some of the measures in this framework include creating basic local laws and regulations relating to sponge infrastructure, outlining and emphasising compulsory standards and targets that had to be met, providing central support in the form of technical guidelines, direct funding and favourable financing instruments, as well as creating peer-to-peer learning across cities. GrowGreen cities need to create their own bespoke local system, which hopefully can engage with positive national policy in this area, as well as with the city region, and look to develop a robust local plan. This may require a consideration of the green finance opportunities that exist at the regional and national level to support such projects.
- Tailoring sponge city design to local conditions is crucial. In Wuhan, the municipality used the national guidelines as a departure point from which to develop their own construction manual - the Planning and Design Guidelines for the Sponge City Programme.
- Utilising land value capture – there are a number of fundamental fiscal and governance issues, particularly growing concerns around increasing municipal debt, that could restrict opportunities for scaling the Sponge City Programme. Leveraging private investment is therefore critical for GrowGreen members. This can be difficult to incentivise where there is no immediate or even long-term yield. Manchester has joined with other UK 'Core Cities' to look at ways of 'bundling' projects to enable a

yield for private investors. By contrast, in several of the Chinese pilot cities, including Wuhan and Beijing, municipalities have been able to collaborate with state-owned enterprises, some of which are even owned by the municipality itself.

- Integrating sponge city approaches into the wider climate programme and maintenance systems - when incorporating a growing number of actors, it will be important to overcome the challenge of coordination – of stakeholders, across programmes and beyond jurisdictional boundaries. Currently, in the Chinese example, tasks can be fragmented among municipal departments, and are then treated as handovers: projects are designed by one subdivision, for example, before being transferred elsewhere for construction, with no single entity participating in the programme from beginning to end. GrowGreen members need to consider how sponge infrastructure projects can link into the wider climate objectives of the city. The stakeholder engagement approach is more readily used in Europe, as noted below, and can deliver real benefits of popular public consent for such projects.
- Improving data sharing - another barrier to effective coordination, and for learning, is the inadequate sharing of data relating to sponge city construction. Designing, constructing and operating a sponge city involves highly complex engineering, requiring a high volume of environmental and socio-economic information that has multiple sources.
- Ensure that every city has a transformative, holistic and locally appropriate climate-resilient water management plan in place - policies and plans for every aspect of urban development need to be “climate proofed” so that they are ready for the more frequent and intense weather events that are predicted.
- Develop and deliver a broader, more integrated, multi-agency approach to watershed-scale management - the Sponge City Programme is not only about improving flood control, but also about water security, environmental restoration and improving the urban realm for citizens.
- Ensure public buy-in and ownership of urban green infrastructure - citizens and private actors should also be seen as partners in the delivery and become co-owners of the sponge city. National governments should look for opportunities for non-governmental stakeholders (for example, Manchester City Council has engaged closely with Groundwork to develop the West Gorton sponge park) to participate in the design of sponge projects. Cities need to ensure that in the post-implementation stage communities have a stake in maintaining interventions over the long term.
- Leverage innovative fiscal and regulatory mechanisms to support green infrastructure and ensure private-sector participation in sponge interventions - national governments can help to create more favourable conditions for investments by offering tax incentives, utility-rate reductions and other, non-financial incentives such as the transfer of development rights or watershed trading.
- Actively enable experimentation and city-to-city learning on nature-based solutions - pilot projects like those in Wuhan are providing practical examples of how the sponge city concept can be applied and are generating wider interest in rolling out such projects elsewhere. National governments should continue to foster this experimental

approach to sponge project implementation, perhaps by issuing calls for proposals and offering seed funding to the winning ideas. Cooperation with regional and local government in this area is also essential.

7. Exchanges between Wuhan and GrowGreen Cities

a) Engagement with Wuhan and Manchester to assist its development of a sponge city approach

Given the close cooperation between Manchester and Wuhan on climate change over a number of years, and the November 2018 visit to China to see the sheer scale of sponge city projects, learning from it has aided Manchester City Council (with a number of other core partners) to develop an exemplary demonstrator project at the West Gorton Sponge Park. Lessons learned from this project are now being applied into other urban city park projects.

The West Gorton Sponge Park has been funded through the European Commission Horizon 2020 Research Programme. This park showcases how to design, fund, deliver and manage a NbS project which achieves climatic, social, economic and environmental benefits.

The project was developed by project partners Manchester City Council, the Guinness Partnership Ltd, the University of Manchester and the Manchester Climate Change Agency. BDP was commissioned as the landscape architects and Groundwork Greater Manchester as the community engagement lead.

The community facility in east Manchester was designed as a park that 'drinks' water, aiming to reduce flood risk or waterlogging and providing a multitude of social benefits for local residents.

It sought early on to engage with the local community, through the owner of the housing estate in the area, the Guinness Partnership, and to bring in specialist environmental consultants and groups like Arup and Groundwork to incorporate ideas and processes learned from Wuhan and other cities. Those involved in the November 2018 visit to Wuhan also provided their direct insights to the construction team using a shared knowledge approach. The site visit to Wuhan gave a valuable insight on the types of schemes that could be delivered, the processes that needed to be considered and the benefits that have been derived from them in terms of reduced waterlogging.

One key difference between Chinese and UK / EU approaches to developing such a demonstrator scheme is a more open discursive culture in the UK (as in other EU countries) encourages both 'top down' and 'bottom up' extensive public stakeholder engagement with the local community and the organisations involved in funding and developing construction.

The West Gorton Sponge Park has several key features similar to those created in Wuhan. The park has been designed to reduce storm water run-off and the associated risk of surface water flooding. It does this through infiltration, attenuation and conveyance of rainwater and urban runoff. It has also replicates a number of schemes that a central to the sponge city approach. These include:

- Sunken garden: sensory planting lets the community relax in a sunken garden, which thrives on rainwater. The planting and associated drainage is aimed at absorbing and

infiltrating rainwater, as well as looking an attractive, relaxing space for the local community.

- Piazza space: a community event space that incorporate permeable paving. Rainwater infiltrates through the paving, where it is then directed through a series of formal channels into a sunken garden.
- Bio-swales: rainwater from adjacent roads is directed to three bio-swales. These linear depressions are planted and have timber check dams to help slow the flow.
- The centre of the park, which is referred to as the meadow, is full of wildflowers, attracting beneficial insects like bees and enhancing biodiversity.
- Rain garden: captures rainwater for utilising by planted vegetation, including alder trees.

