



European Commission 7th Framework Workprogramme
Regions of Knowledge, Call: REGIONS-2012-2013-1
Project no. 319923 BalticFlows
"Monitoring and management of flowing rain water
in Baltic Sea catchment areas"



BALTIC FLOWS

New Knowledge on Urban Stormwater Management

Final Report - Deliverable D3.6

May 2016





This report has been written in the frame of the BalticFlows project, with contributions from other deliverables produced by the BalticFlows partner consortium.

Year of publication: 2016

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ISBN 978-3-00-052932-0

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Abbreviations

BMP	Best Management Practice
BSR	Baltic Sea Region
CBA	Cost-Benefit Analysis
CSOs	Combined Sewer Overflows
EU	European Union
FP7	Seventh EU Framework Programme for Research and Technological Development
GIS	Geographical Information System
IUWM	Integrated Urban Water Management
LCA	Life-Cycle Analysis
OECD	Organization for Economic Co-operation and Development
PA	Porous Asphalt
RTD	Research, Technology and Development
S3	Smart Specialization Strategy
SD	Standard Deviation
USWM	Urban Stormwater Management
SWOT	Strengths, Weaknesses, Opportunities, Threats
WSUD	Water Sensitive Urban Design





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Executive Summary

This report offers a comprehensive overview of best practices and knowledge in the field of urban stormwater management in the Baltic Sea Region, covering findings from Germany, Latvia, Finland, Sweden and Estonia. From a set of different perspectives, it provides its readers new knowledge in urban stormwater management and gives some recommendations for future economic, technical, and environmental development that can benefit and improve the current and future state of the Regions.

Insights on the current regional and global USWM technologies and best practices were collected from survey questionnaires, internal regional reports, and a literature review. The four most popular technologies identified in the region (i.e. green roof, porous pavement, bioretention basins, and bioswales) have been selected for further evaluation and applicability based on the characteristics of each technology and country-specific information which the BalticFlows partners provided. The significance of those USWM technologies has then been assessed from a strategic, a technological and a life-cycle oriented angle: i. through a SWOT analysis; ii. through a technological evaluation; and iii. by means of a life-cycle, i.e. holistic, assessment of a distinctive local case of two kinds of trench systems, a popular approach to manage large quantities of stormwater runoff.

Effectiveness of the implementation of methods and applied technologies was found highly dependent on site-specific conditions ranging from soil type; climatic, geographical, and typographical conditions of a given area. For example, technologies like green roofs showed extensive development in the Hamburg region however with less acceptance in the region of Riga. The evaluation of green roofs technologies, for the purpose of this report, was based on the retention capacity of the systems with results showing positive outcomes ranging anywhere from 50-90 percent total stormwater retention per rain event. The other technologies analyzed, i.e. porous pavements, bioretention systems and bioswales, demonstrated high retention and infiltration capacities contributing to the integration of decentralized Water Sensitive Urban Design (WSUD) methods and best management practices (BMPs) into the stormwater management agenda.

Results from an assessment conducted for trench technologies show that, under the preconditions of the analyses, plastic systems are superior to conventional gravel systems in the evaluated impact categories - one system consisted of gravel, surrounded by PP-geotextile, the other one of half-pipe





plastic shells with holes. However, no conclusions can be drawn from these models as to whether decentralized management practices are more beneficial than centralized systems. As best management practices for water runoff control are site- and case-specific, so are the LCA results.

With regards to the urban context, continuous growth in urbanization keeps creating challenges for implementing strategies that require additional space. For instance, in the country of Finland, there is a need for stormwater management practices to be implemented in dense urban cores. In this case, a combination of technologies and methods would need to be considered to effectively address space requirements on the ground needed for the installation of bioretention/bioswales systems.

Furthermore, successful implementation of stormwater technologies demonstrate the need for an integrative approach and utilization of combined methods. That is, a single technology will more likely not solve issues concerning excessive runoff and flooding. To be effective, an inclusive approach and mix of technologies needs to be oriented towards solving specific urban stormwater problems. Cities are undergoing transformation in the way resources will need to be utilized in the future. There is an obvious need to shift from long-established conventional approaches towards innovative sustainable solutions. With this in mind, a common trend that was found in the sustainable approach to stormwater management relates to three main core benefits:

- i. a more 'natural' water cycle;
- ii. enhancement of water security through local source diversification; and
- iii. water resource efficiency and reuse.

