D4.2 Evidence-Based Narratives

Nature-Based Solutions

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General Information

Authors

McKenna Davis (Ecologic Institute)
Holger Gerdes (Ecologic Institute)
Sandra Naumann (Ecologic Institute)
Christian Hudson (Ecologic Institute)

WP Partners

1 JIIP
2 DTU
3 Ecologic Institute
4 PIK
5 SP
6 Tecnalia
7 Triple E Consulting
8 VTT
9 Wuppertal Institute

Contact

Max Grünig
max.gruenig@ecologic.eu

Christian Hudson
christian.hudson@ecologic.eu

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I. About this Document

This document contains evidence-based narratives within the area of "Nature-Based Solutions". The material found herein has been compiled on request of the Directorate-General for Research and Innovation (DG RTD) with reference to the project RECREATE. Data were obtained from a variety of different sources, including both published and unpublished works, but mainly constitute the result of desk research.

RECREATE (Research network for forward looking activities and assessment of research and innovation prospects in the fields of climate, resource efficiency and raw materials) is a "coordination and support action" supported by the European Union's Seventh Framework Programme under grant agreement No. 603860.

In this chapter we briefly outline the background and general methodology for developing the evidence-based narratives.

The Purpose

Referring to the Impact Assessment Work Package of the RECREATE project, DG RTD has asked for the development of evidence-based narratives for funding and policy activities in the Horizon 2020 societal challenge 5-area with respect to the following DG RTD flagship objectives.

1. Creating a market for Climate Information Services that enables economic actors to seize climate opportunities, governments to take climate-smart mitigation and adaptation decisions and citizens to optimise quality of life in the face of climate change (CIS).
2. Making Europe a world leader in Nature-Based Solutions, which use renewable natural resources and / or ecosystems to address societal challenges, yielding economic, social and environmental benefits (NBS).
3. Positioning Europe as the continent that realises a circular economy through a Systemic approach to Eco-Innovation (SEI).

The evidence-based narratives serve the purpose of assessing potential benefits of investment in innovation. The main focus is on those innovations that—once up scaled—offer favourable effects on the European socio-economic and environmental systems. Following criteria having been used for the selection of relevant innovation cases

- Size of future markets, in terms of revenues, jobs and EU market share
- Amount of investments and possible return on investments
- Extent of benefits on the environment and society
- Stage of development
- Extent of systemic innovation.

Since the selection of innovation cases has taken place before the actual assessment performance, few case works have revealed a different extent of effects than initially anticipated. This circumstance is an inherent challenge of the requested selection and analysis process and is presented in the following casework as transparent as possible.

THE DOCUMENT STRUCTURE

As output to the given request, three standalone deliverables have been developed. Each deliverable comprises evidence-based narratives referring to one of the DG RTD flagship objectives (CIS, NBS, and SEI).

This document describes evidence-based narratives for investment in innovation and diffusion of 'Nature Based Solutions' into EU and global markets. Nature-Based Solutions is a term, which covers many types of specific physical interventions, which are tailored, in combination with others, to meet particular needs in individual economic and geographic situations. This evidence-based narrative is organised around the description of Nature Based Solutions meeting 3 separate primary purposes. This structure has been chosen in order to ensure that DG RTD can draw conclusions and recommendations on the existence of potential investment markets and the interventions, which would support their development.

NBS deliverable	
Specific narrative	**Document page**
Cost Savings from Health Provision by Green Urban Space	p. 14
Use of Natural Solutions for Protecting Cities	p. 29
Sustainable Urban Drainage Systems	p. 42

THE CASE BLUEPRINT

In order to ensure easy reading and comparability between the cases included in this NBS document but also regarding cases treated in the accompanying CIS and SEI deliverables, a case blueprint has been developed and used for the assessment of each of the cases. According to this template, the structure of each of the cases comprises the following parts.

1. The "introduction" part establishes the relationship between the presented case and its coverage of the societal challenge that the RECREATE project is targeting—climate change mitigation, resource efficiency, and raw materials. Furthermore, it provides an overview of the actual innovation being dealt with in the specific case.
2. The part regarding the "estimation of the investment case" describes the amount of effects that can be expected when the considered innovation is up scaled to the European level. Indicators considered in that estimation comprise future market sizes, jobs created and environmental and social benefits that could perhaps be produced by scaling up the effects of innovation. The part concludes with an outlook on possible investments needed in order to push the innovation's diffusion.
3. The part of the "role of innovation policy" is based on an analysis of seven different functions of the respective innovation system. In doing so, the transition management analysis tool of a technology innovation system framework is used, (this framework is explained in "The method" down below). The fulfilment of the innovation's functions is represented in a spider graph, which is closing the part.
4. Based on the function analysis being done beforehand, the part of "policy recommendations" depicts a couple of possible actions, DG RTD could implement in order to push the innovation's diffusion. This selection is understood as a first proposal for policy actions and can give only the impetus for further in-depth policy analyses.

THE METHODOLOGICAL FRAMEWORK

Our methodology is inspired by the technology innovation system (TIS) framework, which ises based on the central idea that the analysis of the targeted dynamic innovation diffusion should focus on systematically mapping the activities that usually take place in innovation systems and finally resulting in the innovation diffusion. Those activities are considered to be functions of innovation systems.

As the name implies, the TIS framework concentrates on technological change. The analysed cases comprise as well technological innovations but also non-technological innovations. Since non-technological innovation is related to larger innovation systems, which also include technologies, we have used the TIS framework as a methodological approach for the analyses of all cases both technological and non-technological.

Following (Hekkert et al., 2007) an innovation system analysis is based on seven functions:[1]

5. "Entrepreneurial activities" maps the level of concrete actions taken by new entrants or incumbent companies generating and taking advantage of new business opportunities. Possible indicators may comprise the number of new entrants, diversification activities of incumbent actors.
6. "Knowledge development" maps the system's ability to learn, either by searching (research) or by doing (development). Possible indicators may comprise the number of R&D projects, patents or technology learning curves.
7. "Knowledge diffusion through networks" maps the flow of information exchange within knowledge networks. Possible indicators may comprise number of workshops and conferences devoted to the specific innovation and other network activities.
8. "Guidance of the search" maps the selection from the results of the knowledge developing activities. Since financial resources are limited, strategic decisions by industry and government set foci guiding future investments and influencing the direction of change. Possible indicators may comprise targets set by industry or government and number of journal articles related to the specific innovation.
9. "Market formation" maps the competition process with the embedded solution the innovation aims to replace or to change. Possible indicators may comprise the number of introduced niche markets, specific tax regimes and new environmental standards.
10. "Resource mobilization" maps the financial and human capital resources that are needed for all the activities within the innovation system. A possible indicator may comprise funds made available for long-term R&D programs.
11. "Creation of legitimacy" maps the process of how the specific innovation becomes part of an incumbent regime or even overthrows it. This process is guided by advocacy coalitions, parties with vested interests in the "creative destruction". A possible indicator may comprise the rise and growth of interest groups and their lobby actions.

[1] Hekkert, M.P., Suurs, R.A.A., Negro, S.O., Kuhlmann, S., and Smits, R.E.H.M. (2007). Functions of innovation systems: A new approach for analysing technological change. Technological Forecasting and Social Change 74, 413–432.

THE ORIGINATION PROCESS

The process having led to the present output consisted in a wide range of coordination activities including several feedback and control loops within the project consortium and DG RTD. Since the launch of the respective Work Package in July, following activities have been conducted in order to generate the available evidence-based narratives.

Period (2014/15)	**Activities**
July	Project meeting 1st round of case collection within the whole RECREATE consortium
August	2nd round of case collection within the whole RECREATE consortium
September	Collection of approximately 100 potential cases of innovations Selection of most promising cases and building of narratives Presentation of selection to DG RTD (Draft 1)
October	Group meeting Re-selection of most promising cases and re-building of narratives Presentation of selection to DG RTD (Draft 2)
November	In-depth research on cases and narratives Preparation of cases and narratives Exchange with Advisory Group Member
December	Development of zero drafts for CIS, NBS and SEI deliverables and presentation to DG RTD
January	Feedback from the Commission
February	Discussion of next steps and selection of narratives to be investigated further in a second step
March	Completion of Deliverable

II. Narrative on Nature-Based Solutions

Nature based solutions can improve the economic, social and environmental resilience of societies in Europe. Urban areas are particularly vulnerable and hence in need of such cost-effective, resource efficient, multi-purpose and multi-beneficial nature based solutions.

The first specific narrative in this report addresses the potential of innovative investments in urban green spaces to reduce the growing number of inactivity-related health complications and their associated costs. Generally, it can be said that investing US$ 1 in physical activity results in US$ 3.20 in medical cost savings. However, to exploit the full potential of urban green spaces, investments and new financing approaches are needed (e.g. new partnerships with government agencies or private individuals and corporations). Further barriers that challenge the implementation of innovative approaches to urban green spaces and limit the collaboration between the urban green areas- and health care sectors are a lack of available information and practical guidance. Besides dealing with practical examples, this narrative outlines the need for additional research on market and non-market benefits of urban green spaces and for the development of standardized indicators by which to measure the effectiveness of such areas for specific health objectives. It also describes the importance of spreading knowledge about existing models, projects, networks, resources and cost-benefit assessments of outcomes.

The second specific narrative focuses on the use of natural solutions for protecting coastal cities from flooding. Globally and in Europe, the risk of coastal flooding events is expected to increase with climate change. Cities located along the coasts and in river deltas will be especially affected by these events. Nature based solutions which offer additional environmental and socio-economic benefits can be a cost-effective way to achieve coastal protection. However, prevailing uncertainties about the effectiveness of nature based solutions and the diffusion of relevant information and networks still pose challenges to the further implementation of nature based solutions in coastal protection. Hence, more research, including on proper cost-effectiveness and cost-benefit analyses, is required, as well as the identification and dissemination of best-practice case studies.

The third specific narrative addresses *Sustainable urban Drainage systems* (SuDs) as a technique which offers a cost-effective and long-term alternative to cope with the increasing frequency of rainfall events causing excessive storm water in urban areas. Projections show a further increase in urban drainage-related flooding, particularly in Western and Northern Europe. SuDs still require further innovation actions to exploit their full potential but it is estimated that benefits obtained from the implementation of SuDs can exceed the benefits from piped drainage systems. These benefits would not only include prevented damage costs of flooding and water pollution, but also changes to property values, creation of green jobs, reduction in greenhouse gas emissions and reduced crime. A specific challenge is the need for technical research to support physical interventions, especially regarding the design of urban drainage systems that can cope with silt and for the development of alternative design procedures. So far, there is a lack of consistent methodologies for assessing the costs and benefits of wide-scale retrofitting and for conducting performance monitoring, which could be addressed via investments in research e.g. through the H2020 Programme.

1. Specific Narrative on "Cost Savings from Health Provision by Green Urban Space"

1.1 Introduction

Coverage of the SC5 Topics

Climate action[2]	Resource efficiency	Raw materials
✓	✓	
CO_2 sequestration; reduced energy usage in buildings close to urban green areas	Increased health benefits from the provisioning of urban green spaces	

Description of the Investment Case

Physical inactivity is the fourth leading cause of death worldwide (Pratt et al, 2014), with 31·1% of adults being physically inactive globally (Hallal, 2012). Some geographic areas have particularly pronounced rates (e.g. 43% physically inactive adults living in the eastern Mediterranean), and the trend has been found to increase with age, be higher in females than males, increase in high-income countries and be more prevalent in urban areas (Nieuwenhuijsen et al, 2014).

Substantial bodies of evidence indicate that low levels of activity correspond to decreased life expectancy and increased risks of numerous adverse health conditions (e.g. cardiovascular diseases, type 2 diabetes, breast and colon cancers, social health aspects, and mental health). More specifically, it is estimated that physical inactivity causes 6% of the burden of disease from coronary heart disease, 7% of type 2 diabetes, 10% of breast and colon cancer, and 9% of premature mortality worldwide (Lee et al, 2012). If inactivity decreased by even 10-25% as compared to current levels, it is estimated that between 533,000-1·3 million deaths could be prevented annually across the world (Lee et al 2012).

With the globally increasing cost of health care and particularly that associated with the diseases and health conditions linked to physical inactivity – estimated at US$ 162.5 billion per year – there is movement in the health care industry towards prevention activities and identifying low-cost, high-yield wellness investment opportunities (Barrett, 2014). In parallel, literature on the health and well-being benefits arising from the regular usage of good quality green space and the associated costs savings for health and related services offer high synergistic potential (Allen, nd).

Recent studies have demonstrated that people who are able to access green spaces are 27% more like to be physically active (BCTV, 2010), have lower levels of obesity and reduced exposure to air pollution in urban settings (Nieuwenhuijsen et al, 2014). In addition to the physical and mental health benefits and health care cost savings that are associated with this increased activity, parks and green spaces offer further economic

[2] The provisioning of urban green spaces also addresses climate action / climate change adaptation.

and environmental benefits. For example, the following have been connected with urban green space creation and maintenance: increased property values and property tax revenues, improved health equality and social cohesion, storm water management, job creation, carbon sequestration, and urban heat island mitigation (Barrett, 2014). Increasing a population's access to and the quality of green space can thus be part of a high-return package to encourage increased physical activity and thereby improve health outcomes and deliver a myriad of additional benefits.[3]

Limited policy and actions have been put in place until now which encourage health practitioners and facilities to be innovative in creating and utilizing green spaces in their prevention and treatment options for inactivity related illnesses, thereby reducing medical expenditures in the long-term.[4] In addition to providing the aforementioned benefits, the creation and maintenance of urban green spaces can assist healthcare facilities in meeting corporate social responsibility targets and performance measures, reduce energy costs, meet sustainability goals, and augment opportunities for green prescriptions and outdoor recovery programs.[5]

This opens up the niche for new investment models, bridging the gap between health care and natural area provision to combat inactivity-related health problems upstream. Two co-ordinated actions are needed, namely the creation and improvement of easily accessible, attractive, safe green spaces for urban dwellers, and encouragement of the use of these spaces for physical activity - particularly by health-care professionals.

Given that the market is so large, the first need is to find routes by which healthcare providers can financially contribute to the creation of publically accessible areas. This includes the health care providers being able to fund other organisations (private or public) to create, improve and maintain public spaces. For the second co-ordinated action, related changes in the practices of health-care professionals that encourage the use of existing and future spaces are needed. This requires a combination of organisational change (to permit them to 'prescribe' activity), knowledge and incentive structures.

Box 1: Case: Rainham Gateway Greenspace

The Rainham Gateway Greenspace project is a capital project aimed at improving access to and enjoyment of the western area of Rainham Marshes for local residents and employees via the creation of high quality, local and accessible natural environment. The project cost a total of £2.8 million, which was spent on the remediation of brownfield land, creation of new publicly accessible foot and/or cyclepath routes supporting safe access to "opportunity" employment areas and the creation of additional flood storage capacity. Two thirds of respondents in the project evaluation indicated that the greatest perceived benefit of the improvements was to their quality of life due to increased exercise.

More concretely, the project is expected to deliver £36,500 market benefits per annum, £985,000 social cost savings per annum and £68,000 non-market benefits per annum. Over a ten-year period, Rainham Gateway Greenspace can be expected to deliver £310,000 market benefits, £8.4 million social cost savings and £582,000 non-market benefits. The benefits are outlined below, but do not include the property price impact as a result of being nearer to a nature reserve (based on km to nature reserve) – which is calculated as £6,400 per property.

[3] This potential is currently being explored in a European context within the EU-funded project PHENOTYPE (Positive health effects of the natural outdoor environment in typical populations in different regions in Europe) – see http://www.phenotype.eu/.
[4] Faculty of Public Health (2010). Great Outdoors: How Our Natural Health Service Uses Green Space To Improve Wellbeing -An action report. Available for download at: http://www.fph.org.uk/uploads/r_great_outdoors.pdf
[5] Shackell, A. and Walter, R. (2012). Greenspace design for health and well-being. Forestry Commission Practice Guide. Forestry Commission, Edinburgh. i–vi + 1–70 pp.

Net Achieved Economic Impacts			
		Annual Value	**Net Present Value (10 year impacts)**
Market	Tourism spend	£36,500	£313,000
Social Cost Savings	Health benefits for population within 300 metres of greenspace as a result of proximity to greenspace	£102,500	£877,500
	Savings to the economy due to created exercise	£883,000	£7,558,500
Nonmarket	Total value for ecosystem service-related goods (includes biodiversity, amenity value etc)	£68,000	£582,000
Total Monetised Benefit		**£1,023,500**	**£8,765,000**

Regarding the overall value for money, every £1 invested will generate in the region of £3.50 (Net Present Value).