The original site in 2013 looked tired, untidy and largely unused, as these images show:

It now looks like this:

The aim of the project has been to provide evidence to show the actual impact that green spaces have on not only the local community but also for responding to climate change as a nature-based solution. With the help of GrowGreen's academic partners at the University of Manchester the garden will be monitored for a number of years.

A core part of the EU-funded project was it being as much community-led as an academic-led demonstrator project. The environmental group Groundwork, who were subcontracted by the Guinness Partnership, and have been a partner in GrowGreen, extensively helped with community engagement and provided community expertise in the area. Extensive local public consultations were held around different sketch and concept designs to create a site that the community could use and be proud of. The Headteacher of one of the local schools commented that the park has "helped the children gain a keener understanding of the ecological benefits of having something like this on their doorstep in the community…We're a bit blown away by the extent of what is here, there is a lot to be learned"[7].

The park has already won two prestigious awards - the Design Council's 'Golden Pineapple' Award for Best Public Space and the Excellence in Flood and Water Management Award from the Landscape Institute Awards 2021.

The success of the project has been disseminated widely through the city and the Greater Manchester City Region. It has clearly influenced two large new developments in the city which are weaving in sponge city developments to their business and design case. These include the Mayfield City Park, which is the first large new public park in Manchester for over a century, and the Victoria North development.

Mayfield Park is a 2.6-hectare site behind Piccadilly train station on the edge of the city centre. Developed by the Mayfield Partnership, and supported by Manchester City Council and the Environment Agency, the scheme has used some of the water management lessons from the likes of the West Gorton scheme as part of an innovative irrigation system that will also reduce potential flooding to the area. Re-using water from old wells that derive from the 19th century, and which were discovered during the construction of the park, they have become a sustainable source of irrigation for trees and plants. The scheme will save approximately 1 tonne of carbon per year and up to 3 million litres of water per year[8].

The project has also recycled and reused materials during the construction of Mayfield Park, which has saved between 230-240 tonnes of CO2 alone. The project team has reused the steel

[7] https://growgreenproject.eu/key-features-manchesters-west-gorton-community-park/
[8] https://www.uandiplc.com/news-and-views/mayfield-park-already-delivering-for-manchester-s-net-zero-goals-months-before-completion/

from a former concrete culvert over the river Medlock to make one of the three pedestrian bridges in the park. In addition, the use of reclaimed bricks, structural steel beams and river walls has also contributed to the saving.

Another learning point from Wuhan and the West Gorton scheme is the planting of 140 new trees around the park. The new mature and semi-mature trees create an attractive, biodiverse natural landscape in an area of the city which previously had little tree coverage. This action has also removed more than three tonnes of CO_2 (equivalent) from the atmosphere per year. The amount of carbon annually captured will increase over time as the trees grow and flourish in the park.

The park is part of a 10-year, £1.4bn project to transform the previously run-down 24-acre industrial site near Manchester Piccadilly Station into a thriving urban neighbourhood. It will be one of the largest regeneration projects in the North of England, comprising 1,500 homes, 1.6m sq. ft of market-leading commercial space and 300,000 sq. ft of retail and leisure facilities. The nature-based solutions within the development will improve climate resilience and have been warmly welcomed by the public.

Lessons from Wuhan and West Gorton are also feeding into an even larger development in the city, the Victoria North scheme. In what is currently the North of England's largest urban redevelopment scheme, the scheme is jointly developed and funded by the Far East Consortium (FEC) and Manchester City Council. Victoria North is aiming to create 15,000 new homes across 155 hectares and seven neighbourhoods over the next 20 years.

The redevelopment project will create better-connected public spaces, new and improved transport links, and more homes, parks, and retail spaces for the city's growing population. The first phase of the development in Victoria Riverside[9], is the City River Park which will cover 46 hectares of new and improved parkland and become one of Manchester's largest city centre green spaces. The park will vary in character providing a diverse and active new recreational corridor for the community including parks and smaller amenity spaces.

City River Park will enhance existing habitats and create new habitats for wildlife and be guided by climate positive design, including sponge city projects, to create results which will be as carbon neutral as possible. It is also aimed to make the area as connected and accessible as possible through high quality pedestrian and cycle movement to aid active lifestyles and general well-being.

As well as some of the practical projects developed in Manchester using some of the learning from Wuhan, the knowledge exchange has also assisted with the development of the 'Our Rivers, Our City' strategy.

'Our Rivers Our City' is the contribution of the city's water management sector to the 'Our Manchester' Strategy. The five main aims of Our Rivers, Our City are:

- Improving the quality and functioning of the river valleys and catchments.
- Ensuring river valleys and sustainable drainage are key components of new developments.
- Improving accessibility to the river valleys.

[9] https://victorianorth.co.uk/

- Promoting a wider understanding of the benefits of river valleys and sustainable urban drainage; and
- Improving flood management and risk mitigation.

To deliver this the strategy has seven strategic objectives, alongside three operational objectives. The seven strategic objectives are:

- Place Making and Manchester's Economy
- Wild Rivers
- Clean Waters
- Access to Water
- Zero Carbon
- People and Neighbourhoods
- Sponge City (where the learning from Wuhan and the West Gorton Sponge City has been put into place)

The three operational objectives are:

- Policy and Partnerships
- Going Digital
- Delivery and Finance

The three operational objectives set out how the Strategy will be delivered over the first 10 years. For policy and partnerships, this means interpreting how "Integrated Water Management" is embedded into projects with:

- Climate resilience
- Delivering housing and a stronger greener economy
- Enhanced environment and greenspaces

The strategy identifies that data, evidence and monitoring are a critical part of integrated water management (IWM), helping partners to engage a wide audience, agree on the priority issues and solutions, and monitor outcomes.

The final operational aspect, Delivery and Finance, looks at how the 10-year strategy can focus on urgently addressing some deep-seated environmental problems which will constrain Manchester's green growth. The delivery plan that accompanies the Strategy unlocks the city's potential for investment with a focus on a green economy, an equitable society and a response to the climate and ecological emergency. Within this, the sponge city concept is a fundamental part of the strategy as the city looks to improve its water resilience.

The Our Rivers, Our City Strategy is also funded through the GrowGreen project. Alongside the other partner cities Manchester is also renewing its Green Infrastructure Strategy to accelerate and upscale the uptake and understanding of nature-based solutions like sponge city.

b) Lessons learned from Wuhan Sponge City to other GrowGreen members

Given the challenges brought about by the Covid-19 pandemic, the other members of the GrowGreen coalition have had less direct exposure to Wuhan's schemes, though they have been clearly disseminated in several informative webinars.