Political and regulatory frameworks also require that we take a closer look at the responsibilities and interests that are specific to each region and that differ from country to country- this as well as an analysis of the current state of the water management resources where participating regions show significant differences.

Further support for transnational capacity-building and exchange of best practices, has been carried out through the mapping of important knowledge networks and actors in RTD, finance/investment, highlighting regional opportunities, demands and needs. Economic factors have been addressed based on short and long term benefits and co-benefits through a cost-benefit analysis approach to planning whereas the availability of proper financial mechanisms that take into consideration private and public sectors is an area for further research.





1. Introduction

Increasing urbanization and higher amounts of sealed surface areas as a result, continues to put cities at risk of flooding, water disruptions and pollution of adjacent rivers and streams. Impervious surfaces coupled with excessive rain during wet seasons, increases the likelihood of combined sewer overflows (CSOs) adding pressured on drainage systems designed for a given capacity. The problem with urban stormwater may get exacerbated by climate change and by the increase frequency and magnitude of flooding events in urban areas worldwide (Semadeni-Davies et al., 2008). The Organization for Economic Co-operation and Development (OECD) has projected that nearly 20% of the world's population will be at risk from floods by 2050 (OECD, 2015). The risk of water pollution and water degradation coupled with water shortages in some areas, has become a global concern – bringing sustainable water management at the forefront of the urban development debate.

The World Economic Forum regards world-class infrastructure investments like green infrastructure as economic imperatives and important means to promote businesses and to open up new opportunities. The European Innovation Partnership on water, EIP Water included cities as part of the 2030 water innovation agenda for Europe-highlighting green space solutions as tools to enable cities regain flexibility, promote awareness and liability.

From in-depth analyses on the current state in urban stormwater management in the participating regions of Germany; Latvia; Finland; Sweden; and Estonia, this reports aims at presenting challenges and opportunities for the advancement of stormwater management practices in urban areas. The report will be a contribution to identifying methods and efficiencies on how to manage urban stormwater at its source; thus, contributing to meet overarching targets in water quality and pollution prevention of the Baltic Sea waters. First, the status quo in rainwater management in the Baltic Sea Region is briefly reviewed, based on a set of regional reports produced by the five BSR countries participating in the EU-funded FP7 project BalticFlows. The report is then subdivided into three parts:

Part A deals with technological perspectives of urban stormwater management. Insights on the current regional and global USWM technologies and best practices were collected from survey questionnaires, internal regional reports, and a literature review. Four technologies (i.e. green roof, porous pavement, bioretention basins, and bioswales) have been selected for further evaluation





and applicability based on the characteristics of each technology and country-specific information which the BalticFlows partners provided. The significance of those USWM technologies has then been assessed from a strategic, a technological and a life-cycle oriented angle, though a SWOT analysis, a technological evaluation and by means of a life-cycle assessment of a distinctive local case of trench systems.

Part B assess capacities and relevant preconditions across BSR as the means to bring out the current development potential of the regions. From this perspective, policy and regulatory aspects which support the implementation of top-down approach to best management practices in USWM are reviewed. A variety of actors and aspects helping stormwater management move from principles into practice are here identified allowing for perspectives on future challenges in implementation. Further, this section offers a detailed introduction to a vast number of sources of information and regional USWM providers such as relevant databases, associations, water networks and other active participants in RTD in the field. Current economic environment of the regions, key financial actors and decision makers as well as mentoring opportunities for capacity building and knowledge transfer, are here highlighted.

The final part C explores which kind of USWM solutions may offer truly sustainable solutions. As choosing the appropriate USWM technology needs to be grounded in economic considerations, a cost-benefit analysis, including a detailed example, is proposed as one method to enable decision-making.

Last, but not least, the concluding section provides a set of recommendations which may be of value to USWM practitioners, decision-makers and further USWM stakeholders.





2. Characterizing Stormwater

Managing stormwater needs to start with an understanding of quantity and quality aspects of the water that will be anticipated for a given area. For the purpose of this report, urban stormwater can be defined as the extreme runoff from pervious and impervious surfaces that include roofs, driveways, pavements, footpaths, and roads infrastructure characteristic of urban areas.