1.2 Estimation of the Investment Case

- Expenditure for health is increasing annually, with global costs attributed to physical inactivity estimated at US$ 162.5 billion per year.
- The direct (health care) and indirect costs of physical inactivity in Europe are estimated to be US$ 128 billion (in 2006).
- These costs can be decreased in part by improved access to (urban) green spaces; a Dutch study found that every 10% increase in exposure to green space could be translated into a reduction of five years in age in terms of expected health problems.
- Spending on health is foreseen to increase at a rate much higher than in the past, in part due to the trend of (European) populations moving towards less physical activity rather than more
- This opens up the niche for new investment models, bridging the gap between health care and natural area provision to combat inactivity-related health problems upstream.

Current Market

According to the World Health Organization (WHO, 2012), the total global expenditure for health in 2010 is valued at US$ 6.5 trillion (accounting for 10.1% of the GDP). This figure corresponds to the sum of public and private health expenditure and covers the provision of health services (preventive and curative), family planning activities, nutrition activities, and emergency aid designated for health; it does not include the provision of water and sanitation.

Global healthcare costs attributed to physical inactivity are one component and are estimated to comprise between 1 and 3% of the sum (BHF, 2013; Pratt, 2014). Further studies focusing on select countries sometimes present higher estimates; for example, it was estimated that 3.7% of total health care costs in Canada in 2009 could be attributed to inactivity (Janssen, 2012). Adopting the figure of 2.5%, global inactivity-related healthcare costs from 2010 are estimated at US$ 162.5 billion. The direct (health care) and indirect cost of physical inactivity in Europe were estimated in 2006 to be US$ 128 billion (based on 2006 exchange rates).[6]

The incurred costs from physical inactivity can be addressed in part by improved access to (urban) green spaces. A Dutch study found that every 10% increase in exposure to green space could be translated into a

[6] WHO Europe (2006). Physical activity and health in Europe. Available for download at: http://www.euro.who.int/__data/assets/pdf_file/0011/87545/E89490.pdf.

reduction of five years in age in terms of expected health problems (Vries et al 2003); similar findings were reported in Canada (Villenveuve et al 2012) and Japan (Takano et al 2002). Resultant cost savings can also be significant. A study by Natural England, for example, estimated that if the English population had equally easy access to green spaces and were thus 24% more likely to be physically active, the life-cost averted saving to the National Health Service would be around £2.1 billion per year (BOP, 2013; BCTV, 2010).

Future Markets

Spending on health is foreseen to increase at a rate much higher than in the past, in part due to the trend of (European) populations moving towards less physical activity rather than more.[7] More specifically, healthcare spending for the direct and indirect costs associated with inactivity are expected to rise substantially by 2020 (Nike, 2012). While exact figures are not available for Europe, the following figures are indicative of the trend towards increased healthcare inactivity-related costs projected until 2030/2060.

	TOTAL SPEND (US$) IN 2008	2008 Direct Costs (US$)	2008 Indirect Costs (US$)	2030 Direct Costs Projection (US$)	% Increase in Direct Costs (US$) 2008-2030
USA	$147B — OR — ~2x the federal budget for the Department of Education (based on US$77.48 2012 budget)	$90.1B	$56.5B	$191.7B	⬆113%
UK	$33B — OR — Close to the National Health Service's annual efficiency target (based on £20B of annual efficiency savings over the next four years)	$16.1B	$16.7B	$26.0B	⬆61%
CHINA	$20B — OR — Almost 1/3 of China's total health care budget (based on 2011 planned investment of approx. US$63B)	$12.2B	$7.5B	$67.5B	⬆453%
INDIA	$2B — OR — Equal to the total annual budget for secondary education (based on US$1.98/year for 2007-2012)	$1.3B	$0.7B	$7.5B	⬆477%

Source: (Nike, 2012: 6)

Figure 1. The economic costs and consequences: current and projected costs associated with inactivity

[7] WHO Europe (2014). 10 key facts on physical activity in the WHO European Region: Website article accessed on 1.12.14 (http://www.euro.who.int/en/health-topics/disease-prevention/physical-activity/data-and-statistics/10-key-facts-on-physical-activity-in-the-who-european-region).

		Expenditure as a % of GDP			Percentage point deviations from starting period
		2006-2010	2030	2060	2060
Total					
OECD	Cost-containment	6.2	8.1	9.5	3.3
	Cost-pressure	6.2	8.8	13.9	7.7
BRIICS	Cost-containment	2.5	3.9	5.3	2.8
	Cost-pressure	2.5	4.4	9.8	7.3
Health care					
OECD	Cost-containment	5.5	7.0	7.9	2.5
	Cost-pressure	5.5	7.5	11.8	6.3
BRIICS	Cost-containment	2.4	3.5	4.4	2.1
	Cost-pressure	2.4	4.0	8.3	5.9
Long-term care					
OECD	Cost-containment	0.8	1.1	1.6	0.8
	Cost-pressure	0.8	1.3	2.1	1.4
BRIICS	Cost-containment	0.1	0.3	0.9	0.8
	Cost-pressure	0.1	0.4	1.4	1.3

Source: (OECD, 2013: 1)

Figure 2. Rising public health and long-term care expenditure over the upcoming decades

Jobs

- Evidence regarding potential job creation is site-specific and difficult to upscale to a European and/or global level due to the high variance involved between existing case studies.
- Job creation pertains both to short-term opportunities relating to the physical construction and implementation of the green spaces, as well as to long-term employment connected to maintenance activities and the support of new businesses migrating to the area post-green space creation/improvement.

In the UK, the 'green space sector' – which includes public park departments, nature reserves, botanical/zoological gardens, and landscape/architectural services – directly employs 122,000 people (this equates to 5% of all jobs in the country) (Eftec, 2013). While localized examples cannot always be up-scaled to represent a total figure for potential job creation from *all* green space provision activities, they are nevertheless useful as indicative exemplar; several case study-specific figures are provided in Table 1 below. It is important to note that associated employment benefits pertain both to short-term job creation (e.g. in the creation or physical construction of green spaces), but also to long-term employment (e.g. maintenance activities, new opportunities via the migration of businesses to attractive areas, etc).

Table 1. Examples of employment and other economic benefits generated by urban green spaces

Case study name	Employment benefits	Economic, business, investment benefits	Reference
Riverside Park Industrial Estate in Middlesbrough (investment in GI with 1800 trees planted)	60 FTE[8] jobs created; reduction in incapacity and sickness related benefit claimants (dropped from 340-280)	Stimulated business growth and investment; attracted new, high profile, occupants; levered over £1 million in private investments; 28 new business start-ups	Saraev 2012

[8] FTE refers to full-time equivalent

Portland Basin Green Business Park in Tameside, Greater Manchester (landscaping improvements)	13 permanent jobs created and 314 jobs safeguarded	Increased local businesses in the park from 120 to 140	Saraev 2012
National Forest Creation	4.1% increase in local jobs from 1991-2001: 213 FTE	By 2001, directly related regeneration programmes resulted in £32.5 million for the area, which created over 500 jobs	Saraev 2012
Manvers Regeneration scheme by Rotherham Metropolitan Borough Council in South Yorkshire	9000 jobs created in 20 years		Saraev 2012
Glasgow Green Renewal Project (rejuvenation of city's oldest park)	28% in number of local employees; 230 jobs supported; 35 FTE created	Stimulated the development of 500-750 new residential properties; increased average housing process; 47% increase in council tax yield; increase of land value	Saraev 2012; Eftec 2013
Greening of rundown industrial estate in Wakefield	Employment of 200 people	Relocation of 16 new businesses to the estate	Eftec 2013

Green spaces have also been linked with increased work productivity and decreased health-related absenteeism. Employees with views of and contact with nature have been shown to demonstrate increased concentration levels and productivity.[9]

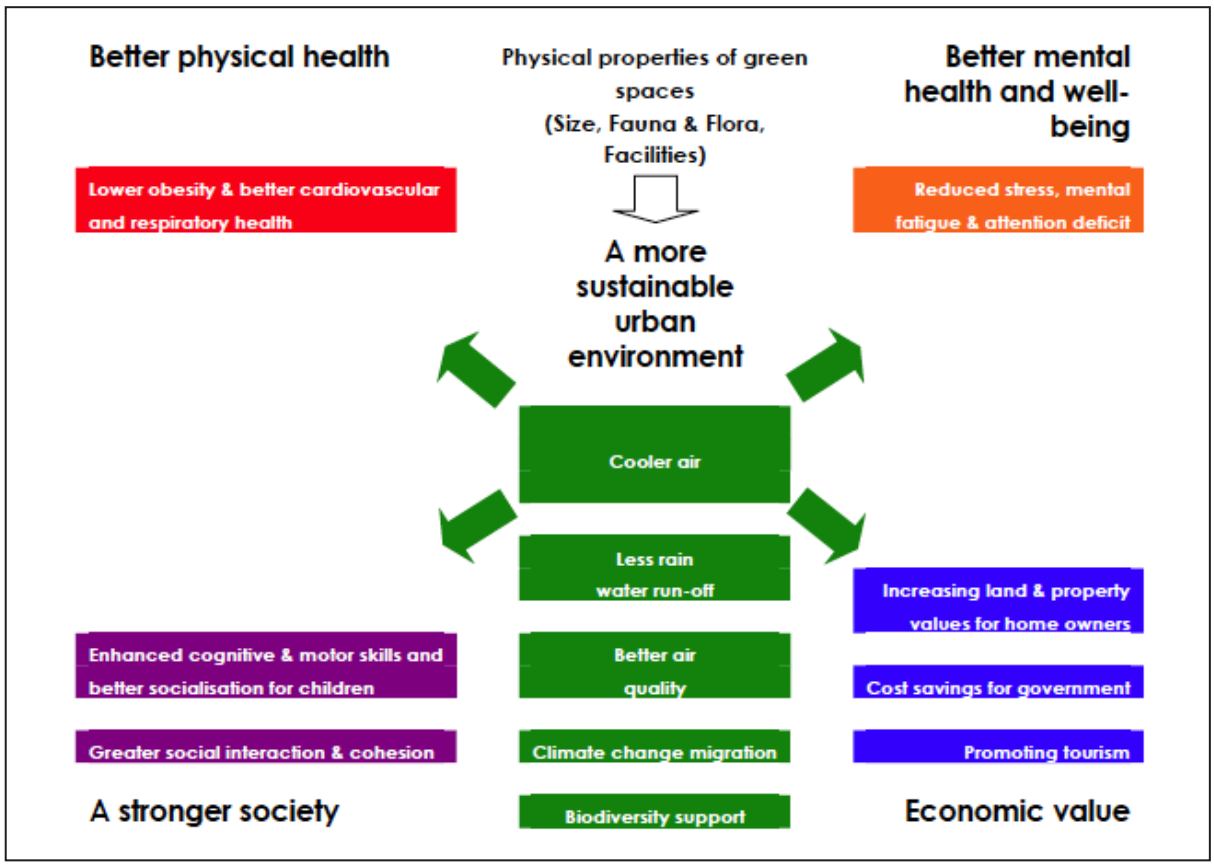
Environmental and Social Benefits

A wide range of co-benefits are provided by improving the quantity of and access to urban green spaces, in addition to increasing physical activity levels, including:

- Economic benefits of water and air pollution reduction (cost savings from avoided medical expenses)
- Reduced income-related health inequality, which weakens the effect of deprivation on health
- Positive effects on mental health from improved companionship and an increased sense of identity and belonging
- Increase in land and property values of surrounding areas and benefits to local economies
- Contribution to climate change mitigation via carbon sequestration and reduced energy consumption and climate change adaptation through reduced urban heat island effect and flooding incidents
- Potentially significant reductions in groundwater run-off

Improving the quality of and access to urban green spaces not only provide health benefits related to increased physical activity, but also generate a range of additional health, environmental and social benefits (see figure below). Some of these aspects are explained in more detail throughout this section, and are presented in an illustrative case study (see following Box).

[9] Faculty of Public Health (2010). Great Outdoors: How Our Natural Health Service Uses Green Space To Improve Wellbeing -An action report. Available for download at: http://www.fph.org.uk/uploads/r_great_outdoors.pdf



Source: (BOP, 2013: 21)

Figure 3. Benefits provided by urban green spaces

Other health and social benefits (beyond those relating directly to increased physical activity)
In addition to the outlined health benefits relating to increased physical activity, a number of additional potential advantages of increased existence and exposure to urban green spaces have been identified in the literature. In a study of Philadelphia's park system, for example, the economic benefits of water and air pollution reduction were highlighted as potentially enabling significant cost savings from avoided medical expenses; in 2007, the savings correlating to park use were estimated to be US$ 69,419,000 (AmericanRivers, 2012). In the UK's Hospital and green space programs, participants in the *Cardiac Branching Out-Style Program* were reported to have experienced such benefits as improved mood and wider peer networks, in addition to improved physical health. More concretely, every £1 that was spent on this activity was estimated to create £3.86 worth of social value (Munoz, 2012).

The Faculty of Public Health report (2010) further emphasizes that green spaces can not only serve as preventative tools, but can also support patient recovery and rehabilitation by speeding up post-operative recovery time and reducing the use of pain relief medicine. These effects stem from patients having access to and views of nature through their recovery room windows.

Regarding mental health, the Dutch case study on Bos es Lommer neighborhood which was completed as part of the TEEB report found in 2014 that with an additional 10% of green spaces in the area, the number of people suffering from depression would decrease by 130 and the costs involved in health care and absenteeism would subsequently be reduced by €800,000 (TEEB NL, 2012). The same study cautiously estimated that an up-scaling of the benefits of a green environment to 10 million people would produce benefits as high as €400 million (the majority of which would be associated with health care savings due to a 50,000 annual reduction in the number of employees reporting sick).

Finally, proximity to areas with green spaces has been linked to notably reduced income-related health inequality, which weakens the effect of deprivation on health[10] (Mitchell and Popham 2008), and levels of mental health (Barton and Pretty 2010) by improving companionship, sense of identity and belonging (Pinder et al 2009) and happiness (White et al 2013). Similarly, the use of green spaces has been found to have a positive impact on neighborhood satisfaction levels for local inhabitants, which could indicate a link with potential means to increase the level of social capital of a community, as well as increased levels of social interaction (Munoz, 2012).

Land and property values

A large body of evidence exists supporting the argument that investment in improving green spaces has a positive effect on land and property values of surrounding areas. Bettering the visual appeal of an area increases land and property prices and may benefit local economies, for example by encouraging further property development in an region and increasing local council tax incomes in the process. While results are varied and location-specific, Saraev (2012) provides evidence that the existence of a well-managed green space was found to result in average property premiums of 2.6% to 11.3% in neighboring areas.

Climate change mitigation and adaptation

Green spaces can play a significant role in climate change mitigation, and specifically in reducing carbon dioxide. A mature tree can, for example, save 22kg of carbon dioxide emissions per year.[11] Further evidence outlines the role of urban green spaces in climate change adaptation, such as providing shade in hot weather events, reducing the urban heat island effect, improving air quality and reducing noise pollution.

While the degree of effectiveness of green spaces varies largely by site and based on the local context, anecdotal evidence is nevertheless useful for providing an indication of the potential effects and relevance to global populations. The following table outlines several case study specific examples of the climate change adaptation and mitigation effects generated by urban green space projects.

Table 2. Climate change adaptation and mitigation effects of urban green space case studies

Project	Estimated benefits
The Mersey Forest	Net additional monetized benefit: £16000 per annum due to carbon sequestration in trees
Woodland planting in North Yorkshire to reduce flood risk	Value of climate regulation benefit (through carbon sequestration) over 100 years of planting 85 ha of woodland is £2.8 million
Scotland, Edinburgh	Optimum placement of shelterbelt trees can reduce energy consumption (heating costs) in offices in Scotland by up to 18%
Various sources	Building energy savings in the order of 3 to 9% from sheltering trees

Source: (Saraev, 2012: 26)

Rainwater runoff benefits

The potential of urban green areas to reduce rainwater runoff have been explored in several studies. In a 2012 Chinese study, the combined potential of Beijing's green spaces were estimated to store approximately 154 million cubic meters of rainwater, which equated to reducing the potential run-off by 2,494 cubic meters per hectare of green area (BOP, 2013). British researchers also explored the potential in Greater Manchester, and found that by increasing green ground cover in residential areas by 10%, run-off could be reduced in those areas by 4.9%; increasing tree cover by the same amount could lead to a further decrease by 5.7% (BOP, 2013).