Three of its member cities, Modena, Zadar, and Brest have shared some of the detail with the GrowGreen Consortium about their development of Sponge City schemes following on from lessons learned from both Wuhan and Manchester.

Modena – a 'little sponge city'

During the GrowGreen project, Modena has always followed the activities carried out by other Partners, especially regarding the solutions proposed and adopted through the demonstration projects.

Modena has recently implemented a strategy for identified solutions and contingent problems closer to Manchester and the sponge city of Wuhan. Modena's interest comes in the area of adopting an integrated and progressive system to cope with the effects of floods and it favours the "sponge" effect of the surfaces.

This last aspect is particularly interesting to Modena, especially if it is considered applied to the three levels (City, District, Site), passing from the large agricultural scale outside the cities to that of urban detail concerning the single courtyard area, with the adoption of widespread retention and storage of water but also biological purification and re-infiltration, especially by recovering impermeable areas through de-sealing interventions.

Modena agrees with Wuhan's approach that it is essential to ensure, through hydraulic and hydrological invariance methods, the right balance between the water cycle and water availability on an annual basis.

Modena, in addition to the study of the most suitable solutions in the NBS field, found it helpful as well to apply cost-benefit evaluation criteria, as proposed by Wuhan. It has constructed a business model to compare alternative solutions in the reconstruction of a paved surface (1.5 hectares) of a large parking lot serving a shopping centre.

The alternatives considered included:

- Traditional refurbishment of the pavement with waterproof asphalting (basic reference).
- The adoption of permeable and semi-permeable flooring.
- Dispersing trenches.
- Dispersing trenches with bio-retention areas.

In considering these options, a complete assessment of the benefits induced both at an environmental, social and economic level was made.

A summary of the results obtained is attached below:

CAPITAL COST									
CHARATERISTIC ELEMETS		**alt 0,1 road resurfacing**	**alt 0,2 road resurfacing + storage volume**	**alt 1,1 permeable paving**	**alt 1,2 permeable paving + storage volume**	**alt 2,1 trenches**	**alt 2,2 trenches + storage volume**	**alt 3,1 bioretention**	**alt 3,2 bioretention + storage volume**
Driveway	mq	296000	296000	296000	296000	263000	230000	263000	230000
Sidewalk	mq	24000	24000	24000	24000	24000	24000	24000	24000
Asphalted parking	mq	200000	200000	0	0	200000	200000	200000	200000
Permeable parking	mq	0	0	395000	395000	0	0	0	0
Trenches	mq	0	0	0	0	96698.25	193396.5	0	0
Bioretention	mq	0	0	0	0	0	0	132115.5	264231
Link to the network	cor	0	1000.0	0	1000.0	30000.0	30000.0	30000	30000
Storage reservoir	mc	0	828750.0	0	669375.0	0	162562.5	0	246712.50
TOTAL CAPITAL COST	**€**	**520.000**	**1.349.750**	**715.000**	**1.385.375**	**613.698**	**839.959**	**649.115**	**994.943**

MANAGEMENT COST									
COST MANAGEMENT		**alt 0,1 road resurfacing**	**alt 0,2 road resurfacing + storage volume**	**alt 1,1 permeable paving**	**alt 1,2 permeable paving + storage volume**	**alt 2,1 trenches**	**alt 2,2 trenches + storage volume**	**alt 3,1 bioretention**	**alt 3,2 bioretention + storage volume**
Mowing		0	0	0	0	0	0	100	160
Staff SUDS		0	0	800	800	800	800	800	800
Sewer Staff		1200	1200	1200	1200	1200	1200	1200	1200
Road Chucks		1000	1000	350	350	100	100	100	100
TOTAL MANAGEMENT COST	**€**	**2200.000**	**2200.000**	**2350.000**	**2350.000**	**2100.000**	**2100.000**	**2200.000**	**2260.000**

ECOSYSTEMIC BENEFITS - BY CIRIA - BEST (€)	**alt 0,1 road resurfacing**	**alt 0,2 road resurfacing + storage volume**	**alt 1,1 permeable paving**	**alt 1,2 permeable paving + storage volume**	**alt 2,1 trenches**	**alt 2,2 trenches + storage volume**	**alt 3,1 bioretention**	**alt 3,2 bioretention + storage volume**
	S1	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
Air quality	0.0	0.0	0.0	0.0	0.0	0.0	815.8	8617.8
Urban regeneration	0.0	0.0	0.0	0.0	0.0	0.0	29404.7	29404.7
Biodiversity	0.0	0.0	0.0	0.0	0.0	0.0	26.8	26.8
CO2 reduction and sequestration	0.0	0.0	310.9	310.9	310.9	363.8	308.1	737.0
Environmental education	0.0	0.0	2149.5	2149.5	2149.5	2149.5	6448.4	6448.4
well-being / health	0.0	0.0	0.0	0.0	0.0	0.0	25855.4	25855.4
Waste water	0.0	0.0	6955.8	6955.8	6893.5	8139.3	6893.5	7744.8
Hydrological recharge	0.0	0.0	55489.3	55489.3	57546.3	66824.7	57546.3	63304.8
TOTALE 2020 - 2050	**0**	**0**	**64905**	**64905**	**66900**	**77477**	**127299**	**142140**
Totale medio annuo €/y	**0.0**	**0.0**	**2163.5**	**2163.5**	**2230.0**	**2582.6**	**4243.3**	**4738.0**