Generally, stormwater transports different pollutants, both organic and inorganic. Hvitved-Jacobsen et al. (2010) divided them into six specific pollution groups (see table 1). Where there is a large amount of pollutants identified in the stormwater, aquatic system may be impacted (Eriksson et al., 2007; Björklund, 2011). It is often argued that season and land use are some of the key factors for those stormwater runoff characteristics (Burton and Pitt, 2002; Goonetilleke et al., 2005; Hathaway and Hunt, 2010). Therefore, the characterization of stormwater runoff should be performed by means of monitoring studies at national and regional sites, for it has been proved that site specific variables play a key role. Especially precipitation, measured in terms of amount, frequency, intensity, duration and precipitation pattern, is causing the transport of pollutants (Hvitved-Jacobsen and Yousef, 1991).

Stormwater can be characterized by flow measurements and sample collection of a significant number of samples for a given location and quality parameters whereas pollutants are described by the range of concentrations (max, min, SD) and the Event Mean Concentrations (EMC)¹. Since these parameters result in different fields and laboratory measurements, there are uncertainties associated with them (McCarthy et al., 2008). These results should be considered estimations of the real value when used for stormwater management purposes. The pollutant annual mass load per unit of area (e.g.: g/ha/yr) is another parameter used to characterize stormwater quality. Stormwater quality measures can be obtained from recorded hydrological data in an urban area. To predict the quality of the stormwater, a quality modelling would be an essential part. The extensive review of Zoppou (2000) on for urban stormwater models is recommended as understanding the urban stormwater modelling is seen essential, but not covered by this report.

¹ The Event Mean Concentrations are calculated for each rainfall event, they resemble the total mass of pollutant divided by the total volume discharged. In contrast, the Site Mean/Median concentration (SMC) is the mean or median of all the measured EMC (Hvitved-Jacobsen and Yousef, 1991).



Table 1: Characteristic of stormwater contaminations

POLLUTION GROUP	MEASUREMENTS AND PARAMETERS	SOURCE	COMMENTS
Solids (suspended solids, SS)	TSS	Pavement wear; construction sites or rehabilitation works; atmospheric fallout; anthropogenic wastes, etc.	60-80% of SS in stormwater could be < 30 mm Ø. Other sewer solids are present in CSO. Solids also accumulate within sewer system, may be discharged at different times. Heavy metals and PAHs bond to the smaller particles (e.g.: 100-250 µm)
Heavy metals	Cu, Zn, Cd, Pb, Ni and Cr	Vehicles parts and components; tire wear; fuel and lubricating oils; traffic signs and road metallic structures. Industries may also be an important source of heavy metals	Relevant due to toxic effects. Generally focus on copper (Cu), zinc (Zn); cadmium (Cd) and lead (Pb). Relevance of Pb minor in countries using unleaded gasoline
Biodegradable organic matter	BOD5 and COD	Vegetation (leaves and logs), animals such as dogs, cats and birds (either fecal contributions or dead bodies)	Organic matter from stormwater less biodegradable (dominated by plant material), therefore also less problematic for the environment than from CS.
Organic micro-pollutants	Numerous, e.g.: PAHs, PCBs, MTBEs, endocrine disrupting chemicals	e.g.: PAH: incomplete fossil fuel combustion; abrasion of tire and asphalt pavement, etc. Phthalate esters: urban construction plastic materials	Currently, large number of compounds (>650 identified) discharged in trace concentrations; sometimes no accurate chemical determination method available
Pathogenic micro-organisms	e.g.: total coliforms; Escherichia coli	Contributions from cats, dogs and birds	Stormwater sources much different than domestic wastewater contribution in the case of CSOs
Nutrients	N, P (e.g.: total Kjeldahl N; NO ₂ þ NO ₃ ; total-P; soluble-P)	Fertilizers and atmospheric fallout	Nutrients can cause eutrophication, water discoloration, odors, toxic releases, overgrowth of plants
Adapted from: Hvitved-Jacobsen and Yousef, 1991; Wanielista and Yousef, 1993; Burton and Pitt, 2002; Björklund, 2011; Eriksson et al., 2005; Lau and Stenstrom, 2005; McCarthy et al., 2008; Hvitved-Jacobsen et al., 2010.			





3. Urban stormwater management in the Baltic Sea Region

In this chapter, a brief overview of the current state of urban stormwater management in the Baltic Sea Region is given. Drawing on insights from the participating project regions in five partner countries, i.e. Germany, Latvia, Finland, Sweden and Estonia, short profiles of selected regions provide the readers with compact background information on challenges and current practice how urban rain- and stormwater is dealt with in a changing climate, in order to better illustrate the need for improved urban stormwater management in the Baltic Sea Region.