[10] In greener areas, all-cause mortality rates are only 43 per cent higher for deprived groups, compared to 93 per cent higher in less green areas.

[11] Faculty of Public Health (2010). Great Outdoors: How Our Natural Health Service Uses Green Space To Improve Wellbeing -An action report. Available for download at: http://www.fph.org.uk/uploads/r_great_outdoors.pdf

Box 2: Case: Economic value of protected open space in southeastern Pennsylvania, USA

A study was conducted to quantify the benefits provided by open green space provision in southeastern Pennsylvania (USA), including 197,000 acres of parks, working farms, trails, nature preserves, and historic and cultural landscapes. Building off of previous valuation studies and using standard economic analysis techniques, the analysis indicates that protected open space adds significant value to the regional economy, including:

- Recreation and health: $795 million in annually avoided medical costs as a result of recreation activities (e.g. lower incidence of cardiovascular diseases, diabetes, depression, certain cancers, and obesity); $485 million in lost productivity costs avoided annually; $577 million in annual benefits for residents who recreate on protected open space
- Economic activity: 6,900 jobs created (e.g. public maintenance workers, park administrators, and rangers; guides and hospitality professionals catering to tourists who visit protected open space)
- Environmental services: $133 million in costs avoided as a result of the natural provision of environmental services (i.e. water supply, water quality, flood mitigation, wildlife habitat, air pollution removal, and the sequestration of carbon in yearly growth of trees on protected open space); specifically, It is estimated that local trees store ca. $61 million in carbon within existing biomass
- Property values: $16.3 billion added to the value of the local housing stock; $240 million in annual property and transfer tax revenue for local governments

Given that the above benefits accrue in different ways (e.g. direct revenue streams to individuals or governments, asset appreciation value, or avoided costs), the estimates provided should not be added together to produce a single aggregate value of protected open space in the southeastern Pennsylvania area.

Source: (Green Space Alliance et al, 2011)

Comments on Investment and Return on Investment

The growing number of inactivity-related health complications and their associated costs have been outlined in this chapter, as well as the potential of innovative investments in urban green spaces to help address this threat. The promising ratio of moderate investment to high return is an important final consideration in pursuing this innovation. To illustrate this point, the cost-benefit ratios of several urban green space investments are outlined below alongside their associated health advantages.

Taking the example of the Regeneris case study presented earlier, for example, every £1 invested will generate in the region of £3.50 (Net Present Value). Birmingham's 'Be Active' programme in the UK returned up to £23 in benefits for every £1 spent in terms of quality of life, reduced National Health Service use, productivity and other gains to the local authority. A cost-benefit ratio of 1 to 2.55 was also established for the UK's Green Gym infrastructure, with £2.55 being saved in the treatment of inactivity related illness for every £1 invested (BCTV, 2010). In the United States, similar findings have been published. For every $1 spent on trails, for example, $3 was saved in direct medical costs12. More generally, it can be said that investing US$ 1 in physical activity (referring to time and the equipment or space needed to perform the activity), result in US$ 3.20 in medical cost savings (Cicea, 2011).

1.3 Role of Innovation Policy

To realize the outlined benefits, it is necessary to understand the current state of affairs for this potential market for urban green space creation for health improvement in order to identify potential problems holding back innovation, and highlight the potential role of innovation policy.

[12] http://activelivingresearch.org/files/ALR_Infographic_ParksRecreation_Oct2012.jpg - infographic

Entrepreneurial Activities

- Most existing initiatives stem from the UK and United States, and are localized pilot projects or nationally coordinated actions
- The UK 'Natural Health Service' has approached the use of urban green spaces for health purposes as a business venture, and developed a 'NHS Business Plan' to centrally promote related opportunities.
- 'Exercise is Medicine' is a global campaign to encourage health care providers to include physical activity when designing treatment plans for patients. Several pioneer projects exist in the United States, such as 'Park Prescriptions' in Oregon or the reimbursement of state park entrance fees by a health insurance provider in California/Colorado.

There are several entrepreneurial activities that bring together health care and green space providers within an urban context to prevent and treat inactivity related illnesses. The largest numbers of initiatives stem from the UK and the United States and include localized pilot projects as well as nationally coordinated actions.

In the UK, initiatives for encouraging physical activity in green spaces started in 1995 when a general practitioner started to prescribe outdoor exercise instead of valium for depressive illness.[13] Since this time, several pioneer activities have followed suit to encourage the use of urban natural areas for combating physical inactivity. 'Green Gyms', for example, promote the participation of individuals in fitness activities outside of the confines of conventional gyms. The programs 'Walking for Health' follows similar lines and encourages individuals to take regular walks to improve their health; there are over 66,000 regular participants across the nation.

On a national level, the UK 'Natural Health Service' (NHS) was developed with support from the Department of Health to increase people's contact with nature as a means of preventing and treating illnesses. As part of this program, a NHS Forest tree planting project has been created to plant 1.3 million trees and thereby increase access to green space on or near to NHS land and encourage greater social cohesion between NHS sites and the local communities around them. Each healthcare site is responsible for finding its own funding for the desired number of trees, which can stem from internal funds or from local/national grants.

Recognizing the potential for capitalizing on the environment-health market, a NHS Business Plan was developed to offer "health commissioners a single point of access to a range of well-developed and evidence based natural environment focussed products to help tackle a range of health and wellbeing issues" (Natural Health Service, 2013)[14]. 'Products' include, for example, health walks (expert led walking activities tailored to individual needs to meet target exercise and physical activity levels), green gyms (physical activity in the local natural environment), and forest schools (outdoor play and learning to inspire individuals through positive outdoor experiences).[15]

An established global movement entitled 'Exercise is Medicine'[16] encourages health care providers to include physical activity when designing treatment plans for patients. Using this concept as a basis and integrating the value of natural areas and green spaces for carrying out the prescribed exercise is a new, still largely untapped market, but several pioneer examples exist. In the state of Oregon in the United States, a state-wide Comprehensive Outdoor Recreation Plan was drafted in 2008 to generate partnerships between local park and recreation providers and the medical community. The underlying principle is to increase awareness amongst health care providers about outdoor recreation opportunities, and therewith encourage the writing of 'Park Prescriptions' for patients. These prescriptions enable inactive individuals to

[13] Maas, J., Verheij, R.A (2007). Are health benefits of physical activity in natural environments used in primary care by general practitioners in The Netherlands? Urban Forestry & Urban Greening. 6(4), 227-233.
[14] Natural Health Service (2013). Natural Health Service – Executive Summary. Available for download at: http://www.naturalhealthservice.org.uk/naturalhealthservice_execsum.pdf
[15] See http://www.naturalhealthservice.org.uk/naturalhealthservice_productsheets.pdf for more detailed information.
[16] http://www.exerciseismedicine.org/

enrol in outdoor classes at nearby park and recreation facilities, save medical costs in the long-term, and generate funds for the park.[17] Similarly, the 'SeeChange Health' health insurance company provides financial rewards to members who take action to improve and manage their health[18]. This includes, for example, reimbursing patients for state park visits to encourage members to be active in the outdoors. The National Recreation and Park Association has also recently published a collection of success stories for 'park prescriptions'[19].

Knowledge Development

- A wide evidence base exists which connects (urban) green spaces to potential health (and other) benefits
- Additional research is needed to quantify benefits and standardize indicators and data collection methods to better assess effectiveness

A substantial evidence body exists, which highlights the benefits of green spaces and urban parks on human health as well as the other co-benefits described. Much of this evidence base is qualitative, although a growing body focuses on quantifying the effectiveness of certain types of green spaces on specific health ailments (both as treatment and prevention). Several guidance documents aimed at various stakeholder groups have also been produced, targeting e.g. individuals (how to better utilize parks for health benefits), city planners (approaches to integrating green spaces into urban spatial plans), health insurance providers (practical considerations and suggestions for incorporating green areas into health facility properties), and general practitioners (outlining local opportunities for outdoor fitness which can be utilized as part of 'green' or 'park prescriptions'. While the majority of the current evidence basis stems from New Zealand (where the term 'green prescription' originates), the UK, and the United States, additional pilot projects and scientific research has been produced in other regions.

As illustrated above, several schemes have capitalized on this knowledge to create programs encouraging urban populations to utilize natural areas with more regularity and therewith help reduce national healthcare costs. However, additional research is necessary in terms of quantifying benefits and particularly in standardizing indicators and data collection methods to better assess the effectiveness of existing programs on specific health outcomes. Further guidance documents targeting specific stakeholder groups are also necessary to increase the level of uptake across Europe. Finally, organisational frameworks are necessary which allow further funding to flow into this field and specifically commission research in this area.

Knowledge Diffusion through Networks

- Two national campaigns are taking place in the UK and the United States in order to increase the amount of research surrounding and funds invested in 'green healthcare'.
- Substantial gaps exist around the world and at an EU level to support such movements and further the evidence base and uptake of this innovation.

While in their infancy, several helpful examples of networks exist in the UK and the United States that aim to increase the application of this innovation. In the UK, the Centre for Sustainable Healthcare (formerly called 'The Campaign for Greener Healthcare') works "on the interface between health and sustainability to bring health messages into the centre of the climate change agenda and to transform healthcare for a

[17] Bashir, Z (2012). Parks a prescription for health. Online article for US Parks and Recreation. Accessed on 1.12.14 at: http://www.parksandrecreation.org/2012/April/Parks-a-Prescription-for-Health/
[18] More information available at: http://partners.seechangehealth.com/offers/caco-state-park-fee-reimbursement/
[19] National Recreation and Park Association (2014). Prescribing parks for better health: Success stories. Available for download at: http://www.nrpa.org/uploadedFiles/nrpa.org/Grants_and_Partners/Health_and_Livability/FINAL%20Prescribing%20Parks%20for%20Better%20Health%20Success%20Stories.pdf.

sustainable future"[20]. The team was established in 2008 and the resultant campaign is at the forefront of promoting this nexus, receiving interest from both the environmental and health sectors. The main fields of work center around engagement, knowledge sharing and transforming ideas in order to develop partnerships, exchange experiences, improve current evidence, and ultimately transform the healthcare systems.

In the United States, the National Park and Recreation Association (NRPA) is collaborating with the Centres for Disease Control and Prevention and the Institute at the Golden Gate in California to support the idea of 'park prescriptions' evolving into a best practice approach in preventative health. To this end, a national agenda is being developed to increase the understanding and acceptance of such green prescriptions and therewith their uptake. In 2013, NRPA distributed grants to five American communities to develop and enhance park prescription programs and strengthen the linkages between these two sectors. A year later, they published a report outlining success stories of 'Prescribing parks for better health' from across the country in order to begin raising awareness and lobby for greater investment in this field.

Coordination between research activities, guidance documents and pilot projects is largely lacking. In particular, a centralized approach is missing on the European level that would help to support these efforts and provide tools for establishing cross-sectoral collaboration.

Guidance of the Search

The push to increase the use of nature based solutions to address health problems, and particularly the growing threat of inactivity-related diseases, can be linked with several European policies as well as national actions. The European Health Strategy (2007) and Investing in Health (2013) have the goal of promoting an active lifestyle consisting of physical activity and healthy eating and recognize the potential of green space for health promotion. The Resource Efficiency Roadmap (2011) has the priority objective of protecting "natural capital"[1] for continued health and social benefits and achieving integrative urban planning to achieve sustainable EU cities (including provisioning green space).

Market Formation

There is considerable scope to increase the number of initiatives and level of cooperation between green exercise and local health care provision. The creation and maintenance of urban green spaces should be promoted for their ability to not only reduce health care costs, but also to assist healthcare facilities in meeting corporate social responsibility targets and performance measures, reduce energy costs, meet sustainability goals.[21] Opportunities for green or 'park' prescriptions and outdoor recovery programs should be augmented, opening up the niche for new investment models to bridge the gap between health care and natural area provision and combat inactivity-related health problems upstream. The potential for translating available programs that were developed in a more traditional healthcare setting into emerging Park Prescriptions programs is immense, as well as for repurposing existing park programs to suit the needs of health care practitioners prescribing exercise.[22]

Resources Mobilization

This chapter has outlined the increasing cost of inactivity-related healthcare costs, and the potential to reduce these demands by utilizing urban green spaces. Another key factor in encouraging innovation

[20] http://www.env-health.org/members/article/the-centre-for-sustainable

[21] Shackell, A. and Walter, R. (2012). Greenspace design for health and well-being. Forestry Commission Practice Guide. Forestry Commission, Edinburgh. i–vi + 1–70 pp.

[22] Institute at the Golden Gate (nd). Park Prescriptions: Profiles and Resources for Good Health from the Great Outdoors. Available for download at: http://atfiles.org/files/pdf/park-prescriptions-2010.pdf.

within this nexus is the significant financial investment necessary to maintain and create such areas. In the UK alone, it is estimated that the cost of maintaining and renovating urban green space was about £700 million in 2004-05.[23]

Without augmented levels of investment and new financing approaches, it will not be possible to exploit the full potential of urban green spaces for reducing inactivity-related expenses. Here, new partnerships are needed with other government agencies (e.g. between park and recreation agencies and health departments) or with private individuals and corporations. Additional support can come from, for example, the utilization of corporate 'wellness programs' which pay their employees incentives for exercising in order to gain returns in the form of improved health and thus reduced absences.

Creation of Legitimacy

- Increased uptake of this innovation requires: raising the profile of green exercise across sectors, encouraging partnerships and investment in related services and increasing the level of confidence in the effectiveness of green exercise prescriptions.

While evidence of the multiple benefits of green spaces is substantial, realizing their potential for addressing the growing problem of inactivity is dependent upon several factors. It is of key importance to raise the profile of green exercise across sectors, encourage partnerships and investment in related services, and increase the level of confidence amongst the general public that green exercise 'prescriptions' are as effective as drugs in preventing and treating many of the illnesses associated with physical inactivity.[24] Further activities require logistical support, and the availability of recreational opportunities within close proximity to the local health care facilities or residences of patients.

Summary and Outcomes

Figure 4. Fulfilment of innovation system functions: Cost Savings from Health Provision by Green Urban Space

[23] UK National Audit Office (2006) Enhancing Urban Green Space. Available for download at: http://www.nao.org.uk/publications/0506/enhancing_urban_green_space.aspx.
[24] UK Department of Health (2010). White Paper: Healthy Lives, Healthy People: our strategy for public health in England. Available for download at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/216096/dh_127424.pdf

As has been highlighted throughout this chapter, several barriers challenge the implementation of the outlined innovation. A key factor currently limiting the collaboration between urban green areas and the health care sector is the lack of information and practical guidance available. While growing numbers of practitioners are recognizing the value of green and park prescriptions for their patients, it is commonly unclear which local natural spaces are suitable for meeting their needs and how they can best be utilized to meet given health objectives. Communication is also absent in the opposite direction, emphasizing the need for local park representatives to better communicate and cooperate with medical staff to increase awareness of existing services and the potential benefits. In short, local strategic partnerships should be supported to optimize the use and effectiveness of urban green spaces for the prevention and treatment of inactivity-related illnesses. Additional research continues to be necessary on the market and non-market benefits of urban green spaces and the development of standardized indicators by which to measure the effectiveness of such areas for specific health objectives. Finally, dissemination is crucial to raise awareness of existing models, projects, networks, resources and cost-benefit outcomes.

On the European level, policy interventions can support these needs through e.g. the commissioning of targeted action-based research to put these finance models in place, awareness-raising of park prescriptions and potential benefits, investment support for the creation of green spaces via targeted loans and grants for pilot projects, and the fostering of a European platform or network coordinating action in this field. Exercise prescription schemes can also be highlighted as best practice and national campaigns such as "Walking for Health" and "Green Gyms" can be encouraged.