ECONOMIC AND BENEFITS (€)	**alt 0,1 road resurfacing**	**alt 0,2 road resurfacing + storage volume**	**alt 1,1 permeable paving**	**alt 1,2 permeable paving + storage volume**	**alt 2,1 trenches**	**alt 2,2 trenches + storage volume**	**alt 3,1 bioretention**	**alt 3,2 bioretention + storage volume**
Storage reservoir	*0.0*	*828750.0*	*0.0*	*669375.0*	*0.0*	*162562.5*	*0.0*	*246712.5*
TOTAL BUILDINGS COST	520000.0	1349750.0	715000.0	1385375.0	613698.3	839959.0	649115.5	994943.5
TOTALE COST MANAGEMENT €/y	2200.0	2200.0	2350.0	2350.0	2100.0	2100.0	2200.0	2260.0
TOTALE COST MANAGEMENT 2020-2050	66000.0	66000.0	70500.0	70500.0	63000.0	63000.0	66000.0	67800.0
ECOSYSTEMIC BENEFITS €/y	0.0	0.0	2163.5	2163.5	2230.0	2582.6	4243.3	4738.0
ECOSYSTEMIC BENEFITS 2020 - 2050	0.0	0.0	64905.5	64905.5	66900.1	77477.3	127298.8	142139.5
REAL ECONOMIC SOCIAL AND ENVIRONMENTAL COST BASED ON 30 YEARS	**586000.0**	**1415750.0**	**720594.6**	**1390969.6**	**609798.2**	**825481.7**	**587816.8**	**920604.0**
REAL ECONOMIC SOCIAL AND ENVIRONMENTAL COST BASED €/y	**19533.3**	**47191.7**	**24019.8**	**46365.7**	**20326.6**	**27516.1**	**19593.9**	**30686.8**

EVALUATION MATRIX SCENARIO 1	alt 0,1 road resurfacing	alt 1,1 permeable paving	alt 2,1 trenches	alt 3,1 bioretention
	S1	S1	S1	S1
Air quality	0.0	0.0	0.0	1.0
Urban regeneration	0.0	0.0	0.0	1.0
Biodiversity	0.0	0.0	0.0	1.0
CO2 reduction and sequestration	0.0	1.0	1.0	0.99
Environmental education	0.0	0.33	0.33	1.0
well-being / health	0.0	0.0	0.0	1.0
Waste water	0.0	1.0	0.99	0.99
Hydrological recharge	0.0	0.96	1.0	1.0
TOTAL CAPITAL COST	1.0	0.72	0.85	0.80
TOTAL MANAGEMENT COS	0.95	0.89	1.0	0.95

EVALUATION MATRIX SCENARIO 2	alt 0,2 road resurfacing + storage volume	alt 1,2 permeable paving + storage volume	alt 2,2 trenches + storage volume	alt 3,2 bioretention + storage volume
	S2	S2	S2	S2
Air quality	0.0	0.0	0.0	1.0
Urban regeneration	0.0	0.0	0.0	1.0
Biodiversity	0.0	0.0	0.0	1.0
CO2 reduction and sequestration	0.0	0.42	0.49	1.0
Environmental education	0.0	0.33	0.33	1.0
well-being / health	0.0	0.0	0.0	1.0
Waste water	0.0	0.85	1.00	0.95
Hydrological recharge	0.0	0.83	1.00	0.95
TOTAL CAPITAL COST	0.62	0.60	1.00	0.84
TOTAL MANAGEMENT COS	0.95	0.89	1.00	0.93

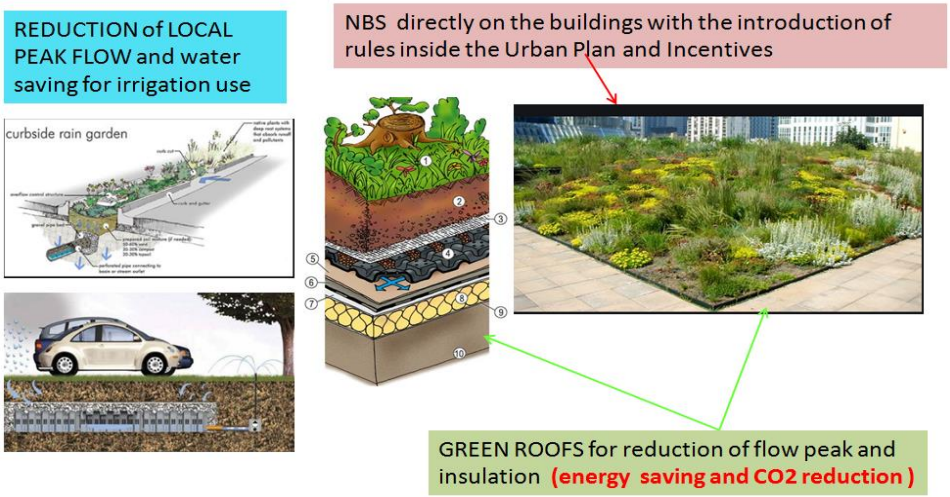
The evaluation of this data highlighted the following points:

- **Alternative 3 - bio-retention areas** has the best performance in terms of all additional ecosystem services (air quality, urban regeneration, biodiversity, CO2 emissions and sequestration, environmental education, well-being / health, wastewater, groundwater recharge), as well as on hydraulic issues.
- **Alternative 2 - infiltrating trenches** is the same as alternative 3 (bio-retention areas) only for the criteria related to hydraulics (wastewater, groundwater recharge).
- **In terms of the CO_2 emissions and sequestration**, all alternatives perform better than alternative 0 as they reduce the flow into the sewer of water destined for energy-consuming processes (lifting and treatment).
- In terms of construction costs, **the alternative 0, standard basic**, is the simple remaking of the road surface, performs better in terms of costs only in Scenario 1 (total cost approx. Euros 520,000); on opposite, if it were necessary to foresee retention volumes due to hydraulic invariance, the high costs of creating underground volumes with concrete tanks (see total construction costs for alternative 0 – Scenario 2 that are over Euros 1.3 million) lead to prefer solutions SuDS (Sustainable Urban Drainage Systems) hybrids all valued from € 0.8 to €1 million.

- **Permeable flooring**, one of the most widespread and most promoted practices, is in fact the most expensive solution both for Scenario 1, given the high construction costs compared to the greater surfaces required compared to other **SuDS** solutions, and for Scenario 2, given the impossibility of laminating volumes of water on the surface (if compared with the other **SuDS** techniques) it produces a higher investment cost unbalanced by a lower average flow coefficient. This consideration could fail, if the relatively poor permeability of the dispersing surface were supported with a storage system for the volumes of water provided as a porous layer of gravel under the entire surface of the car park in place of the creation of a specific concrete reservoir of the necessary capacity. This means creating a layer of gravel with a porosity of 0.3 and a thickness of 0.5 meters below the surface used for parking. In this case, the costs of the rolling tank built with an alternative method is of the order of € 120,000 compared to € 670,000 with a saving of over € 500,000, becoming a solution comparable in terms of cost to the solution that involves the construction of infiltrating trenches with storage volume (alt 2.2).
- In terms of **operating costs**, **the alternatives are equally valid**; in fact, if on the one hand the use of **SuDS** techniques involves additional management and maintenance activities compared to the standard pavement (checks of the correct functioning of sustainable urban drainage systems, management of the new green of naturalistic solutions), on the other hand we expect less costs for the management and maintenance of road drains, which will receive fewer loads of sediments (all SuDS alternatives) and will only operate from overflow (Alternative 2 - infiltrating trenches; Alternative 3 - bio-retention areas).