3.1 Germany

Germany was one of the first countries to include rainwater and stormwater management measures (especially addressing decentralized solutions) into policies (Jin, 2005; WHG, 2009). Their application is incentivized through tax reductions, e.g. rain taxes are collected for the amount of impervious surface cover on a property that generates runoff directed to the local storm sewer. As a result, more rainwater is caught and conserved, less is the runoff added to the storm drains which allows construction of smaller storm sewers at the site and property owners can apply for rain tax reductions by converting their resistant pavement/roof into a porous one (Rainwater Harvesting, 2015). However, as combined sewer networks still appear to be the status quo, runoff increases the amount of water that needs to be cleaned in a central sewage treatment plant. Other parts of the runoff are not treated and end up in the receiving bodies that lead to the Baltic Sea, causing the water quality to worsen. Runoff quantity management, therefore, needs to be improved and combined with water quality management (DWA, 2015).

Zooming into Northern Germany, the Metropolitan Region of Hamburg, which is geographically located between the North Sea and the Baltic Sea, resembles a large monocentric region comprising the city state of Hamburg and further nineteen administrative districts and district-free cities from three adjacent states (Länder) in Northern Germany, i.e. Schleswig-Holstein, Niedersachsen and Mecklenburg-Vorpommern (see Figure 1). Hamburg is the second largest city in Germany next to Berlin, and a city state. Whereas this city state has an area of 755 km² with a total population of about 1.8 million people, the Hamburg metropolitan area covers a total area of 26,103 km² and has a population of about five million inhabitants. (MRH, 2014; Statistikamt Nord, 2014).



The river Elbe flows through the Metropolitan Region of Hamburg and the city and into the North Sea. Moreover, the city lies at the junction of the Elbe with two smaller rivers, i.e. Alster and Lake Außenalster. The climate of Hamburg can be categorized as oceanic temperate, characterized by warm dry summer and cool winter. Most of the precipitation occurs between the months of November and April (Consulaqua, 2012). The annual precipitation in Hamburg varies between 507-985 mm with the average annual value considered to be about 750 mm. June, July and August are the rainy months. The mean annual temperature in Hamburg is 9.4°C (BSU, 2006).

Figure 1: Map of the extended Hamburg Metropolitan Region since 1.5.2015



Source: Metropolregion Hamburg, available at <http://metropolregion.hamburg.de>, [CC BY 3.0 DE](https://creativecommons.org/licenses/by/3.0/de/).

Hamburg was the first city on the European continent that established a centralized system for drinking water supply. Municipal authorities were in charge of wastewater management. The source of the city's water supply is exclusively groundwater, with an average quantity of 300,000 m³ of water supplied each day (Waldhoff, 2010). Rainwater is managed through a main sewage system which consists of both combined (23%) and separate sewers (77%) (Consulaqua, 2012). Increasing efforts to implement decentralized rainwater management systems in Hamburg have been made over the last decades. For example, after the legalization of rainwater utilization in Germany in 1980, Hamburg was, in 1988, the first city to provide subsidies for the implementation of rainwater harvesting systems (TRCA, 2011).

However, like many other metropolitan regions in the world, Hamburg faces an increase in the amount of sealed surface areas due to new development. In Hamburg, 8% of the city area consists of surface water, 40% of it is covered by green areas, with the remaining 52% covered by traffic and settlement areas. Of the traffic and settlement area 72% (280 km²) is considered to be covered with impervious surface. This combined with rainfall variability and extreme weather events have created a likelihood of increased stormwater runoff and risk of flooding (Waldhoff, 2009).





Moreover, Hamburg is endangered by stormwater surges and has since then gained many experiences in its management. Based on historical records reaching back to 1750, stormwater surges in Hamburg can be categorized in three phases: The frequent damage-period prior to 1850, a calm period between 1855 and 1962, and a period of elevated but well-managed storm surge levels since 1962. However, the extreme storm surge in 1962 which resulted in severe damages all along the German North Sea coast caused many dikes in Hamburg to break. More than 300 lives were lost in Hamburg alone (CCA, 2014). In 1976, the water level of another once-in-a-century flood superseded the 1962 levels by about one meter, yet almost all dikes held at that time. Then, in 2013, another storm surge hit Hamburg, being the second most extreme storm surge with water levels higher than 1962 but below 1976 levels. However, the damage was limited due to improved dikes and disaster control measures (Brautlecht, 2013).