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2. Specific Narrative on "Use of Natural Solutions for Protecting Cities from Flooding"

2.1 Introduction

Coverage of the SC5 Topics

Climate action	Resource efficiency	Raw materials
✓	✓	
Increased co_2 storage in created/restored ecosystems	Reduced use of concrete/cement	

Background to the Innovation Opportunity: Problem and Innovation

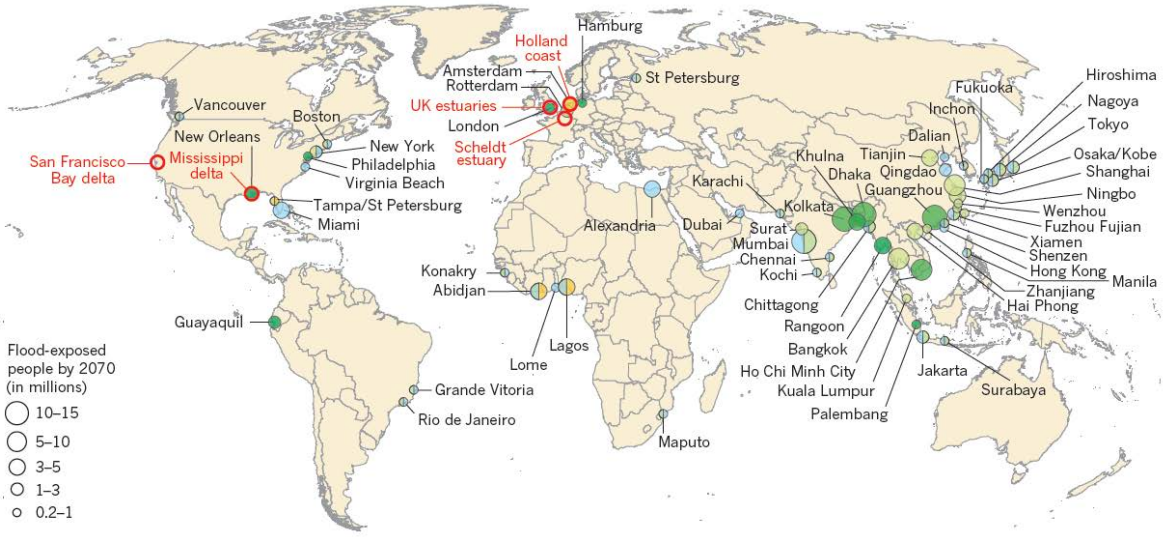
- In Europe and globally, climate change effects will lead to an increased risk of coastal flooding events in the period to 2070.
- Cities located along the coasts and in river deltas will be most affected.
- In the EU, up to 425,000 additional people might be affected by coastal flooding by 2080 and the estimated expected annual damage caused by coastal flooding might be as high as € 25.4 billion.
- On a global level, potential damage costs in affected regions might increase by factor 10 until 2070.
- Nature-based solutions can be cost-effective ways to achieve coastal protection goals; compared to traditional engineered approaches they offer additional environmental and socio-economic benefits.
- Within the expected market for coastal defence solutions, ecosystem-based approach can be expected to cover a certain share if they are included in coastal defence strategies, e.g. as part of a 'hybrid approach'.
- European enterprises, which are currently important market players in the development of traditional coastal protection measures, can be seen to play a major role in this future market if the innovation system is appropriately supported.

Increasing Coastal City Flood Risks

In a recent study, Temmerman et al. (2013) summarise the current knowledge and future scenarios regarding coastal flooding events and the effects they may have on coastal communities: "Coastal flood disasters are an ever-present threat to coastal societies. Recent examples include the flooding caused by Hurricane Katrina in 2005 in New Orleans, Cyclone Nargis in 2008 in southern Myanmar, Hurricane Sandy in 2012 in New York, and Typhoon Haiyan last month in the central Philippines. Such flood disasters are caused by extreme storm surges that can raise the local sea level by several metres through severe wind, waves and atmospheric pressure conditions.

Coastal flood risks are likely to increase over the coming decades owing to global and regional changes that include increasing storm intensity, accelerating sea-level rise and land subsidence. Growing coastal populations mean more people will be exposed to these increasing flood risks5. At least 40 million people and US$3,000 billion of assets are located in flood-prone coastal cities today, and these are expected to

increase to 150 million people and $35,000 billion by 2070." Figure 5 provides an overview of the most affected cities globally and, based on the assessment of Temmerman et al. (2013), the potential for applying ecosystem-based defense measures (green colour).



Source: (Temmerman et al. 2013)

Figure 5. Global need for coastal flood protection, and large-scale examples and potential application of ecosystem-based defense

From Figure 5 it becomes apparent that the greatest potential for the application of nature-based solutions in the context of coastal defense strategies lies in Southeast Asia. Thus, for European enterprises the future market will to a large extent be an export market. However, Europe will also be affected from increased coastal flooding events. Fenn et al. (2014) estimate the number of affected people by coastal flooding in the EU and the expected annual damages by 2080.

According to these estimates, up to 425,000 additional people might be affected from coastal flooding by the 2080s and annual damages up to €25.4 billion might occur (see Table 3). Even though these figures are not confined to urban areas, one can assume that most of the damage will occur in coastal cities and populated estuaries, particularly in the Netherlands and in the UK.

Table 3. Coastal flooding scenarios for the EU

Estimated number of people flooded annually - coastal flooding[(1)]	Current: 10,000 By the 2080s: additional 121,000 to 425,000 (A1B scenario) or additional 40,000 to 145,000 (E1 scenario)
Estimated expected annual damages from coastal flooding[(1)]	Current: €1.9 billion By the 2080s: €25.4 billion (A1B scenario) or €17.4 billion (E1 scenario)

Source: (Fenn et al. 2014)

These numbers show that there is a need for action – and a potential global market for European technologies and skills. While European companies are already successful in exporting *traditional* flood protection technologies and skills to affected regions, the potential for nature-based solutions is imminent.[25]

[25] This statement will be substantiated by conducting interviews with key experts at companies such as Deltares (NL). Interviews will be conducted between March and May 2015.

The Innovation

Nature-based solutions in coastal protection can take the form of wetland or salt marsh creation, beach nourishment, oyster reef creation, or mangrove protection. According to Ysebaert (2014), the main arguments for applying ecosystem-based approaches to coastal flood protection are:

1. They are adaptable;
2. They are resilient, robust and sustainable;
3. They lead to cost reduction;
4. They provide benefits (i.e. ecosystem services).

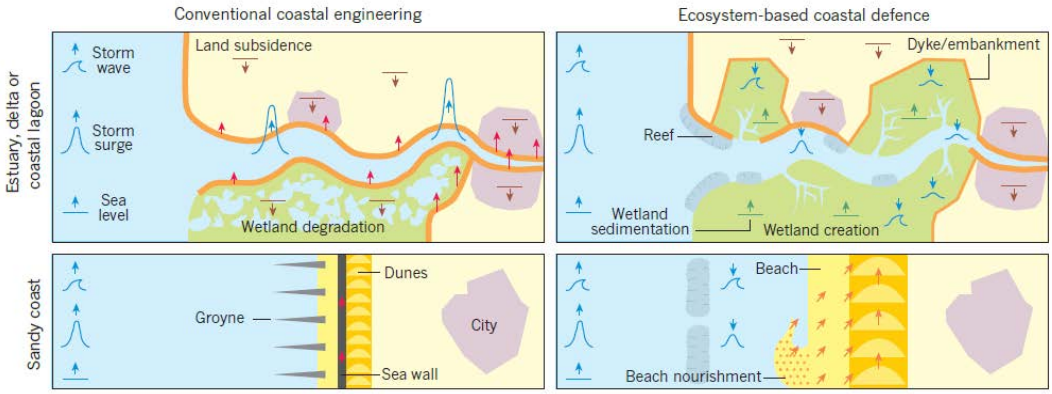
These arguments have, for instance, been taken up by management bodies in New York City where oyster reefs are being created to protect the shoreline from waves. While it is acknowledged that more research is required to assess the effectiveness of nature-based solutions with regard to mitigating major flooding events (e.g. the potential to reduce storm surges), initial research results show that marshes, for instance, are significantly effective in reducing waves and erosion, and in stabilising and growing shorelines (Shepard et al. 2011). In the case of New York City, managers decided to go for a 'hybrid approach', i.e. the combination of traditional and nature-based solutions for coastal flood protection.

An example which shows that nature-based solutions can likewise be implemented in rural areas is the Wallasea Island Wild Coast Project in the United Kingdom. Wallasea Island was reclaimed from the ocean over 400 years ago and converted to agricultural land. 'Grey' infrastructure flood defences were constructed, but have recently been found to no longer be economically viable, making continued public expenditures unlikely and putting the surrounding 12,100 ha floodplain at risk. The aim of the project was to combat the threats from climate change and coastal flooding by restoring the wetland landscape of mudflats and saltmarshes, lagoons and pasture.

Nature-based solutions for flood protection have also been evaluated and implemented within the long-term flood risk management plan for the Scheldt estuary in the Netherlands. Here, planners had to choose between a set of potential flood protection measures, including the creation of a storm surge barrier, dyke heightening and additional floodplains with or without the development of wetlands. In a comprehensive cost-benefit assessment, researchers found that while drastic measures such as a storm surge barrier offer more protection for very extreme storms, a combination of dykes and floodplains can offer higher benefits at lower costs.

These examples show that nature-based solutions are starting to be recognized by decision-makers and that they can potentially play an important role in future coastal protection strategy in Europe and beyond.

Taking the example of wetland creation, Figure 6 below describes the concept of ecosystem-based coastal defence approaches versus conventional coastal engineering solutions. The table below lists different types of nature-based flood protection measures and describes their coastal protection functions.



Source: (Temmerman et al. 2013)

Figure 6. Conventional vs. ecosystem-based coastal defence measures

Table 4. Overview of nature-based coastal protection solutions and their specific functions

Traditional approach	Nature-based approach: creation/restoration of...	Nature-based coastal protection functions
Dikes and embankments	Coral reefs	Wave attenuation and erosion protection (NOAA 2008)
	Mangroves	Shoreline stabilization via wave attenuation (Gedan et al. 2011, Zhang et al. 2012)
	Oyster beds	Wave attenuation and erosion protection (Piazza et al. 2005; Beck et al. 2011)
	Sea and dune grasses	Coastal erosion protection (Coastal Dune Protection & Restoration 2008)
	Coastal salt marshes	Wave attenuation, shoreline stabilization via soil accretion, reducing erosion, and increases in marsh elevation (Shepard et al. 2011)
	Coastal wetlands	Enlarged water storage and friction, lower inland storm surges (Wamsley et al. 2010)
	Beaches and dunes	Long-term build-up with rising sea levels (Temmerman et al. 2013)

2.2 Estimation of the Investment Case

Future Markets

Besides the EU market, i.e. the need for increased coastal protection in European coastal cities and estuaries, there is considerable potential for a global export market for European technologies and skills related to ecosystem-based coastal flood protection. The tables below show the most affected cities by 2070 (based on exposed population) and the exposed assets in urban agglomeration under the same scenario. These cities and countries, most of them are emerging economies, will have to invest considerable amounts in flood protection technologies over the next decades.

While it is not clear to what extent these countries will favour nature-based solutions over traditional approaches, it can be assumed that nature-based solutions will be part of the picture.26 How large a share of the flood protection market is taken by nature-based solutions is likely to depend on success in over-coming systemic barriers to innovation diffusion. In addition, potential technical and social barriers at the site need to be taken into account when developing nature-based solutions for coastal flood protection.

[26] While a comprehensive assessment of the most exposed areas/cities in terms of the potential for applying NBS would go beyond the scope of this study, the planned expert interviews (March – May 2015) might result in more detailed information regarding this aspect.

Table 5. Most affected cities by 2070

Rank	Country	Urban Agglomeration	Exposed Population Current	Exposed Population Future
1	INDIA	Kolkata (Calcutta)	1,929,000	14,014,000
2	INDIA	Mumbai (Bombay)	2,787,000	11,418,000
3	BANGLADESH	Dhaka	844,000	11,135,000
4	CHINA	Guangzhou	2,718,000	10,333,000
5	VIETNAM	Ho Chi Minh City	1,931,000	9,216,000
6	CHINA	Shanghai	2,353,000	5,451,000
7	THAILAND	Bangkok	907,000	5,138,000
8	MYANMAR	Rangoon	510,000	4,965,000
9	USA	Miami	2,003,000	4,795,000
10	VIETNAM	Hai Phòng	794,000	4,711,000
11	EGYPT	Alexandria	1,330,000	4,375,000
12	CHINA	Tianjin	956,000	3,790,000
13	BANGLADESH	Khulna	441,000	3,641,000
14	CHINA	Ningbo	299,000	3,305,000
15	NIGERIA	Lagos	357,000	3,229,000
16	CÔTE D'IVOIRE	Abidjan	519,000	3,110,000
17	USA	New York-Newark	1,540,000	2,931,000
18	BANGLADESH	Chittagong	255,000	2,866,000
19	JAPAN	Tokyo	1,110,000	2,521,000
20	INDONESIA	Jakarta	513,000	2,248,000

Source: (Nicholls et al. 2007)

Table 6. Damage potential by in the most affected regions by 2070

Rank	Country	Urban Agglomeration	Exposed Assets Current ($Billion)	Exposed Assets Future ($Billion)
1	USA	Miami	416.29	3,513.04
2	CHINA	Guangzhou	84.17	3,357.72
3	USA	New York-Newark	320.20	2,147.35
4	INDIA	Kolkata (Calcutta)	31.99	1,961.44
5	CHINA	Shanghai	72.86	1,771.17
6	INDIA	Mumbai	46.20	1,598.05
7	CHINA	Tianjin	29.62	1,231.48
8	JAPAN	Tokyo	174.29	1,207.07
9	CHINA,	Hong Kong	35.94	1,163.89
10	THAILAND	Bangkok	38.72	1,117.54
11	CHINA	Ningbo	9.26	1,073.93
12	USA	New Orleans	233.69	1,013.45
13	JAPAN	Osaka-Kobe	215.62	968.96
14	NETHERLANDS	Amsterdam	128.33	843.70
15	NETHERLANDS	Rotterdam	114.89	825.68
16	VIETNAM	Ho Chi Minh City	26.86	652.82
17	JAPAN	Nagoya	109.22	623.42
18	CHINA	Qingdao	2.72	601.59
19	USA	Virginia Beach	84.64	581.69
20	EGYPT	Alexandria	28.46	563.28

Source: (Nicholls et al. 2007)

Jobs

So far, limited empirical evidence exists specifically with regard to jobs created by nature-based solutions for coastal flood protection in an urban context. For the Wallasea Island Wild Coast project, Eftec (2008) estimated that implementation of the project would have a variety of employment impacts in the local economy (Essex) and the wider region. The table below shows that up to 16.6 net jobs can be created in the local economy and up to 20.9 in the wider region over a 10-year period.

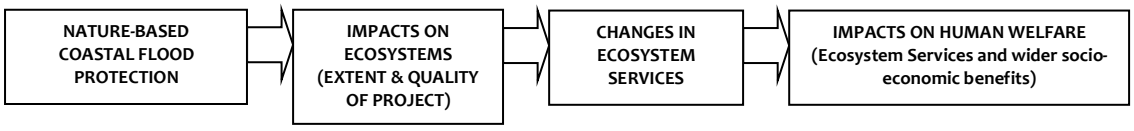
Table 7. Estimated employment impacts of the Wallasea Island Project, full-time equivalent (FTE)

Economic activity	FTE jobs safeguarded		
	Local Economy (Essex) over 10 yrs	EEDA Region, over 10 yrs	Longer-term (10 - 20 yrs), EEDA Region
Oyster fishery	10	10	10
Wallasea infrastructure	c 100	c. 100	c. 100
Total jobs safeguarded	**110**	**110**	**110**
	Additional FTE jobs created		
Direct employment at site	8.9	10.9	4
Site development spending	5.2	7.5	0
Sheep grazing	0	0	0.7
Oyster fishery	2.5	2.5	5 -10
Visitor spending	1	1	0 - 5.9
Gross jobs created	17.6	21.9	9.7 - 20.6
Lost agricultural employment	- 1	- 1	0
Net jobs created	**16.6**	**20.9**	**9.7 - 20.6**

In addition to the jobs created on-site, it can be assumed that new jobs would be created in the research sector and in enterprises which specialize in the design and construction of nature-based solutions. The extent of these jobs depends on the extent to which nature-based solutions capture market share. Existing jobs in enterprises currently dealing with the development of 'traditional' solutions for flood protection would probably (partially) shift towards the development of nature-based solutions.