In the **Site level** or "local level" Modena are working to propose NBS solutions functional to the reduction of water supplies but also able to reduce temperatures and above all to cross energy savings. In few words it will help reduce carbon emissions.

At the local level, the actions are mainly aimed at the initiative of private individuals who, at the level of general urban planning, will be regulated and incentivized, but which will only be able to foresee, alongside the application of the principle of hydraulic invariance for new transformations, the adoption of NBS solutions typically applicable **in the local area, rain gardens, green walls, green roofs also bioretentions basins at the service of roofs and coverings**.



Zadar – implementing sponge city principles

In Zadar´s NBS Action plan, there are two measures planned, that can be connected to the sponge cities concept, and building on learning from Wuhan and Manchester:

Implementation of a retention-infiltration area within the stormwater drainage system -

Under the larger project for the improvement of the water and communal infrastructure of the Zadar-Petrčane agglomeration, the construction of 11 retention-infiltration areas in district Novi Bokanjac will be developed. Implementation of this measure will provide the final disposition of rainwater within the catchment area and infiltration in underground through retention points located at the lowest points of the area. Infiltration-retention points are interconnected by safety overflows so that in the period of heavy precipitation it is possible to redirect the overflow water to the first next point. Infiltration area is generally dry, except immediately after precipitation when water is retained only for a short period. The landscape will be designed with suitable free-growing greenery that will become rest and recreation area during the drought.

This project will ensure the protection of the drinking water resources of the nearby water pumping station, protection of large residential and business complex from flooding and enrichment of area with greenery.

This project is already under construction as shown in these images:

Permeable surfaces -

Permeable surfaces will be conducted on the parking lots, pavements and local roads for the purpose of reduction of the amount of rainwater that reaches the stormwater drainage system, thus reducing the risk of flooding in urban area. These measures include, whenever possible, the replacement of existing concrete surfaces with permeable surfaces while undertaking road maintenance or construction of all new parking lots, pavements or roads.

Brest- Storm water management

Flash floods are a major problem in Brest. The city drainage system was designed and built fore the 1-in-10 year storm event. However, more severe storm events of 1-in-30, and 1-in-100 year fequencgies have occurred since 2008 – evidence of climate change. As part of water wise-cities, Brest wanted to explore how NbS could be an approach to tackle flooding, and how sanitation compliance could be a lever to further explore NbS as climate change adaptation tool.

This idea has led to studies on the feasibility of applying a deconcentrated method to address combined sewer overflows and mitigate against intense rainfall. A key objective has been to balance between 'grey' infrastructure implementation downstream, and NbS schemes upstream.

Brest Métropole has developed an **integrated approach associating urbanists and water specialists to face some of these issues using NbS**. In addition, a range of stakeholders have been implementing NbS, including schools and social housing.

The GrowGreen project has enabled Brest Brest Métropole to develop an action plan which incorporates NbS. It relies on awareness-raising, identification of opportunities, coordination and planning interventions, implementation, evaluation, learning, and adjustments of the action plan.

Central to the action plan is the main measure of reducing the frequency of discharges into the natural environment from the combined sewerage system during rainy episodes. Aligned with the sponge city approach-this plan includes two complementary actions:

- The creation of underground structures for the temporary storage of excess water, which is then redirected into the sewerage system once the rainy episode has passed
- The reduction of rainwater inflows into the combined sewerage system, by disconnecting these inflows with the help of devices and surface development allowing infiltration into the soil, as close as possible to where the water fell

The plan, which is currently being disseminated among the different stakeholders, proposes a process of identification of opportunities, the planning of actions in 2023 and their subsequent implementation until 2037.

8. Conclusions and learning points

The exchange between Wuhan and the members of GrowGreen has emphasised the real benefits of the 'sponge city' concept. Section 7 of this report shows how GrowGreen members have readily implemented learning from Wuhan's experience to deliver effective schemes that are already reducing flooding, improving water quality and are proving popular with the local community. Over time, they are likely to show real financial reductions in construction cost compared to conventional schemes, and they are likely to become essential parts of strategies creating more climate adapted and resilient cities.

The Chinese 'sponge city' approach is heavily centralised and coupled with huge levels of resource to accommodate the local necessity in reducing flooding and waterlogging, as well as the expected significant impacts of climate change in the medium to longer-term. It is clear it has various economic, financial, social and health benefits to local communities.

Wuhan is an exemplar city in China of the 'sponge city' approach and it has taken it into the core strategy of its wider construction programme. This is essential for not just embedding the policy into the city's approach to construction design, but necessary for considering the medium and longer-term impacts of climate change. Wuhan and China are only likely to get considerably more rainfall and extreme weather over the coming decades, and the sponge city approach may be one of the most effective ways to ensure the city can adapt to it, and remain resilient.

Through GrowGreen, Manchester delegates were able to visit the city and hold a number of informative webinars to disseminate Wuhan's approach. Manchester has been able to put in place an exemplar demonstrator 'sponge city' project in the West Gorton Sponge Park. It is also evident that the recorded and reported benefits of this scheme are beginning to permeate the city's wider construction programme, given its use in two of the largest current developments in the city through the Mayfield and Victoria North. This is being showcased in greater detail in the website 'Manchester Climate Ready', which provides guidance and case studies on the benefits of the sponge city approach and other elements of climate adaptation and resilience - https://www.manchesterclimateready.com/ - in a variety of areas such as critical infrastructure, 'blue and green' infrastructure and looking for available climate finance.

The examples given from Modena and Zadar also emphasise that the sponge city approach is being used across a wide range of developments and being incorporated into official city construction policy. The financial benefits from taking up this approach is particularly impressive in the expansive examples used by Modena, which show how much the city can benefit in savings that can be used for other projects.

Wuhan has also benefited from engagement with GrowGreen, particularly for understanding the different approach taken in Europe to stakeholder engagement. It also benefits from practical engagement with academic partners and in the dialogue between the EU and China across many other schemes. It has gained useful access to engage with a wide range of European cities interested in the sponge city concept.