Hamburg is affected in a number of ways by climate change. For Northern Germany, the temperature forecast has an average rise of 2.8 to 4.7 °C by the end of the 21st century. A change in the distribution of rainfall with 40% increase in precipitation in winter; and a decrease by the same amount in summer, is estimated (BSU, 2011). Moreover, extreme weather events such as dry summers with extreme heat periods, high precipitation and severe storms levels in winter will be more frequent. Hamburg would be affected both by rising storm floods from the North Sea and by higher levels of the River Elbe due to rain and snow melt from inland. A rise in sea level would also have an impact on water levels of the Elbe, and carry increased amounts of sediment into the port and the river (BSU, 2011).

3.2 Latvia

Rain water management in Latvia is regulated by the national legislation in the field of environment, construction and land drainage, enforced at the local (municipal level) through construction control (mainly during the process of technical design). Maintenance of the rainwater management infrastructure is mainly ensured by local municipalities or municipal water companies. Legislation and existing practice in rainwater management in Latvia may be considered relatively outdated due to lack of attention and financing during the past 20 years. For example, rain water sewers are designed according to Latvian Construction Norm LBN 223-99 "External networks and buildings of sewerage", which is inherited from the Soviet construction norm SNIP. The main approach of the construction norm is ensuring necessary sewer dimensions for the maximum calculated runoff





(maximum intensity method), however, it does not explicitly consider rain water retention and infiltration.

There is a large need for capacity building in Latvia itself, thus much knowledge and technology is currently being transferred into the country (Latvian Ministry of Education and Science, 2014). However, expertise of the leading Latvian players in the rainwater management and monitoring field may be of interest to the immediate neighbours – Estonian and Lithuanian institutions and companies as well as other countries of the former USSR, due to common historical background, similar engineering practice and knowledge of the Russian language. To improve the sustainability of rainwater management in Latvia, sustained mentoring actions as pursued in the BalticFlows project could prove valuable to share experiences on rainwater tariffs, the improvement of legislation and the regulatory base for sustainable rainwater management, the construction and the maintenance of sustainable rainwater management systems and the pollution reduction potential of different techniques, most cost-effective techniques for specific pollutants.

Zooming into the central part of Latvia, the Riga planning region contains the capital city Riga and Riga agglomeration including smaller towns and villages close to Riga, with other major population centers being the city of Jurmala, Ogre and Tukums towns (see Figure 2). The total population of this region is estimated to be more than one million, which constitutes 50 % of entire Latvian population. Four river basin districts of Latvia, formed by the catchment areas of the large rivers Daugava, Gauja, Lielupe and Venta are partly located in Riga planning region.

The mean average annual temperature in the region is around 5.5°C and the annual precipitation is around 700 -720 mm, including around 490 mm in the warmer months of the year. Between 1954 and 2012, average annual precipitation has increased by 20 mm (around 3% of annual average). Medium-term forecast for precipitation amount increase is around 20% for more frequent rain events (2-5 years) and 17-18% for less frequent rain events (10-200 years).



In recent years the occurrence of extreme rain events has increased. For example, in the period of four days between August 8-12, 2014, rain events with a statistical occurrence frequency of once in 5 years (38 mm in 12 hours), once in 10 years (43mm in 12 hours) and once in 20 years (52 mm in 24 hours) occurred in Riga. In Sigulda on 29 July 2014, a heavy rain with total precipitation amount of 121 mm over 4 hours (and 84 mm during 1 hour) was registered, which exceeds even the precipitation amount for once in 200 years rain event.

Figure 2: Map of Riga Planning Region



Source: Riga Planning Region

The groundwater resources are plentiful in the Riga planning region, with the exception of Riga area, where due to high concentration of water users (centralized water extraction sites of Riga, proximity of Jurmala, Jelgava and other cities) water extraction is higher than the natural recharge of the aquifer and with increasing water consumption there is a risk of regional depression and seawater intrusion.