Environmental Benefits

Besides direct economic impacts (e.g. jobs created), the environmental benefits (ecosystem services) provided by nature-based solutions are probably the strongest argument for supporting their implementation. The evaluation of the environmental and socio-economic benefits provided by nature-based flood protection is based on the following conceptual framework:



Source: Adapted from Defra (2007) – Framework for Ecosystem Services Valuation

Figure 7. Benefits of nature-based coastal flood protection

The additional benefits provided by ecosystem services have been valued in many instances (e.g. Turner et al. 2007 and Barbier et al. 2011). In the Netherlands, Broekx et al. (2011) have conducted a comprehensive cost-benefit analysis for the establishment of a long-term flood risk management plan for the Scheldt estuary. Taking into account the ecosystem services provided by an ecosystem-based approach, they

concluded that out of several alternatives "a combination of dykes and floodplains can offer higher benefits at lower costs". The results of their valuation exercise are summarised in the tables below.

Table 8. Valuation approach in the case of the Scheldt estuary, the Netherlands

Table 5 Valuation of ecosystem benefits (€/ha year) for newly developed ecosystem types (controlled inundation areas, reduced tidal areas, wetlands)

Function	Quantification (unit/ha.year)					Valuation (€/unit)	
Ecosystem type *Watertype*	*FCA* *Fresh*	*CRT* *Fresh*	*CRT* *Salt-brackish*	*Wetland* *Fresh*	*Source*	*Value*	*Source*
Production functions (fish, aquaculture, wood)	pm	pm	pm	pm	pm	pm	pm
Regulation functions							
Denitrification		176 kg	107 kg	102 kg	MOSES: Soetaert and Herman (1995a, b)	2.5	CIW (1999)
Decrease in N washed away		252 kg	252 kg	252 kg	VMM (2003)	2.5	CIW (1999)
Decrease in P washed away		31 kg	31 kg	31 kg	VMM (2003)	8.5	CIW (1999)
Aeration	pm	23 mol/ha/year	10 mol/ha/year	pm	MOSES: Soetaert and Herman (1995a, b)	0.14	Witteveen and Bos (2004)
Erosion protection		2 m^3	2 m^3	2 m^3	Expert judgement	5	Witteveen and Bos (2004)
Climate		6.8 ton/ha/reed	6.8 ton/ha/reed	pm	Goosen et al. (1996)	66	Bickel and Friedrich (2005)
Regulation functions only first 15 years after construction							
Sedimentation		200 m^3	200 m^3	4 m^3	Expert judgement	5	Witteveen and Bos (2004)
C-burial		1.5 ton	1.5 ton	pm	MOSES: Soetaert and Herman (1995a, b)	66	Bickel and Friedrich (2005)
N-burial		148 kg	148 kg	pm	MOSES: Soetaert and Herman (1995a, b)	2.5	CIW (1999)
P-burial		25 kg	25 kg	pm	Dennhardt and Meyerhoff (2002)	8.5	CIW (1999)
Recreational amenities	25 Visits/day/km dyke				Witteveen and Bos (2004)	1.68	Witteveen and Bos (2004)
Non-use value						*pm*	

Source: (Broekx et al. 2011)

Table 9. Sensitivity of costs and benefits of the optimal bottom-up solution for various assumptions on sea level rise

Table 8 Sensitivity of costs and benefits of the optimal bottom-up solution for various assumptions on sea level rise

Sea level rise between 2100 and 2000	0 cm	30 cm	60 cm (baseline)	90 cm	120 cm
Investment and maintenance costs	132	132	132	132	132
Loss of agriculture	12	12	12	12	12
Flood protection benefits	138	437	737	1.036	1.335
Ecological benefits and visual intrusion	4	4	4	4	4
Total net benefits	−2	297	596	896	1.195
Payback period (years)	92	24	16	12	10

Figures are net present values in million Euro 2002, based on central estimates for sea level rise, economic growth and discounting (4%). Non-use values for nature development are not included in the figures

A similar cost-benefit analysis has been carried out for the Wallasea Island Wild Coast project, although on a more general level (Eftec, 2008). In this specific case, it was found that the vast majority of costs were incurred at the beginning of the project (for modelling, planning, permissions, land purchasing etc). The financial costs of the project that are related to management and administration activities were estimated to be on the order of £190,000 per year (excluding staff costs). Costs related to ecosystem maintenance and/or restoration included over £5 million of land purchase and physical implementation works of around £17.5 million, mainly involving deposition of material on Wallasea Island and managed realignment through controlled breaches of the existing sea wall. The project also involved opportunity costs, such as the loss of

farmland in the area, and potential negative impacts on recreational yachting and oyster fisheries. It was determined, however, that these negative impacts would have been more significant in the (inevitable) event of an unmanaged breach. In summary, none of the above land-use restrictions has led to reductions in land values.

On the benefits side, it was estimated that intertidal habitat is capable of capturing up to 2.2 tonnes of carbon per hectare per year, while the same land used for farming would act as a net source of carbon. The primary benefits of the project are environmental (habitat creation), but secondary benefits also include waterborne nutrient processing and provision of fish feedings and nursery habitats. The benefits generated from carbon sequestration were valued at £1.7 million over a period of 50 years (Eftec, 2008). In addition, the authors found that society at large would benefit from avoided expenditures for flood defence infrastructure (ca. £5 – £10 million) and from the avoided loss of built assets on Wallasea worth £3.1 million under moderate flood event scenarios.

Summary and Estimation of Return on Investment

As shown by Naumann et al. (2011), comparing the costs and benefits of ecosystem-based projects to those of engineered approaches (i.e. the construction of traditional flood prevention systems or traditional habitat management practices) is rather difficult. In most cases, the limited evidence base does not allow for a profound monetary assessment of costs and benefits to be compared to those associated with traditional engineered approaches. However, evidence from selected case studies suggests that investment and management costs are not necessarily higher than in the case of traditional engineered approaches. For instance, the costs of dyke redevelopments are estimated to be as high as €1 million per km. With regard to return on investment, Broekx et al. (2011) provide estimations of the payback periods for a selected (ecosystem-based) flood protection measure under different scenarios. They show that the payback period depends on the expected sea-level rise, i.e. the payback period will be shorter if the sea level-increase is higher.

Among the projects reviewed by Naumann et al. (2011), some aim at regulating flood events by providing additional retention areas along rivers and coasts. The created or maintained ecosystem often provides regulating services such as nutrient processing and aquifer recharge. The construction of traditional embankments and dykes, on the other hand, usually leads to increased water drainage and has a negative impact on water purification and local water supply. Gedan et al. (2011) provide an overview of the ability of coastal wetlands to stabilize shorelines and protect coastal communities. They find that ecosystem-based approaches (mainly mangrove and salt marsh vegetation) can protect the shoreline from erosion, storm surge, and potentially small tsunami waves. Such nature-based solutions may reduce wave heights, property damage, and human deaths in the affected regions.

2.3 Role of Innovation Policy

A major advantage of nature-based solutions for flood protection is that, besides flood protection, they offer additional benefits by contributing to climate change mitigation and increased resource efficiency. The development, design and implementation of natural solutions for protecting cities from flooding, however, requires combined efforts from all actors involved. Experiences from the Netherlands[27] show that "the private sector, knowledge institutes and public users need to unite their skill and expertise through an integrated effort to achieve a cohesive, practical approach to determining and mitigating flood risk" (Vermeer et al. 2012). Apart from the technical (i.e. construction) side, increased research is particularly needed on the effectiveness of nature-based solutions for flood protection (Temmerman et al. 2013).

[27] Specific cases/projects will be identified and interviews with planners/project officers will be conducted between March and May 2015 in order to discuss potentials, barriers, advantages and disadvantages of NBS in the Dutch context.

Entrepreneurial Activities

The Netherlands, where more than 85% of the coastal zones are located five metres below sea-level, is highly vulnerable to coastal floods. This situation has lead to highly research and innovation structures in the field of coastal protection. Specialised research institutes such as Deltares (http://www.deltares.nl) have been created, which are highly experienced in the design and construction of (traditional) coastal defense measures. The Flood Control 2015 programme (http://www.floodcontrol2015.com/) is a five-year innovation programme, which provides a best-practice example for the collaboration between private companies and applied research institutes on flood protection measures. These kinds of collaborations seem most promising when it comes to the further development of nature-based solution for urban flood protection. A few promising case studies already exist in the Netherlands.[28] It can be assumed that entrepreneurial activities will pick up in countries where there is already some existing knowledge available, particularly the Netherlands, the UK, Germany and Denmark.

Knowledge Development[29]

The knowledge required for the effective implementation of nature-based solutions for coastal flood protection can be divided into two parts. On the one hand, there is the technical side, i.e. the design and construction of flood protection measures. Here, innovative measures related to ecosystem-based approaches need to (further) developed and tested. On the other hand, additional research is needed on the effectiveness of nature-based solutions. So far, only few long-term studies exist and the available knowledge is mostly limited to tidal marsh creation (Temmerman et al. 2013). Thus, ecologists and hydrologists and experts from other disciplines will need to increase their efforts to produce reliable research results with regard to the effectiveness of nature-based solutions in the context of coastal protection strategies. Fountain (2013) states that "while some natural barriers like dunes have been shown to be very effective at absorbing much of a storm's energy, it is less clear that marshes, oyster reefs, kelp beds or the like provide much protection. [...] Interactions between a storm and natural features are complex, and the dynamics of every storm are different, making protection difficult to quantify." Thus, research will be needed on the effectiveness of alternative solutions in different geographic contexts.

Knowledge Diffusion through Networks

It has already been stated that the Netherlands provide a good example for the effectiveness of public-private collaborations when it comes to the investigation of effective flood protection measures. It can be assumed that knowledge diffusion on the topic of nature-based solutions for coastal flood protection can take place through similar or even through the existing networks. The existing market players, which currently collaborate in the context of innovation programmes, joint industry projects and EU-funded projects, will have to take up nature-based approaches in their research and innovation strategies. It is realistic to assume that many of the actors, which are currently involved in developing 'traditional' flood protection measures, would increase their involvement in the development of nature-based solutions if this will become part of a public strategy.

[28] Specific cases/projects will be identified and interviews with planners/project officers will be conducted between March and May 2015 in order to discuss potentials, barriers, advantages and disadvantages of NBS in the Dutch context.

[29] The main conclusion would be that research needs to be promoted to a) further develop NBS and b) to assess the effectiveness of NBS. This statement will be discussed with relevant experts in the context of the planed interviews (March – May 2015).

Guidance of the Search

Innovation in the field of nature-based solutions for coastal flood protection is unlikely to take place in the absence of public money which supports research efforts. Already in 2011, the European Commission has published a note entitled 'Towards Better Environmental Options for Flood risk management' (European Commission 2011). Thus, there are signs for increased awareness among policy-makers. This could eventually lead to the integration of nature-based solutions into coastal protection strategies and the reallocation of available funds.

Market Formation

A prerequisite for the formation of a (global) market for nature-based solutions for coastal food protection in an urban context is certainly the availability of reliable research results with regard to the effectiveness of these solutions. However, initial results show that nature-based solutions are effective and offer additional benefits to society. In the previous sections, a considerable global market potential for coastal defence measures in an urban context has been identified over the coming decades. Whether nature-based solution will cover a big or a small share of this market will largely depend on public strategies, i.e. the decision on whether ecosystem-based approaches should be supported and potentially favoured over 'traditional' solutions.

Resources Mobilization

Financial resources are required for research efforts on the technical implementation and the effectiveness of nature-based solutions for urban flood protection. To a large extent, these resources will have to be provided by public funds.[30] The EU and individual Member States currently provide financial support to coastal protection research; part of it would need to be allocated to research on nature-based solutions. In addition, the implementation of nature-based solutions for urban flood protection requires the involvement of relevant stakeholders and the wider public. Experiences from the Netherlands in the "Room for Rivers" programme have shown that it is crucial to initiate public debates on (ecosystem-based) flood protection measures, particularly if they rely on the conversion of urban or agricultural land into floodplains.

As of today, EU programmes have already provided funds for research related to flood protection. Following table shows that money has been provided through the EU cohesion policy (operational programmes and selected projects) and through the Framework Programmes for research and technological development. In parallel, Member States have provided additional funding through their own flood protection programmes. On an EU level, it seems that the existing funding structures will remain the most promising routes for policy intervention in the innovation system.[31]

[30] We were not yet able to obtain that book. The main issue here is that flood protection as such and the related industry will not be driven by market forces, as it is largely a matter of public security policies. Thus, a market will only be created if policy-makers decide to integrate NBS into their flood protection strategies. In order to achieve this, we need to conduct research on the (cost-) effectiveness of NBS and raise awareness among policy-makers and the general public. Currently, NBS for flood protection are not widely accepted (Temmerman et al. 2013).

[31] By including this information our aim was to show that there are established mechanisms in place through which funding could eventually be provided.

Table 9. EU and Member State funds with relevance to coastal protection research

Money provided through the EU Cohesion Policy[2]	Risk prevention: Adopted OPs: €5,533 million Allocated to selected projects AIR 2011: €4,031 million Other measures to preserve the environment and prevent risks: Adopted OPs: €1,684 million Allocated to selected projects AIR 2011: €1,299 million
Money provided through research projects under the Framework programmes[3]	5th Framework Programme: €26.9 million EU funds 6th Framework Programme: €36.8 million EU funds 7th Framework Programme: €85.0 million EU funds
Investment made by Member States (total)[4]	Incomplete – data not available for all Member States or for all types of expenditure, not appropriate to provide total as this would be significantly uncertain. Range of expenditure is very wide, with greatest levels in Netherlands and UK and lowest levels countries such as Cyprus and Lithuania (but here information on investment may not be complete). On average, over a large number of projects, the benefits of investment appear to outweigh the costs by 6-8 times, although it is important to note that there is considerable variation between projects such that the actual benefits have to be determined on a project-by-project basis
Investment made by Member States in green infrastructure[5]	Information found suggests this is limited in many Member States, but may be of increasing importance as implementation of the requirements of the EU Floods Directive (2007/60/EC) continues. Progress is more advanced in countries with a longer history of significant flooding, such as the Netherlands, Germany, Belgium and the UK where plans for making room for rivers are already in place and being delivered. Green infrastructure projects found to require significant up-front investment that may require investment to encourage uptake. There is then potential to deliver significantly greater environmental benefits alongside reduction in flood damages and, potentially savings from reduced costs compared with traditional defences, deferment of investment in new defences and, hence, opportunity to use funds in other locations

Source: (Fenn et al. 2014)

Creation of Legitimacy

Legitimacy is required on different levels: Firstly, policy-makers must be convinced that nature-based solutions for coastal protection in an urban context will be effective and thus fulfil the objectives laid down in the relevant (public safety) legislation. Secondly, the wider public needs to accept nature-based solutions as reliable and beneficial flood protection measures. Thirdly, enterprises, which have so far been involved in the development and implementation of 'traditional' flood protection measures need to be willing to shift (part of) their efforts towards the development nature-based solutions. In this context, the identification and dissemination of best-practice case studies will be essential. They should include proper cost-effectiveness and cost-benefit analyses.

System Functioning

Based on the preceding sections, the fulfilment of innovation system functions is graphically represented in the following figure. Fulfilment of individual functions is the authors' own assessment, based on the information provided in the above sections. Fulfilment is scored on a five point scale: 0 - absent, 1 - very weakly developed, … , 5 - very strongly developed.

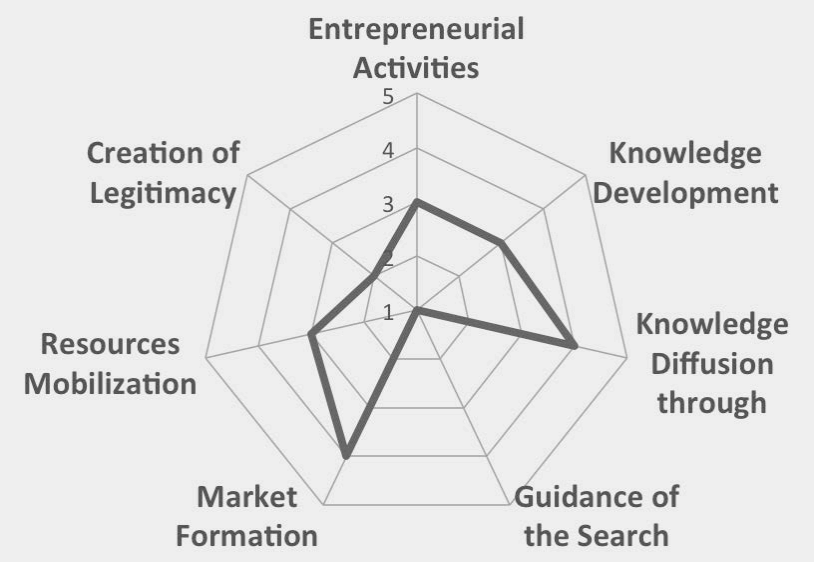


Figure 8. Fulfilment of innovation system functions: Use of Natural Solutions for Protecting Cities from Flooding

2.4 Implications for Innovation Interventions

The current barriers to the development and use of nature based solutions for coastal flood protection are the starting point for the appropriate EU level (and national) interventions in the innovation system.