China's rapid industrialisation and modernisation, coupled with an expansive centralised approach, has allowed it to move extensively forward with concepts like the sponge city. With the urgent challenges brought about by the global climate emergency, it has also had to think

flexibly and dynamically of solutions that will not only bring economic growth, but assist cities in dealing with the externalities of growth. The Sponge approach, for example, does not just reduce waterlogging for Wuhan, but it always will make it more resilient to climate change and adapt it to some of the multifarious challenges increased temperatures will bring. China also has substantial resource to invest in these type of solutions now and in the future, which it is clearly doing in terms of the sponge city approach.

European governments and city regions are engaging heavily in tackling the climate emergency (though at different speeds and policy regimes given the multifarious nature of the governments across the continent) and the sponge city concept is an attractive one to take up. GrowGreen is one of the areas which may be able to promote it to a wider city and city region audience, and it also needs to be disseminated to governments to be incorporated into a national as well as local green construction policy programmes. The examples shown in this report in Manchester, Modena and Zadar reiterate the economic, financial, social and wellbeing benefits of the sponge city approach. The challenge will be to put them into local and national approaches to construction as well as finding the initial resources to develop them.

Some of the core learning points from the project include:

- There needs to be a whole-process management in flood prevention, with sponge projects playing an important role in city construction projects.
- Integrating sponge projects in planning policy with the collaboration of the city and core partners agencies is essential.
- Developing localized strategies and technical standards is really important, with effective stakeholder management essential.
- There is a real need to establish a fund-raising mechanism and attracting social participation for risk- and benefit sharing. Attaining climate finance is determined in different ways across Europe, but showing the benefits of the sponge approach and how it can interact with other schemes is important to develop.
- Sponge projects should link the need for more resilient architecture with the urgency of tackling the climate emergency. Whilst much attention is made to climate mitigation, the sponge approach shows that coupling it with developing climate adaptation projects has real benefits for the future.
- Sponge schemes have great potential and a range of long-term benefits. GrowGreen has shown their take-up would benefit a green construction city programme. There is a key communications role to disseminate them to key decision-makers. We recommend the D5.5 Urban by Nature proper EU China Forum could be the best vehicle to continue further discussion and dissemination.

Annex 1 – List of Webinars and Meetings

Webinars:

a. **2020 - 11th November - How to deepen further cooperation around Sponge City & GrowGreen project. Wuhan Sponge Cities Programme.**

Attendees:

Name and designation	Organisation
Cllr June Hitchen, Lord Mayor of Manchester	Manchester City Council
David Houliston, Strategic Lead, Policy & Partnerships	Manchester City Council
Dave Barlow, Senior Policy Officer (Biodiversity Lead)	Manchester City Council
Jonny Sadler, Director of MCCA	Manchester Climate Change Agency
Professor James Rothwell	University of Manchester
Dr Adam Barker	University of Manchester
Michelle Oddy, GrowGreen Project Coordinator	Manchester City Council
Claire Yang, Project Officer	British Consulate-General in Wuhan
D U Juan, Climate Change and Energy Officer	British Consulate-General in Wuhan
Peng Yunyue, GrowGreen Project Intern	Manchester City Council

Representatives from Wuhan Municipal People's Government:

Mrs Li Min, Director of Research Office	Wuhan Water Research Institute
Mrs Kang Dan, Director of Water Environment Research	Wuhan Water Research Institute
Key Project Inspector	Wuhan Coordination Office
Representative officer	Wuhan Meteorological Bureau
Vice Chair	Wuhan Sponge City and Utility Tunnel Construction Management Office
Representative officer	Wuhan Sponge City and Utility Tunnel Construction Management Office
Representative officer	Wuhan Water Affairs Bureau

b. **2022 - 22nd February – Manchester Wuhan Webinar: Digitalisation for Sponge City Showcase experiences and to further cooperation** –

This webinar was co-organised by the British Consulate-General Wuhan, Manchester City Council and the GrowGreen team, and supported by Wuhan Foreign Affairs Office, marks the third webinar. Supporting Wuhan on data management collection.

City / organisation attendees:
Representatives from Manchester City Council
Representatives from Salford City Council
Representative from ARUP
Representative from Datang Telecom Technology
Representatives from GrowGreen Project cities: Wroclaw (Poland) Valencia (Spain) Brest (France) Modena (Italy) Zadar (Croatia)
Invited NGO and GrowGreen project partners: Tecnalia (Spain) University Polytecnica de Valencia (Spain) Trinomics (Netherlands)
Invited guests: Greater Manchester Ignition project representatives Greater Manchester Natural Capital Coordinator Greater Manchester EU LIFE 'Natural Course' Project Manager Greater Manchester Resilience Officers
Wuhan representatives: Wuhan Development and Reform Commission Wuhan Ecology and Environment Bureau Wuhan Water Affairs Bureau Wuhan Municipal Engineering Design and Research Institute

c. **2021 FCO event – sponge city virtual event**

The UK Government Foreign and Commonwealth Office held a webinar showcasing the Wuhan Sponge City concepts, and how Manchester was using some of those ideas for its own projects. The webinar received presentations from Dr James Rothwell from the University of Manchester on local ways of implementing sponge infrastructure and Peng Yunyue providing an overview of Wuhan's sponge city developments and benefits.

Attendees:

Name	Organisation
Robbie Green	Foreign and Commonwealth Office
Hazel Cameron	Foreign and Commonwealth Office
Andreia Cavaco	Foreign and Commonwealth Office
Estibalitz Morras	Foreign and Commonwealth Office
Michelle Oddy	Manchester City Council
Laura McIntosh	Manchester City Council
Craig Neate	Manchester City Council
Lisa Lingard	Manchester Climate Change Agency
Ellie Bradley	Manchester Climate Change Agency
Anne-Marie Cabon	Brest Municipality, France
Lucy Vilarkin	Bristol City Council, UK
Susanne Dippel	Gelsenkirchen Municipality, Germany
Juliet Staples	Liverpool City Council, UK
Peter Massini	Greater London Authority, UK
Roberta Machioro	Commune of Mantova, Italy
Elisa Parisi	Commune of Mantova, Italy
Maria Gina Mussini	Commune of Modena, Italy
Gerd Seehuus	Commune of Stavanger, Norway
Kasper Alev	Tartu Commune, Estonia
Jila Comba	Valencia City Council, Spain
Malgorzata Bartyna-Zielinska	Wroclaw City Council, Poland
Maciej skroban	Wroclaw City Council, Poland
Zana Klarij	City of Zadar Council, Croatia