3.3 Finland

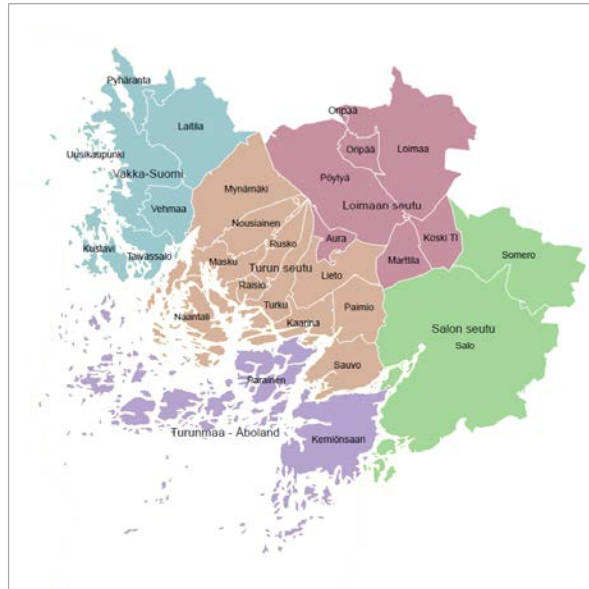
In Finland, a trend towards Integrated Urban Water Management (IUWM) can be observed. IUWM aims at taking into consideration all interactions of the urban water cycle, i.e. stormwater, water supply, wastewater, groundwater, and ecological and health aspects (Sänkiäho et al., 2011). However, the current municipal organisation structures, design guidelines and regulations do not support these long-term goals. In cold climate countries such as Finland, snowmelt also makes up a considerable part of annual stormwater runoff, amounting to 70-80% of the annual maximum flows (Kuusisto, 1984). As reported by Ashley et al. (2007), the overall stormwater regulations and guidelines are considerably less conclusive in Finland compared to the USA.

Southwest Finland is situated by the Coast of Archipelago Sea (see Figure 3). The region is the third biggest in Finland with a population of about 474,000 inhabitants (Varsinais-Suomen liitto 2016) and has a total area of 20,537,78km² of which about half is covered by land and the rest is water. There are also about 22,000 islands in the region. Southwest Finland is divided into five sub regions:



Turku, Loimaa, Salo, Åboland and Vakka-Suomi. Capital of the region is Turku, which is the fifth biggest city of Finland with 186,000 inhabitants (Varsinais-Suomen liitto 2016).

Figure 3: Map of Southwest Finland Region



Source: Varsinais-Suomen liitto 2016,
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The region is characterized by cold climate with a mean annual temperature of 5.5°C. The average annual precipitation varies between 500-650 mm (annual rainfall varies from 500-550 mm in the archipelago areas to the 600-750mm of the inland areas of the region). Based on climate change predictions, winter and autumn flows will increase and water levels will rise with more rain and less snow. These can potentially cause increased winter and autumn flooding. Longer snow and frostless periods can increase nutrient loads and erosion. Snow will also melt during the winter causing increased flows. Severe

flooding caused by stormwater will increase in cities and smaller coastal water bodies during summers (Kersalo and Pirinen, 2009; Veijalainen *et al.*, 2010). Some of these risk areas are the coastal areas of the cities of Turku, Raisio and Naantali, all of them situated in the region of Southwest Finland. Evaluation was based on the general harmful effects of flooding, regional and local circumstances and probability of flooding (Maa-ja metsätalousministeriö, 2011).

Finnish water supply is mostly made up of groundwater (48% natural groundwater, 13% artificial groundwater, surface water 39 %) (GTK, 2014). Most of the region's wastewater is treated in the central treatment plant of Kakolanmäki situated in the regional capital of Turku. This central wastewater plant collects wastewaters from almost 300,000 inhabitants as well as most of the industrial wastewater generated in the region. In 2013 approximately 83,000m³ of wastewater was treated daily of which 68% came from Turku. The sewer network consists of both combined and separate sewers. The length of the combined sewers is about 58 km and the total length of the separate rainwater sewers is about 528 km. However, the sewage network does not cover all areas, and 4500 properties are currently not connected to the rainwater sewer system. Nevertheless, the

aim is to connect most of the properties to the existent rainwater system in the future (Turun kaupunki, 2011; Lounais-Suomen vesi- ja ympäristötutkimus, 2014).

Most of the bigger Finnish cities and municipalities have made plans for rainwater management and rainwater harvesting strategies in recent years (Nurmi et al, 2008, Turun kaupunki 2009, Tampereen kaupunki 2015). Finnish rainwater management and harvesting is moving more and more towards natural infiltration and retention solutions.