Key drivers for innovation are:

- Increase in risk and severity of coastal flooding caused by storms
- Desire for cost-effective solutions to coastal flooding, including those which complement existing flooding.
- Generation of multiple benefits

Key barriers are:

- Uncertainty about the effectiveness of nature based solutions - until they are more widely tested, proved and improved, in practice
- Diffusion of relevant information actors relevant institutional and stakeholder networks

EU level interventions could focus on the provision of co-funding for nature-based coastal flood protection projects[32] together with support for the monitoring of its performance under different conditions.

At global level and with a particular focus on developing countries, an innovation support would be needed for the adaptation of these nature based solutions to different conditions (and given market conditions) for a widespread penetration of such systems. In Asia, this would involve a translation of lessons learnt in Europe to different geographic and ecologic situations.

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[32] The current state-of-the-art (and implications for innovation interventions, e.g. what kind of projects should be promoted) will be further investigated in the context of the planned expert interviews (March – May 2015).

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3. Specific Narrative on "Sustainable Urban Drainage Systems"

3.1 Introduction

Coverage of the SC5 Topics

Climate action	Resource efficiency	Raw materials
	✓	
Mitigation: Increased co_2 storage in created/restored ecosystems (Climate change adaptation by preventing damage from natural (disaster) events)	Improved use of land to deliver multiple economic benefits, Reduced use of sealed surface	

Background to the Innovation Opportunity: Problem and Innovation

High and increasing economic cost from storm flooding in EU and globally
Economic losses from flooding in the European Union are projected to increase from currently €4.9 billion annually to €23.5 billion by 2050 (Jongman et al. 2014).[33]

Urban flooding is caused inter alia by the increasing rate of stormwater in built environments, which are characterised by high shares of impervious surfaces reducing the drainage of rainwater and resulting in stormwater run-off. Assuming around 25 % of these costs could be attributed to stormwater events in urban areas, economic losses from urban flooding could be estimated at ca. €1.2 billion annually (to date) and ca. €5.9 billion annually in 2050. Projections show a further increase of urban drainage flooding in particular Western and Northern Europe.

High and increasing economic cost from storm flooding globally
60% of the urban infrastructure required to accommodate the globes growing population by 2060 remains to be built. As much urban space may be developed in the next 100 years as has been built on in the whole preceding history of man (Dr Joan Clos 2014).[34]

This brings huge potential urban flooding problems. For example, by 2070, Asia will be home to 15 of the world's top 20 global cities for the exposure of the population to vulnerability to floods and 13 of the top 20 for exposure of assets, also requiring improvement and adjustment of existing urban drainage systems.

[33] Jongman, B., Hochrainer-Stigler, S.,Feyen, L.et al. (2014): Increasing stress on disaster - risk finance due to large floods. Nature Climate Change 4, 264–268.
[34] Dr Joan Clos, Under-Secretary-General and Executive Director, United Nations Human Settlements Programme (UN-Habitat) 2014.

The Innovation

The traditional solution and its problems
The traditionally solution to urban drainage in western cities has been piped drainage systems, which are implemented to cope with rainwater. However old drainage infrastructures often do not have the capacity to keep pace with on-going urbanisation and the increasing rate of stormwater. This leads to urban flooding (American Rivers 2912).[35]

Another, indirect consequences is an inadequate discharge of excess water to the regional water system, increase of pollutants in the water caused by run-off and even increase in algal blooms, harming wildlife and reducing amenity value.

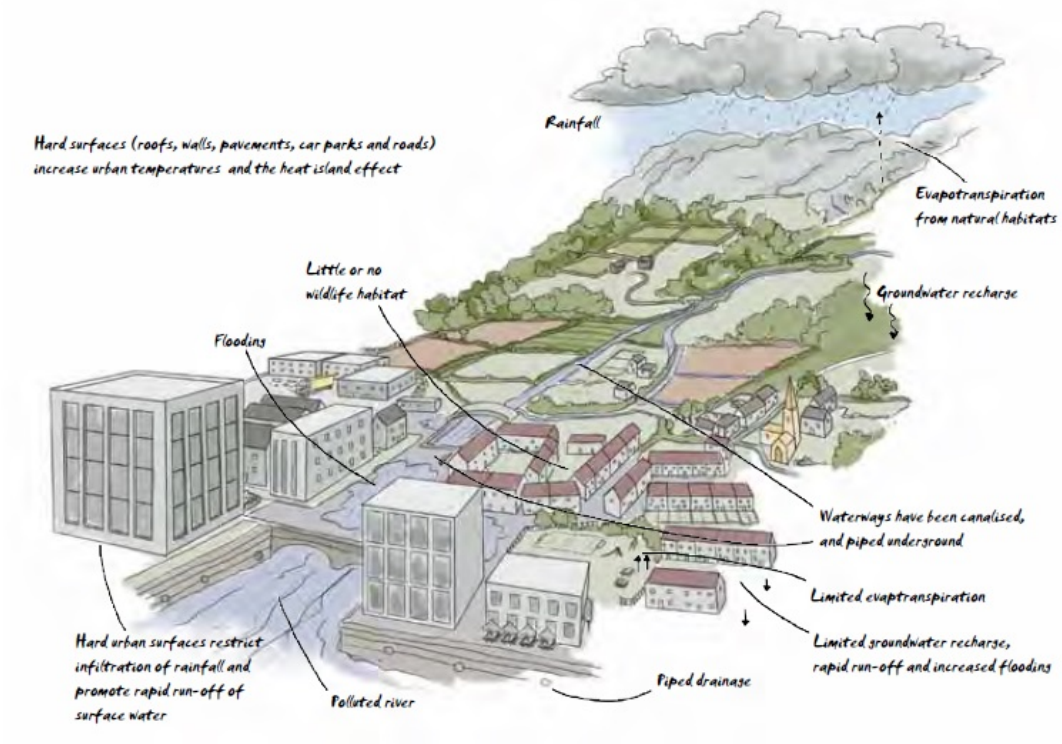
The Innovation
Sustainable urban Drainage systems (SuDs) as a surface technique which offers cost-effective and long-term alternative. There are estimations that benefits obtained from the implementation SuDs can exceed the benefits from piped drainage systems up to 30 times. These benefits would not only include prevented damage costs of flooding and water pollution , but also changes to property values, green jobs created, reduction in greenhouse gas emissions and reduced crime (MWH 2013).[36]

Innovation needs
SuDs have been proven to be a cost-effective solution to reduce urban flooding and run-off, but still require further innovation actions to exploit its full potential, both in the EU and for expanding global markets. The variety of actors involved in the implementation of Suds also calls for a systemic innovation, covering several aspects of innovation system (e.g. diffusion of information and generation of new knowledge through research coupled to deployment (demonstration projects) and networking around suitable legal conditions for success).

What is a Sustainable urban Drainage System?

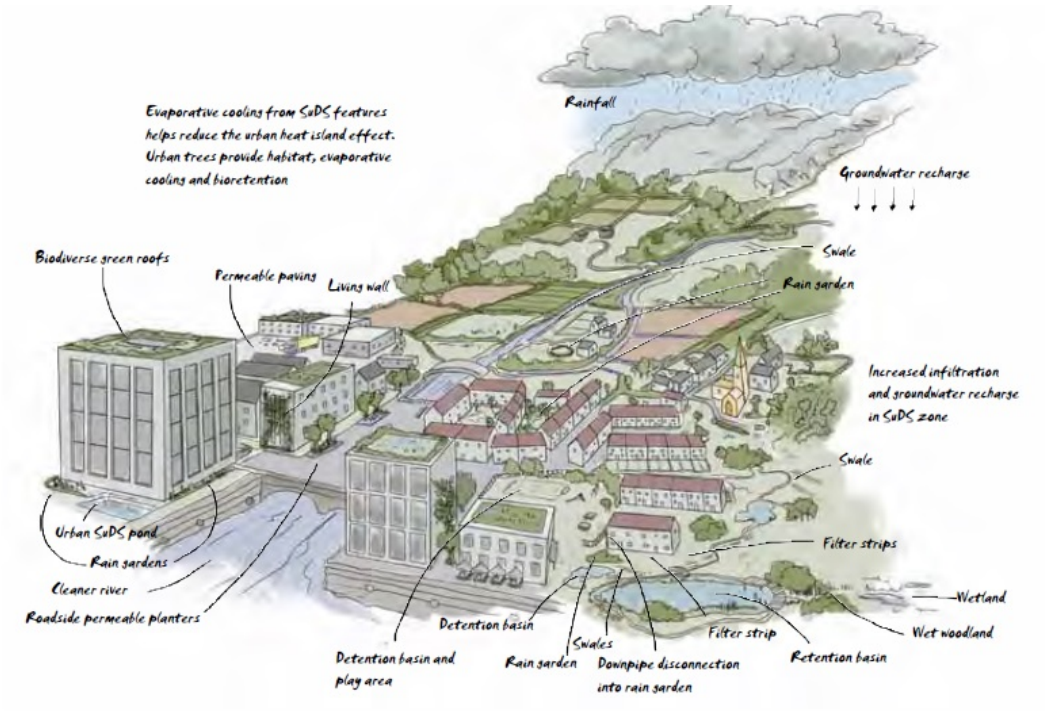
A sustainable urban drainage system (SuDs) is designed to reduce the potential impact of new and existing developments with respect to surface water drainage discharge and entails a sequence of practices and facilities. These practices, which rely on natural processes like evaporation, infiltration, and plant transpiration, can effectively and affordably complement traditional "grey" infrastructure, and can reduce stormwater runoff and pollution as well as energy and water treatment costs, diminish the impacts of flooding, improve public health, and reduce overall infrastructure costs, while also creating amenity values in urban areas. Such "green infrastructure" (GI) practices and facilities (or respectively nature based solutions) can include for example: permeable surfaces, filter strips, filter and infiltration trenches, green roofs, swales, detention basins, underground storage, wetlands and/or ponds (see following figures).

[35] American Rivers (2012): Banking on Green.; CNT (2013): The Prevalence and Cost of Urban Flooding: A Case Study of Cook County, IL. The Center for Neighborhood Technology
[36] MWH (2013): CIRIA Research Project RP993. Demonstrating the multiple benefits of SuDS – A business case (Phase 2). Draft Literature Review (October 2013)



Source: Graham et al. (2012)[37]

Figure 9. Traditional urban drainage system



Source: Graham et al. (2012)[38]

Figure 10. Urban catchment with Sustainable Urban Drainage System

[37] Graham, A., J. Day, B. Bray and S. Mackenzie (2012): Sustainable Drainage Systems - Maximising the potential for people and wildlife. A guide for local authorities and developers. RSPB and WWT

[38] Graham, A., J. Day, B. Bray and S. Mackenzie (2012): Sustainable Drainage Systems - Maximising the potential for people and wildlife. A guide for local authorities and developers. RSPB and WWT

The following table presents the responses of SuDs to climate change in comparison with traditional drainage systems

SuDS drainage performance compared to alternatives
In the stormwater management programme in the City of Philadelphia, the net benefits of using surface techniques has been estimated at almost $3 billion compared with less than $100 million for the piped alternative. The $3bn figure includes many diverse benefits such as: changes to property values; green jobs created; reduction in greenhouse gas emissions; and reduced crime. We consider the evidence for these and other claims (MWH 2013).[39]

By increasing infiltration and retention (introducing SuDs), green infrastructure can substantially reduce the overall amount of water entering local storm sewers or surface waters and reduce flooding-related impacts, including decreased property values and tax revenues associated with flooding, damages to public infrastructure and associated repair costs and damages to private and public property.

According to Liu et al. (2014)[40] the reduction capacity for single green infrastructure (GI) facility is limited, especially in bigger storm events. However, the integrated GI configuration has effective reduction percentage, such as the total runoff reduction could range from 100% to 85.0% and the peak flow could be reduced 100–92.8%.[41]

3.2 Estimation of the Investment Case

- Economic losses from flooding in the European Union are projected to increase from currently €4.9 billion annually to €23.5 billion by 2050.
- Around 25 % of these costs could be attributed to stormwater events in urban areas, economic losses from urban flooding could be estimated at ca. €1.2 billion annually (to date) and ca. €5.9 billion annually in 2050.
- SuDS is more effective than existing piped solutions at avoiding urban flooding, and brings co-benefits which can deliver a return on investment of up to 750%.
- There is a huge global market, as urban areas expand. 60% of the urban infrastructure required to accommodate the globes growing population by 2060 remains to be built. Populations living in urban floodplains in Asia, as a whole, may rise from 30 million in 2000 to between 83 and 91 million in 2030, and then to 119–188 million in 2060

The investment case for SuDS is based on the estimation of the damage costs in the EU and globally from stormwater based urban flooding, in the EU and global markets. These provide an estimate of the value of expenditure which would be justified on SuDS as a mitigation measure. This is coupled with the evidence that SuDS is both more effective (in certain circumstances) than traditional solutions, more cost-effective, and offers very significant co-benefits.[42]

[39] MWH (2013): CIRIA Research Project RP993. Demonstrating the multiple benefits of SuDS – A business case (Phase 2). Draft Literature Review (October 2013)
[40] Wen Liu, Weiping Chen, Chi Peng (2014): Assessing the effectiveness of green infrastructures on urban flooding reduction: A community scale study. Ecological Modelling 291 (2014) 6–14
[41] *Author's comment:* For this kind of analyses further research and data would be required incl. expert interviews, which would be part of the second (in-depth) phase. The major challenge in estimating the investment case is the availability of data (damage costs from urban flooding caused by stormwater), in most of the cases this data is part of broader estimates (e.g. on flooding in general) or limited to individual case studies.
[42] NOTE: The approach to use the damage costs stems from the authors analysis, which needs to be tested and applied (building on available data). The fact that SUDS is providing multiple benefits has been proven by various studies such as MWH (2013): CIRIA Research Project RP993. Demonstrating the multiple benefits of SuDS – A business case (Phase 2). Draft Literature Review (October 2013), Environment Agency (2007): Cost-benefit of SUDS retrofit in urban areas

Box 1: Case: Damage Example, Flooding in Copenhagen (July 2011)

After a very hot period Copenhagen was hit by a huge thunderstorm on 2 July 2011. During a two hour period over 150 mm of rain fell in the city centre, constituting the biggest single rainfall in Copenhagen since measurements began in the mid-1800s.

The city's sewers were designed to handle much smaller amounts of precipitation and combined rainwater and sewage together thereby making the city vulnerable if the amount and intensity of rainfall increases. Therewith the sewage system was unable to handle all of the water and as a result many streets were flooded and sewers overflowed into houses, basements and onto streets thereby flooding the city. The consequences were quite drastic as emergency services had to close roads and attend to people trapped in their cars. The emergency services were within minutes of having to evacuate the city's two biggest hospitals because of flooding and power cuts.