Ana Bajlo	City of Zadar Council, Croatia
Gregory Vandenbold	Eurocities
Louise Coffineau	Eurocities
Heather Brooks	Eurocities
Eddy Smith	EA Consultants
Andrew Jackson	Arup Consultants
Dima Zohgeib	Arup Consultants
Sachin Bhoite	Arup Consultants
Sheree Thomas	Arup Consultants
Samuli Rinne	Ouka Commune, Finland
Mariliis Kolk	Ouka Commune, Finland
G Korsuize	Utrecht City Council, Netherlands
D Langerak	Utrecht City Council, Netherlands
P G Paree	Breda City Council, Netherlands
V Kuiphuis	Breda City Council, Netherlands
Julie Dewar	Edinburgh City Council, UK
Syliva Pinterits	Munich City Council, Germany
Yves Prufer	Nice City Region, France
Marian Expert	Nice City Region, France
Tea Turtumoygard	Oslo City Council, Norway
Karine Hertzberg	Oslo City Council, Norway
M Puchal	Barcelona City Council, Spain
Kai Lipsius	Essen City Council, Germany
Petra Thetard	Essen City Council, Germany
Magnus Rothman	Stockholm City Council, Sweden
Peter Wiborn	Stockholm City Council, Sweden
Julia Huisman	Amsterdam City Council, Netherlands
A N Lars	Copenhagen City Council, Denmark
H Ansch	Copenhagen City Council, Denmark

In person meetings:

November 2018 - Manchester Visit Wuhan

See section 4 above. Attending from Manchester were Professor James Rothwell and Dr Adam Barker from the University of Manchester, Jonny Sadler from Manchester Climate Change Agency and Dave Barlow from Manchester City Council. They met a wide range of officials from Wuhan City Council and technical agencies.

a. **2021 – 19th March Visit by UK Embassy staff to Wuhan**

Attendees:

Name and Designation	Organisation
Head of Climate Change &Environment, Harriet Dalrymple	British Embassy in Beijing
Counsellor Communication, Ashley Rogers	British Embassy in Beijing
Bilateral Officer (Henan) & Climate Change and Energy, Juan Du	BCG Wuhan
Manchester Project Officer, Claire Yang	BCG Wuhan

Conferences:

November 2022 – GrowGreen conference "Cities of the Future" Brest, France

Prof Xiang Zhang, Director of Hubei Key Lab of water system science for Sponge City at Wuhan University gave a virtual presentation at the event. The presentation looked at the optimisation of green-grey-blue infrastructure along the Yangtze river and the impact on water quantity and water quality.

Attendees:

Iñaki	Romero	Paisaje Transversal
Pilar	Diaz	Paisaje Transversal
McGrory	Karl	One Tree Planted
Mcloughlin	Rebecca	Manchester City Council
Grainne	Bradley	Manchester City Council
Javier	Orozco-Messana	UPV
García	Igone	TECNALIA R&I, Basque Research and Technology Alliance (BRTA),
Tommis	Martine	Manchester City Council
Tomasz	Śpiewak	ARAW
Malgorzata	Bartyna-Zielinska	Wroclaw Municipality
Bartosz	Moch	ARAW
Malgorzata	Brykarz	Wroclaw Municipality
Rebecca	Ward	Alan Turing Institute
Cabon	Anne-Marie	Brest métropole
Gionfra	Susanna	IUCN

Maria	Nunez Rodriguez	IUCN Europe (International Union for Conservation
Delphine	HERRY	Brest métropole
Raphael	BROOKES	Brest métropole
Dorota	Olearnik	Gmina Wrocław
Bradley	Grainne	Manchester City Council
Gemma	Garcia Blanco	TECNALIA Research & Innovation
Oddy	Michelle	Manchester City Council
Alejandro	Gonzalez	Bipolaire
Nicolas	Floch	Brest métropole
Foivos	Petsinaris	Trinomics
PAGOTTO	ADELIO	COMUNE DI MODENA
Valentina	Tavaglione	Comune di Modena
Amélie	SAINT-GERMAIN	BREST MÉTROPOLE
JULIÁN	TORRALBA	LAS NAVES
Calabuig Moreno	Raimon	UPV
SARA	TONIOLO	COMUNE DI MODENA
Gonzalo	Sandoval	Las Naves
Francisca	Hipólito	Las Naves
Eva	Pubill	Las Naves
Empar	Soriano	Las Naves
Filippi	Alessandra	Comune di Modena
Gaudes	Ainhoa	Leitat
James	Rothwell	The University of Manchester
Rebecca	Ward	The Alan Turing Institute
Tommis	Martine	Manchester City Council
Ron	Cameron	The Guinness Partnership
Caroline	Cavanagh	The Guinness Partnership
David	Alfonso-Solar	UNIVERSITAT POLITÈCNICA DE VALÈNCIA
Elisa	Peñalvo-López	UPV
Zana	Klaric	City of Zadar
COUSQUER	Audrey	ENER'GENCE - ALEC du Pays de Brest

Annex 2 - Overview of EU / China Nature-based solutions collaboration

Within the Smart and Sustainable Cities call (H2020-SCC-2016-2017) there has been a number of EU/ China collaborations on the topic of nature-based solutions (NBS) which are summarised below:

a) GROWGREEN

With Wuhan - https://growgreenproject.eu/

A knowledge exchange programme has been developed between Wuhan and the 6 GrowGreen Cities of Manchester, Valencia, Wroclaw, Brest, Zadar and Modena. This has focussed specifically on the "sponge cities" approach adopted in Wuhan to reduce flood risk and improve water quality. This has involved a site visit to Wuhan in Nov 2018 by GrowGreen representatives and a number of webinars sharing good practice and results.

b) UNALAB

With Hong Kong - https://unalab.eu/en/our-cities/city-hong-kong

Hong Kong is a follower city in UNALAB. UNALAB's work partnering with the Hong Kong Polytechnic University has been on the integration of permeable pavement systems to improve urban drainage and stormwater harvesting to mitigate seasonal water shortages.

Hong Kong is on the eastern side of the Pearl River estuary in South China. With over 7.4 million people in a territory of 1,104 square kilometres, Hong Kong is the fourth most densely populated region in the world.