3.4 Sweden

Sustainable water and wastewater management is a priority in Sweden since 1990's, with research programs such as "Sustainable Urban Water Management" (Malmqvist, 1999) funded by the Swedish Foundation for Strategic Environmental Research (MISTRA) (Hellström, 2000). In addition, the Swedish Water & Wastewater Association was set up by the municipalities in 1962 to assist with technical, economic and administrative issues and to represent the interests of the municipalities in negotiations with authorities and other organizations on regulations (Svensk Vatten, 2016).

The European Water Framework Directive (2000/60/EC) (WFD) was aimed to achieve good ecological and chemical status for surface water bodies and good chemical status for ground water by 2015. However, according to Aronsson (2016), the inland water management coordinator of Sweden, these objectives have not been met and deadline for achieving these goals has been extended by 2021. Nevertheless water management and quality is a main goal for Sweden and has been included in its main environmental Objectives (Swedish Agency for marine and water management). Additionally Sweden publishes all the water quality related data on a water information system database (WISS) publicly available on-line.

Figure 4: Map of Uppsala Region



Source: Länsstyrelsens Web-GIS, available at <http://ext-webbgis.lansstyrelsen.se/uppsala/underlag/>



Uppsala county (see Figure 4) covers an area of 8, 202 km² and is divided into eight municipalities with a total of about 350,000 inhabitants (Länsstyrelsen, 2014). The topography of Uppsala County is characterized by small differences in elevation. Sweden has a total of 119 main catchment areas, nine of which are found in Uppsala County (SMHI, 2013).

The measured mean annual precipitation in the region varies between 484 – 662 mm and the mean annual temperature is 6.5°C. The climate in the county is regulated mainly by the distance to the sea in the east and to some extent also by Lake Mälaren in the south. Heavy rains are expected to increase in future. The increase is most noticeable for short-term rainfall with a return period of one year where the increase is estimated to be 20-30% of the rainfall. The climate projections for the county show that the mean annual precipitation will increase gradually, but with considerable variation between years. At the end of the century, the median value shows an increase of 20% compared to the reference period of 1960-1990 (SMHI, 2013).

Large part of the surroundings of Uppsala consists of flat plains of clay layers. This means that the infiltration of larger amounts of stormwater often can be difficult as well as the difficulty of diverting the water due to a slight slope. Because the source of water supply in Uppsala is groundwater, and part of the urban area is a protected for the supply of drinking water, Uppsala has higher requirements for stormwater management. In addition, the Fyrisån river which runs through the center of Uppsala city is a large and important recipient for stormwater flows (Uppsala kommun, 2014).

Currently, there are more than 2000 publically owned sewage treatment plants in Sweden that take care of not only sanitary sewage and stormwater from combined systems, but also drainage and infiltrated water. According to the Swedish Waste Water Association, combined sewers were used until the mid of the previous century. New developments nowadays feature separated systems consisting of a foul sewer and a stormwater sewer, however, to date the old system still can be found in up to 25% of the urbanized areas. Sweden's sewer network totals about 92.000 km, of these 32.000 are stormwater sewers (SWWA, 2016).