Insurance damages alone were estimated at EUR 650–700 million. Damage to municipal infrastructure not covered by insurance, such as roads, amounted to EUR 65 million

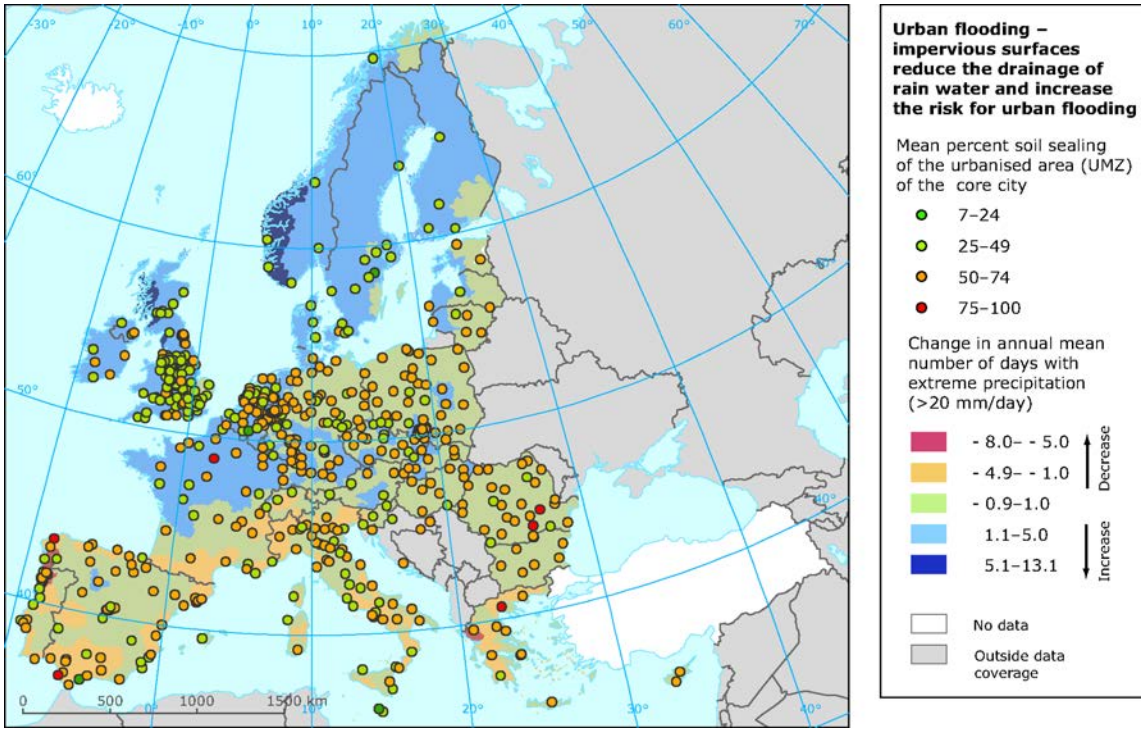
Source: (EEA 2012)

State and Trends in Urban Flooding in the EU

In Europe the natural hazards, which have caused the greatest economic losses are flooding and storms. 2002 proved to be a record year with major flood events in six EU Member States and material damages rising to more than $ 21 billion. Many European cities have to deal with flood risk management issues on a regular basis. Warmer climate projections show a further increase of urban drainage flooding in particular Western and Northern Europe

Figure 11 shows the projected change in the annual number of days with heavy rainfall in 2071–2100 against the reference period (1961–1990). It shows an approximate north-south division. There will be a decline in southern regions the number of days with extreme precipitation of up to five days and more. Most northern regions expect an increase, mostly of one to three days, while the coastline of Norway as well as Ireland and Western UK and some parts of the Atlantic coast of France can expect an increase of between four and 13 days (EEA 2012).[43]

[43] EEA (2012): Urban adaptation to climate change in Europe - Challenges and opportunities for cities together with supportive national and European policies



Source: EEA (2012)

Figure 11. Urban flooding — impervious surfaces reduce the drainage of rain water and increase the risk for urban flooding

Impacts of urban flooding entail damages to private (e.g. roads) and public property (houses) and therewith repair costs, which sum up to several billions Euro annually in the EU and at global level. In addition urban flooding hurts small business owners. Estimations reveal that almost 40% of small businesses never reopen their doors after a flooding disaster. Moreover property values can decrease by 10-25% due to wet basements (CNT 2013)[44], %, not including the indirect costs of flooding to the homeowner such as lost work hours, lost personal mementos, and lost use of a part of their property, at least temporarily.

The UK has estimated the current and future impacts of storm flooding. Urban flooding due to drainage systems being overwhelmed by rainfall is estimated to cost £270 million a year in England and Wales; 80,000 homes are at risk. Its impacts are expected to increase if no policy changes are made. A Foresight report (Evans et al. 2004)[45] said that the costs of urban flooding could rise to between £1-10 billion pounds a year by the 2080s if no action were taken to reduce the risks.

Table 10. Estimate of flood risk and flood defense costs

Flood risks expressed as Expected Annual Damage (EAD) and the baseline costs of flood defence for the business as usual option (continuation of current flood-management policies and expenditure into the future) – intra-urban					
	Present day	World Markets	National Enterprise	Local Stewardship	Global Sustainability
Baseline case, EAD £ million/year	270	7,880	5,060	740	1,870
Baseline cost £ million/year	320	320	320	320	320

[44] CNT (2013): The Prevalence and Cost of Urban Flooding: A Case Study of Cook County, IL. The Center for Neighborhood Technology

[45] Evans, e., Ashely, R., Hall, J., Penning-Rowsell, E., Sayers, P., Thorne, C. and Watkinson, A. (2004): Foresight Future Flooding, Volume I and Volume II. Office of Science and Technology, London.

Global Trends in Urban Flooding at Global Level

Vast amounts of urban expansion, particularly in Asia and Africa, will greater increase the infrastructure and population at risk from flooding in the coming decades.

For example, populations living in urban floodplains in Asia, as a whole, may rise from 30 million in 2000 to between 83 and 91 million in 2030, and then to 119–188 million in 2060 according to different scenarios of the future. By 2070, Asia will be home to 15 of the world's top 20 global cities for the exposure of the population to vulnerability and 13 of the top 20 for exposure of assets.

Poor stormwater management can be a significant factor in many localized flooding events, increasing damage to property and public infrastructure. Climate extremes are expected to exacerbate the situation with increased risk of riverine, coastal and urban flooding by 2030–2040, which would lead to widespread damage to infrastructure, livelihoods and human settlements (ODI 2014).[46]

The Emergency Management Agency (FEMA) in the US estimates that 25% of the $1 billion (ca. 800 Mio €) in annual damages from caused by flooding are linked to stormwater caused by piped drainage systems being overwhelmed by the intensity of rainfall (CNT 2013).[47] [48] The US National Flood Insurance Program estimates that its payments at ca. $2.8 billion since 1978 to claims related to localized urban flooding (CNT 2013).[49]

A Multi-Billion Investment Market

There are three market areas for SuDS across the globe:

- Installation in new build urban space
- Complementing or substituting piped drainage solutions (e.g. to cope with changing demands); and
- Being chosen as the drainage system when existing (mainly piped) drainage systems come to the end of their life and need replacement.

For example, in the e US alone a total of ca. 85 billion Euro is needed for stormwater management and combined sewer correction upgrades or improvements (American Rivers et al. 2012)[50] to cope with future stormwater events.

The major driver for implementing SuDs and retrofitting existing drainage systems is the need to tackle the increasing rate of stormwater runoff resulting in flood events in urban areas.[51] In general, old drainage infrastructures do not have the capacity to keep pace with on-going urbanisation. In addition, the share of impervious surfaces (soil sealing) increases resulting in an overload of the capacity of the sewage system in the face of extreme events. Some regions are also dealing with inadequate discharge of excess water to the regional water system (as e.g. in delta areas in the Netherlands).

[46] ODI (2014): Humanitarian trends and trajectories to 2030: North and South-East Asia. Regional Consultation. Author: Katie Peters

[47] CNT (2013): The Prevalence and Cost of Urban Flooding: A Case Study of Cook County, IL. The Center for Neighborhood Technology

[48] Total insurance claims paid out that were related to urban flooding in Cook County (Illinois) totaled $660 million in just 5 years. Up to 25% of economic damages caused by flooding occur because runoff overwhelms urban drainage systems (CNT 2013).

[49] CNT (2013): The Prevalence and Cost of Urban Flooding: A Case Study of Cook County, IL. The Center for Neighborhood Technology

[50] American Rivers et al (2012): Banking on Green.

[51] Note: River flooding is not necessarily linked to stormwater events and flooding damages in urban areas. The cases looked at under SuDs primarily deal with heavy precipitation exceeding the capacity of piped drainage systems.

Co-Benefits: Significant Further Economic, Environmental and Social Benefits

Compared to traditional piped drainage systems SuDS offer very substantial additional economic, environmental and social benefits. These are listed in tables below. After the description of a case study of a successful case of retrofitting SuDs (illustrating several benefits described in the table).

Box 2: Case: Retrofitting SuDS in an urban regeneration area, Augustenborg / Malmö (Sweden)

Augustenborg, a highly populated neighbourhood in Malmö, was the target of this project after having experienced socio-economic decline and floods from overflowing drainage. The key aim of the initiative was to create a more socially, economically, and environmentally sustainable neighbourhood by focusing on combating flooding, waste management and enhancing biodiversity. In order to minimise flood risk, a system was created to collect rainwater from rooftops and other impervious surfaces and channel it through canals, ditches, ponds and wetlands before finally draining into a traditional closed sub-surface storm water system (known as a "Sustainable Urban Drainage System" (SUDS)). Biodiversity was addressed through the creation of new wetland habitats.

In the case of the Augustenborg project, the total sum invested in the area added up to around SEK 200 million (€22 million). Costs related to project planning amounted to approximately SEK 6 million (€660,000) and infrastructure investments (pumping station and storm water pipes) amounted to approximately SEK 17 million (€1.9 million). Ongoing costs of maintenance equal SEK 155,410 (€17,000) per year. No opportunity costs related to foregone land-use were reported; however, there were potential foregone recreational uses (i.e. large open fields used for sports, were to be used for retention ponds) in the initial design of the project.

The benefits provided by the project are mainly associated with improved water regulation in the area: the system of swales, retention ponds, green roofs and other elements of the Sustainable Urban Drainage System serve to protect the neighbourhood of Augustenborg from flooding and regulate surface runoff. However, WWF and RSA (2011) reported additional benefits, including:

- improved water quality;
- reduced carbon emissions:
- reduced pluvial and sewer flood risk;
- aquifer recharge (relieving stress in water scarce areas);
- enhancement of urban spaces; and
- increased biodiversity

Habitat creation has led to an enhanced level of ecosystem resilience. As a side-effect, the project contributed to increased aesthetic and amenity values of the landscape and resulted in increased eco-tourism in the region. The City of Malmö has become known for sustainable architecture, innovative ecosystem-based adaptation and mitigation and a high quality of life for residents. Moreover, a neighbourhood in decline has been transformed into a recreational hub (as a result of the many new parks, ponds etc.) and symbol of social sustainability.[52]
According to Kazmierczak, A. and Carter, J. (2010)[53] Rainwater run-off have decreased by half. The image of the area has improved. Biodiversity has increased by 50 % (green roofs have attracted birds and insects and an open stormwater system provides a better environment for the local plants and wildlife. The impact on the environment decreased by 20 %. Unemployment rate has fall from 30 % to 6 %. The turnover of tenancies has also decreased by 50 %.

[52] Naumann, S., Anzaldua, G., Berry, P. et al. (2011b): Assessment of the potential of ecosystem-based approaches to climate change adaptation and mitigation in Europe. Final report to the European Commission, DG Environment, Contract no. 070307/2010/580412/SER/B2. Brussels; European Commission.
[53] Kazmierczak, A. and Carter, J. (2010) Adaptation to climate change using green and blue infrastructure. A database of case studies. GRABS-Project. http://www.grabs-eu.org/membersArea/files/malmo.pdf

The following table lists and describes the co- environmental, economic and social benefits of introducing SuDs.

Table 11. Overview of environmental and social benefits resulting from SuDs

Benefit	Examples (figures)
	Economic benefits
Increase in labour productivity	In case habitats are improved or cultural heritage is sustained, labour productivity in dependent tourist industries will increase, which again improves labour productivity in other connected industries. People will be employed in construction periods and in the subsequent maintenance activities. The impacts on labour productivity can include: • Physical health improvements – resulting principally from increased exercise and improved air quality; • Mental health improvements – from the calming effects of the presence of trees and green spaces, and also from physical exercise. Both of which are linked to health benefits; improvements at work because it was found that when workers have access to plants and green spaces they can be more patient, better at problem-solving and more productive; A reduction in short-term absenteeism. Labour productivity of SuDs (using GI) can be estimated through the impact on labour productivity and increased profit as a result of reduced costs of recruitment (both enhancing the GVA per company). (Ashley et al. 2012)[54]
Energy savings and reduced GHG emissions	If SuDs are installed in an existing development over 1 ha permeable area: avoided cost of pumping to the water company: £88 /yr; potential carbon savings: 0.5 t/yr (EA 2009)[55]
Reduces water treatment needs / Reduces need for water purification & waste treatment	One approach to value the reduction in stormwater runoff for these cities is an avoided cost approach. Runoff reduction is at least as valuable as the amount that would be spent by the local stormwater utility to treat that runoff. In this case, the valuation equation is simply: runoff reduced (gal) * avoided cost per gallon ($/gal) = avoided stormwater treatment costs ($) This figure can be aggregated to a larger scale to demonstrate the cumulative benefit that can be achieved in a neighbourhood/region. Reducing or limiting volume of flow to the sewage treatment works will help reduce energy costs. Reduced pumping from storage facilities and less diluted sewage may result in more efficient treatment of wastewater. This would also help reduce the need to provide additional capacity. A number of sewage works are already at the limit of their capacity. (EA 2007)
CSO reduction monetary savings	Improved river water quality by reducing pollutants discharged to surface water sewers and by reducing discharges from Combined Sewer Overflows (CSOs): £51,000 per CSO (EEA 2007) Traditional (piped) drainage systems prevent moreover natural percolation of rainfall into groundwater resources that support summer river flows. This can lead to the concentration of nitrates and phosphates in rivers and wetlands, causing an increase in algal blooms, harming wildlife and reducing amenity value
Reduced water use **Discounted water bill savings**	Some SUDS, such as water butts and rainwater harvesting, provide an alternative source for non-potable water within domestic and commercial settings. These will help to meet water efficiency targets. (EA 2007) Total water bill savings of a scheme is estimated as the product of total water savings and cost per m^3 of water saved (this was estimated as £2.01/m3 for properties on meters) (EEA 2007)
Enhances tourisms	The value of GI to increased tourism is calculated by assessing the money spent on

[54] Ashley R M., Christensson A., de Beer J., et al. (2012): Selling sustainability in SKINT. SKINT INTERREG IIIb project report. Cited in: CIRIA (2013): Demonstrating the multiple benefits of SuDS – A business case (Phase 2).Draft Literature Review.

[55] Environment Agency (2009): Potential of SUDS in reducing water related greenhouse gas emissions, Report: SC070010/R4

	travel and local expenditure in order to visit a particular site (calculations can also include the number of jobs supported by tourism and GVA associated with employment)
Environmental benefits[56]	
Reduce flooding, Storm protection	Direct disconnection of rainwater from the sewer systems or by reducing the volume and rate of run-off of the rainwater that still enters the sewer system. The context of flooding is highly site specific, no general instructions for the valuation of reduced flooding exist. Hedonics can be used to assess how flood risk is priced into the real estate market. Insurance premiums paid for flood damage can be used as a proxy for the value of decreased flood risk. The most robust technique uses hedonics to investigate housing price discounts associated with a floodplain location. A 2-5% Discount was found for houses within the 100 yr flood plain when compared to those outside. According to EEA (2007)[57] a uniform 10% reduction in the connected area to the sewer system over the entire country would achieve a 90% reduction in the numbers of incidents of flooding due to hydraulic overload of the sewer system in the UK. (For each SUDS scheme, the annual run-off reduction = unit benefit of run-off reduction/ m^2 of impermeable area and cumulative total potential area constructed over the conversion life of the scheme.) Monetary savings resulting from reduced number of flooding incidents: £39,000 per incident.
Reduced stormwater runoff	Valuing water benefits is to determine the amount of rainfall (gallons) retained on the site. This is then used as the resource unit for all water benefits.
Improves water quality (e.g. health of local waterways by reducing erosion and sedimentation and reducing the pollutant concentrations in rivers, lakes and streams.	Studies in USA have estimated implicit marginal prices for a one meter change in water clarity (turbidity reduction) ranging from $1,100 to $12,938 per waterfront property. Estimates of the value of not having to treat runoff at wastewater plants – for example a 5,000 ft2 green roof contributes to an annual electricity savings from reduced water treatment needs of 110.77 kWh
Reduces need for grey infrastructure	The SEA streets in Seattle provide cost savings for the city of 15–25%, or $100,000–$235,000 per block, as compared with conventional stormwater control design. One US city estimates that it costs the city $2.71/ ft2 in infrastructure costs to manage the stormwater generated from impervious areas using: *total expenditure for grey approach ($) * % retained = avoided cost savings ($)*
Reduces urban heat island effect, / Climate regulation (local temp, GHG sequestration etc.)	For example, adding 10 % green cover keeps maximum surface temperatures in high density residential areas and town centres at or below the 1961-1990 baseline up until the 2080s (Newcastle University, 2007).
Improves biodiversity	Many SUDS types, such as swales, filter ditches and infiltration ponds mimic the natural environment, retaining water that will attract wildlife, creating stable habitats and providing corridors along which wildlife can move. (EA 2007)
Social benefits	
Preserves/ sustains/creates heritage	The use and non-use values = the economic value of a heritage asset or of the goods and services to which it gives rise. (potential methodologies: contingent valuation methodology (CVM, incl. WtP), travel cost assessments, and hedonic pricing.)
Increases amenity and recreation opportunities	The value of added recreational opportunities may be measured by avoided costs in connection to health benefits, or via an increase in recreational trips, the "user days", gained from GI.
Improves aesthetics	Increased greenery has been shown to increase the aesthetic value of neighbourhoods. For example Willingness to Pay studies have shown an increase in property values of 2-

[56] Some of these benefits could be also provide economic advantages
[57] Environment Agency (2007): Cost-benefit of SUDS retrofit in urban areas

	10% in areas with new street tree plantings. In Portland, Oregon – street trees have been shown to add $8,870 to sale prices in residential properties and reduce the time on the market by 1.7 days.
Social relations (e.g. fishing, grazing, cropping communities)	Investment in green infrastructure (and SuDs) can enhance access to natural green space and provide opportunities for various forms of formal and informal recreational activity

Source: (based on Ashley et al. 2012)

The table below provides a summary of the comparable benefits for water management between SuDS and current systems.