Despite Hong Kong's intense urbanisation, it has tried to promote a green environment. The city has ambitions to implement nature-based solutions like:

- Stormwater retention ponds,
- Green spaces,
- Permeable pavements and green facades.

c) URBANBYNATURE (CLEVER CITIES & CONNECTING NATURE & ICLEI)

With China Hub - https://urbanbynature.eu/hub/china

CLEVER Cities and Connecting Nature have joined to bring the UrbanByNature programme to China. Thereby, UbN China is using CLEVER Cities' expertise on NBS for urban regeneration and Connecting Nature's knowledge on NBS for climate & water resilience.

Tailored to the needs and interests of Chinese local governments and urban stakeholders, UbN China is providing capacity-building and good practice exchange on a variety of topics including stakeholder engagement, technical implementation, and monitoring of nature-based solutions

d) URBANGREENUP

With Chengdu - https://www.urbangreenup.eu/cities/followers/chengdu.kl

Chengdu is a follower city in the Urban Green Up project. Within the project, the city will set up its own Renaturing Urban Plans to replicate the URBAN GreenUP strategy and its green economy approach.

Chengdu, the capital of Sichuan Province, covers an area of 14,600 km square and has a resident population of more than 16 million people.

Chengdu is planning to build a greenway system with a main road of about 1,500 km long. The Jinjiang greenway is an important green axis planned and designed for Chengdu's high-tech zone. Following the "Innovation, Coordination, Green, Open, Sharing" development philosophy, Chengdu is speeding up the construction of ecological zones, greenways, parks, small gardens, and micro-green lands. The goal of the city is to follow a path leading both to economic development and environmental improvement.

e) PROGLREG

With Ningbo - https://progireg.eu/ningbo/

ProGlreg have created a living lab in Ningbo's Yuehu Park, it is the parkland surrounding an urban eutrophic lake in the central district of the city district of the city called Yuehu Park (Moon Lake Park). The proGIreg living lab in Ningbo has been focusing on innovative water quality monitoring and aquatic plant maintenance in 2021, to improve the water quality in Moon Lake and to gather data to support the planning of local environmental compensation processes.

Located in the N E province of Zhejiang between the East China Sea and various mountain ranges, Ningbo has over 1500km of coastline and over 600 islands. Like many cities on the easter coast, Ningbo is facing the challenges of rapid urbanisation and ongoing industrialisation.

f) UrbiNAT

With Nanhai District - https://urbinat.eu/cities/china/

Nanhai district is a high technology area in Foshan, Guangdong province in south China, and is under consideration as an Observer city in URBiNAT.

A Healthy corridor will be built and act as a "green connection" that connects important nodes of the city, improves citizens' travel convenience, and contributes to healthy footpaths in the city. Five Living labs will be built and various NBS will be implemented when creating the Healthy corridor.

China's participation is coordinated by the National Smart City Joint Lab (NSCJL), founded by the Chinese Society for Urban Studies (CSUS) to create a strongly networked body focused on supporting a development-oriented smart cities agenda across China. NSCJL cooperates closely with numerous cities in China, such as Shenyang, Nanhai (Foshan), and Hefei, that are connected with and get inspiration from URBiNAT's notions of NBS, Healthy corridors, Living Labs, and co-creation.

g) EdiCiNet

With Guangzhou - https://www.edicitnet.com/green-cities/

Guangzhou is a follower city in EdiCiNet.

The Guangzhou City Team, which includes representatives from government agencies and specifically municipal community engagement teams, research institutions, and a design agency, is envisioned as a policy research and planning team that aims to promote ECS planning projects effectively. The main objectives of the City Team are to promote a safe, stable, and efficient food supply in the city, and to encourage community-based public participation in urban food planning.

h) REGREEN

With Bejing, Shangai, Ningbo - https://www.regreen-project.eu/

REGREEN will substantially improve the evidence and tools for supporting the co-creation of nature-based solutions (NBS) in urban settings, implementation of decision support systems for planning and governance, and development of business models for realising spatially relevant NBS, that provide multiple ecosystem services and wellbeing in Europe and China.

REGREEN works through Urban Living Labs (ULLs) as the central elements of the project, where co-creation of knowledge involves local citizens, schools, businesses, organisations and public administrations enabling new forms of urban innovation.

Three Chinese cities are part of the project:

Beijing, where the following ULL actions are in place: development of best management practices in urban greening, involvement of a broad range of stakeholders in NBS projects, educating school children

Shanghai, where the following ULL actions are in place: preparation of a wetland field practice base for college students, organisation of bird watching tourism and mangrove planting

Ningbo, where the following ULL actions are in place: integration of policy guides and business models with technical measures of NBS, participation of stakeholders in participatory boards, implementation of educational outreach of NBS knowledge

i) CLEARING HOUSE

With Beijing, Hangzhou,Hong Kong, Guangzhou, Huaibei and Xiamen - https://www.metropolis.org/clearing-house

The main objective of CLEARING HOUSE is to analyse and develop – across China and Europe – the potential of UFNBS (Urban Forest Nature-Based Solutions) for enhancing the resilience of cities facing major ecological, socio-economic, and human wellbeing challenges. The experiences of the European case studies are shared and compared with those of the Chinese cases.

GrowGreen deliverable 5.5 will evaluate the impact of the wider EU/China NBS collaboration and identify ways this can be sustained in the future.

Annex 3 – Bibliography and further reading

GrowGreen detailed case study on Wuhan's Sponge City programme

https://growgreenproject.eu/wp-content/uploads/2021/01/Sponge-City-Programme-in-Wuhan-China.pdf

Coalition for Urban Transition – Building climate resilience and water security in cities: lessons from the Sponge City of Wuhan, China

www.researchgate.net/publication/339973440_Building_Climate_Resilience_and_Water_Security_in_Cities_Lessons_from_the_sponge_city_of_Wuhan_China

China's New Urbanisation Opportunity: A Vision for the 14th Five Year Plan

https://urbantransitions.global/en/publication/chinas-new-urbanisation-opportunity-a-vision-for-the-14th-five-year-plan/

C40 Cities: Wuhan – rehabilitated river embankment becomes beach park.

https://www.c40.org/case_studies/cities100-wuhan-rehabilitated-riverembankment-becomes-beach-park

Netherlands Environment Assessment Agency: The geography of future water challenges

https://www.clingendael.org/sites/default/files/2018-04/The-geography-of-future-waterchallenges_pdf.pdf

IUCN. 2019: Nature-based solutions - https://www.iucn.org/commissions/commission-ecosystem-management/our-work/nature-based-solutions