Table 12. Responses of current traditional and flexible sustainable drainage systems to climate change

Urban water management aspect	Non-exhaustive examples of climate change impacts	Current system response example	Potential responses to changing conditions from a flexible system
Water supply	Reduced water supply, either seasonally or throughout the year	Increasing water supply through additional infrastructure such as dams, boreholes, desalination facilities or bulk supply transfers	Demand reduction through efficiency increases, active leakage management, behaviour change or pricing policies
			Sourcing of alternative supplies for non-potable demand: rainwater harvesting or treated wastewater effluent reuse
			Increasing sustainable storage capacity, for example through Aquifer Storage and Recovery
Wastewater management	Increased inflow of pollution, caused by flooding	Improving treatment technology	Control of pollution at source and use of natural treatment techniques
	Flooding of wastewater treatment plants located near rivers or coasts	Construction of protective barriers or lifting of equipment	Use and appropriate siting of decentralised natural treatment techniques
Stormwater management	Increased stormwater flows and combined sewer overflows	Improving and extending the infrastructure conveying stormwater away from the city	Attenuation of runoff through the use of Sustainable Urban Drainage Systems options, for example green roofs, porous paving, swales, rainwater harvesting, and detention ponds and basins

Source: (ICLEI European Secretariat 2011)[58]

[58] ICLEI European Secretariat. (2011). SWITCH Training Kit - Integrated Water Management in the City of the Future. Freiburg, Germany: ICLEI European Secretariat.

Jobs

Some case studies (projects) indicated that through the implementation and maintenance of SuDs, jobs are being created and maintained as e.g. illustrated by the example of Severn Trent Water (see box below).

Box 3: Case: Severn Trent Water Ripple Effect investigation: benefits of retrofitting SuDS to create green streets in Coventry

Creating green streets would require maintenance and care of the landscaped areas. One job is equivalent to eliminating job-seekers allowance for one person. At £65.45 per week for a year, this is £3,403.40. If the value of housing benefit is included of £63/week this would be an additional annual cost saving of £3,276. Combined, this is £6,679. Scaled across Coventry this is equivalent to 48 jobs created, or roughly £320,592 benefit to the city. Over 40 years these jobs are worth more than £7.4 million (MWH 2013).[59]

Source: AECOM & Severn Trent Water, 2013

Return on Investment: Case Study Valuation of Benefits together with Co-Benefits
Accumulating the value of the various forms of benefit often gives very high returns on investment, as indicated by an existing example from the UK, below.

Box 4: Case: Severn Trent Water Ripple Effect Investigation 2: full benefits

In the case of "Severn Trent Water Ripple Effect investigation" city-wide benefits of retrofitting SuDS through the creation of green streets (not including the benefits relating to heat-related deaths, biodiversity and health) were quantified at £1.5 billion over 40 years. For the site at Stoney Road, there is a benefit of over £906,000 or 7.5 times the site costs of £121,000. If water reuse infrastructure was added to store and recycle runoff locally for irrigation and toilet flushing, the benefits would increase dramatically to nearly £8.3 billion across the city and nearly £3 million at the site scale (AECOM & Severn Trent Water 2013[60]; see also MWH 2013[61]).

3.3 Role of Innovation Policy

The current state of the innovation system influencing the development and diffusion of SuDS is assessed in this section, to provide the analysis of where innovation policy - particularly EU innovation policy, can play a role in SuDS market penetration.

Entrepreneurial Activities

The Augustenborg case (Sweden) demonstrates the value of partnerships between multiple authorities within an urban context. Without the partnership between the Malmö water company, housing authority, and others, the funding for this project would not have been sufficient.

There are several initiatives and demonstration projects revealing entrepreneurial activities in the implementation of SuDs, stemming from the UK, Sweden, the US and Australia, bringing together sanitation engineers, water supply staff, environmentalists, road engineers and communities.

[59] MWH (2013): CIRIA Research Project RP993. Demonstrating the multiple benefits of SuDS – A business case (Phase 2). Draft Literature Review (October 2013)
[60] Aecom & Severn Trent Water (2013): The Ripple Effect - Building resilience of urban water systems to climate change. Technical Report: The Case for Birmingham and Coventry.
[61] MWH (2013): CIRIA Research Project RP993. Demonstrating the multiple benefits of SuDS – A business case (Phase 2). Draft Literature Review (October 2013)

These examples indicate that entrepreneurial activity is required more on the purchaser's side (e.g. the city authority) than it is on the supply side. We believe that the level of authority entrepreneurial capacity is very diverse.

Knowledge Development

There is an extensive body of literature and knowledge about SUDS encompassing guidance for technical implementation (e.g. for local authorities and developers) as well as costs and benefits involved. Majority of this literature stems from European countries (in particularly the UK) and the US.

Moreover, there are some international websites such as for example:

- International Best Management Practices (BMPs) Database – a platform featuring a database of over 530 BMPs performance analysis results studies (from New Zealand, the US, Sweden, Taiwan and Canada), tools for use in BMP performance studies, monitoring guidance and other study-related publications.[62]
- Stormwater Industry Association of Australia[63]

Evidence on the implementation and effectiveness of SuDS in cities in developing countries is lacking, which reveals the need for additional research. Further areas for research include: adequate institutional arrangements, human resource requirements and performance indicators for urban drainage and the improved quantification of benefits.

SuDs are already being used (often informally) successfully in urban areas of low-income countries and therefore can be considered a technology that is suitable for use in these countries. Water pollution is a major problem countries and an adverse impact of poorly managed urban drainage, leading to disease and poor drinking water quality. There is a strong need for technical research to support physical interventions, especially for the design of drainage systems that can cope with silt and also for the development of design procedures where there is limited data and staff with limited drainage expertise. [64]

Knowledge Diffusion through Networks

There exist platforms to inform about SuDs, e.g. susdrain[65] an UK-based, independent and authoritative platform for stakeholders involved in delivering sustainable drainage. It provides up-to-date guidance, information, case studies , videos , photos and discussion forums that help to underpin the planning, design, approval, construction and maintenance of SuDS. Susdrain is created by CIRIA an independent member based, not-for-profit construction industry research and information association. Another UK-based platform is 'Engineering Nature's Way', [66] providing information and best practice on SuDs relevant to people working in flood risk management strategy or concerned with SuDS in local and central Government, developers, consulting engineers and contractors.

These show that networking is possible. However, guidance, dissemination and promotion of information across affected regions and for relevant stakeholders is lacking. It would be most relevant to provide information on SuDs to all relevant actors including drainage and highways engineers, planners, urban designers, landscape architects, land or housing developers, drainage consultant or suppliers, flooding managers, biodiversity/environment managers and members of the general public.

[62] http://www.bmpdatabase.org/
[63] http://www.stormwater.asn.au/
[64] Reed (2004): Sustainable Urban Drainage in Low-income Countries - a Scoping Study. Project report
[65] www.susdrain.org
[66] http://www.engineeringnaturesway.co.uk/

Guidance of the Search

There is an urgent need to cope with increasing stormwater events in urban areas, which exceeds the capacity of pipe drainage systems and cause urban flooding and can cause high damage costs. There is evidence from several cases that the cost-benefit ratio of SuDs often performs better than the adjustment of traditional piped drainage systems.

Further market penetration partly depends on adaptation to different administrative systems. We are not aware of research focusing on this aspect of innovation.

Market Formation

The implementation of SuDs requires the involvement of multiple agencies including residents, housing association, parish councils, local authorities and highway authorities and adequate consultation and communication mechanisms. Adequate institutional arrangements (e.g. legal frameworks) to promote SuDs in new developments and for retrofitting processes are needed (EA 2013)[67]. In addition to adjusting legal frameworks and e.g. the introduction of green factor approaches (Berlin[68] and Seattle) to enforce ecologic compensation for new developments, research on adequate institutional arrangement for implementing SuDs can address this issue as well.

A further barrier to wider implementation of SuDs is the uncertainty over responsibility for ownership and maintenance; diffuse stakeholder roles for stormwater management (EA 2013)[69] (e.g. a car park is owned and the owner would be responsible for maintenance of the paving) (EA 2007)[70]. Prospects of reduced drainage charges for these areas or larger development allowances may help to address this challenge.

Resources Mobilization

Large financial resources for SuDS are available, out of public flood prevention funding, or in inclusion of costs for new development. Existing funding budgets may not yet have been adapted to future increased risks, and the need to update and replace piped infrastructure. For example, aging stormwater infrastructure, along with the pressure to construct new facilities, adds billions of dollars to future municipal, state and federal fiscal needs. According to the Environmental Protection Agency (EPA), U.S. communities are facing a total of $106 billion (ca. 85 billion Euro) in needed stormwater management and combined sewer correction upgrades or improvements (American Rivers et al. 2012)[71].

These funding sources are, however, more than adequate to fund the types of practical research and monitoring of SuDS in different situations.

The major challenge to the transition of traditional below ground system of pipes for surface water management system to SuDS results from the complexity of the interconnected networks of services, utilities and uses of land in urban areas, the ways in which these are planned and the fact that SuDS is more evidently consumptive of land. This transition has been successfully made in some countries like Australia and USA and is underway in many other places such as Scandinavia, Netherlands, Germany, France and the UK.

[67] Environment Agency (2013): An assessment of evidence on Sustainable Drainage Systems and the Thames Tideway Standards
[68] http://www.stadtentwicklung.berlin.de/umwelt/landschaftsplanung/bff/index_en.shtml
[69] Environment Agency (2013): An assessment of evidence on Sustainable Drainage Systems and the Thames Tideway Standards
[70] Environment Agency (2007): Cost-benefit of SUDS retrofit in urban areas
[71] American Rivers et al (2012): Banking on Green.

Market formation requires the co-ordination of different actors involved in urban planning, development and water management. Implementing SuDs also requires the availability of a minimum area of public open space for SuDs (for retrofitting permeable paving) in densely built areas, which might be addressed through regulatory intervention or financial resources for land purchase.

Creation of Legitimacy

There have been a wide range of successful cases, in which SuDs has been show to generate multiple benefits compared to traditional pipe systems with underground storage in addition to the long-term management of stormwater and avoidance of flooding incl.

Some additional legitimacy comes from SuDS' ability to deliver long-term solutions to adapt to climate change (as noted in public policy strategies, like the EU Adaptation Strategy). It has also been noted to contribute to objectives of the EU efforts to increase the resource efficiency by saving energy and reducing GHG emissions as well as reduced water treatments (water purification).

Despite these numerous benefits, there is still a need making SuDs as alternative technique "legitimate" and not second- best and so overcome the reluctance to pioneer alternative drainage methods (Reed 2004)[72]. For instance, there is lack of consistent cost and benefit methodology for wide-scale retrofitting, monitoring performance and quantifying benefits (EA 2013)[73], which could be addressed via investments in research e.g. via H2020 Programme.

System Functioning

The spider diagram in following figure shows the estimated current state of the innovation system. Based on the preceding sections, the fulfillment of innovation system functions is graphically represented in the following figure. Fulfillment of individual functions is the authors' own assessment, based on the information provided in the above sections. Fulfillment is scored on a five point scale: 0 - absent, 1 - very weakly developed, … , 5 - very strongly developed.

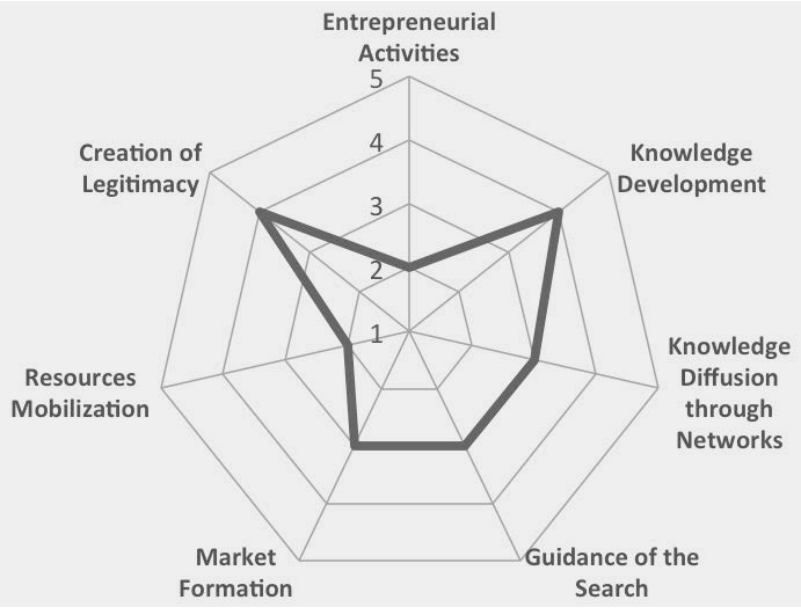


Figure 12. Fulfillment of innovation system functions: SuDS

[72] Reed (2004): Sustainable Urban Drainage in Low-income Countries - a Scoping Study. Project report
[73] Environment Agency (2013): An assessment of evidence on Sustainable Drainage Systems and the Thames Tideway Standards

3.4 Implications for Innovation Interventions

SuDs have been proven to be a cost-effective solution to reduce urban flooding and run-off, but still require further innovation actions to exploit its full potential. The variety of actors involved in the implementation of Suds also calls for a systemic innovation, covering several aspects of innovation system (e.g. diffusion of information and generation of new knowledge through research coupled to deployment (demonstration projects) and networking around suitable legal conditions for success).
For uptake and development of SuDs:

Key drivers are:

- Increase in stormwater/ high precipitation in some urban areas exceeding capacities of pipe wastewater systems
- Generation of multiple benefits and demand of urban society for green spaces

Key barriers are:

- Current institutional arrangements
- Uncertainty about ownership and responsibilities
- Diffusion of relevant information actors relevant institutional and stakeholder networks

At the EU level and other industrialized countries, the innovation support required would focus on the experimentation with and adjustments of institutional settings, considering alternative local capacities and cultures. Another focus would on the development of new business-model for public-private partnerships, combining green spaces, human well being, water management and climate change adaptation interests.

In addition, increasing awareness and legitimacy could be done either through targeted websites at national and regional level across all EU member states (e.g. embedding this information in websites of Ministries for Environmental infrastructure planning and as well as at global level), and through relevant education programmes e.g. for urban planners and engineers.

At global level and with a particular focus on developing countries, an innovation support would be needed for the adaptation of SuDs to different conditions (and given market conditions) for a widespread penetration of such systems. One specific challenge is the need for technical research to support physical interventions, especially for the design of drainage systems that can cope with silt and also for the development of design procedures.

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