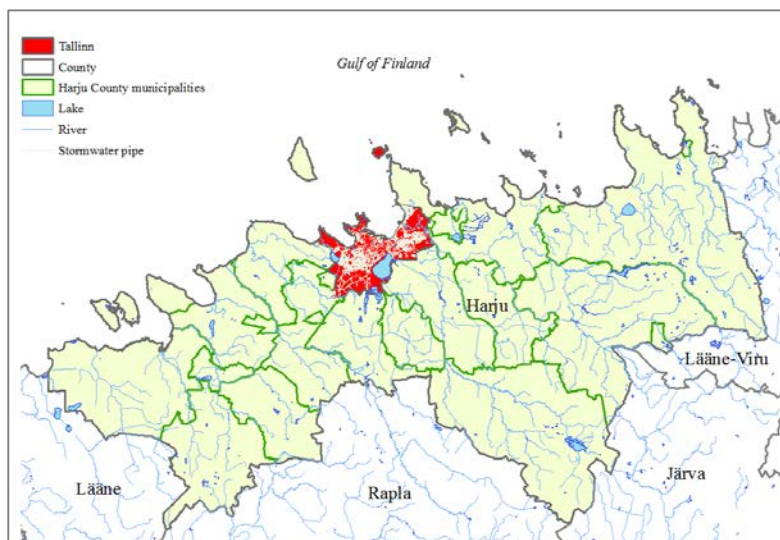


3.5 Estonia

The main water issues in Estonia are wastewater collection and treatment, quality of drinking water, losses from agriculture, nutrient loads in water, hydro-energetic production in small rivers and sites already polluted (old pollution sites) (EME, 2016). The first Public Water Supply and Sewerage Act was adopted by the Estonian Parliament on 10th of February 1999. This Act regulates the organization of water supply and the collection and treatment of wastewater, rain water, drainage water and other soil and surface water through the public water supply and sewerage system (OECD, 2011). In 2009 an environmental board was formed within the Ministry of the Environment to cope with the implementation of policies on the use of the environment, nature conservation and environmental education (Hiiob, 2013). For over a decade now, Estonia has been actively involved in drinking water and waste water projects supported by EU funding. The most important projects have been focused on the improvement of waste water treatment in residential areas, and availability and quality of drinking water (Kalev, 2011).

Tallinn region (see Figure 5) covers an area of 4,333 km² inhabiting about 40% of the total population of Estonia which is estimated to be 1.29 million. Almost half of the Estonian land area is covered by forests, one-third of the agricultural land (arable land 24% and pastures 6%); about 4% is covered by built up areas, and the rest of the territory is covered with swamps and bogs. Estonia is a lowland country, its highest point rising to only 318 meters above sea level (Jaakola *et al.*, 2014).

Figure 5: Map of Tallinn



Source: Created by Tallinn University of Technology 2016

The mean annual temperature in the region is 5.2°C and the annual precipitation varies between 550 and 800 mm. Climate models assume an overall increase in precipitation. Most scenarios for the year 2100 show a 10%-20% increase in annual precipitation volume with the biggest increase during the



winter months. Some of the models are predicting even a slight decrease in summer rainfall, but due to higher increase in winter rainfall there is a net increase in annual rainfall (Nöges et al., 2012).

The water demand for the most part of Estonia, is supplied by groundwater, but in Tallinn and Narva, primarily surface water is the source of water supply, as groundwater reserve is not sufficient. Tallinn public water supply system comprises almost 1,111 km of water networks, 17 water-pumping stations and 64 ground water borehole-pumping stations with 93 boreholes throughout the entire service area. The public sewerage system comprises 1,093 km of wastewater networks, 443 km of stormwater networks and 174 sewerage-pumping stations across the service area (Environmental Report, 2013).

There are 20 flood-related risk areas in Estonia including six areas in Tallinn. Stormwater from residential and industrial areas is either diverted to municipal wastewater treatment plants and treated with sewage or is collected in a separate stormwater system and mainly discharged to water bodies without any treatment. There are 63 stormwater outlets in Tallinn of which 47 discharge their water directly to the coastal sea, 7 to the watercourses and 9 to soil in the Tallinn catchment area (Environmental Report 2013).

The main characteristics of the regions involved in the BalticFlows project are summarized in table 2 on the following page.



Table 2: Summary of key characteristics of the regions involved in the BalticFlows project

Region	Area (km ²)/ region (km ²)	Population / region	Annual rainfall (mm)	Conventional rainwater management	Water supply	Approach to storm-/rainwater management
Germany, Hamburg	755 /26,103 (Metrop. area)	1,800,000 / 5,000,000 (Metrop. area)	507-975	Separate (77%) and combined sewerage	Groundwater	Rain-/stormwater management policies and measures
Finland, Turku	306 / 20,538 (SW Finland)	186,000/ 474,000 (SW Finland)	550-650	Separate (528 km) and combined (58 km) sewerage	Groundwater (61%)	Integrated urban water management
Latvia, Riga	304 / 10,133 (Metrop. area)	643,000 / 1,098,000 (Metrop. area)	700-720	Separate and combined sewerage	Groundwater	Territorial flood mgt policies and rain/stormwater mgt integrated in sectoral policies
Sweden, Uppsala	49 / 8,202 (Uppsala county)	140,000 / 337,000 (Uppsala county)	484-662	Separate and combined sewerage	Groundwater	Rain-/stormwater management policies and measures
Estonia, Tallinn	160 / 4,333 (Metrop. area)	404,000 / 524,000 (Metrop. area)	550-800	Separate (443 km) and combined (1093 km) sewerage	Mainly surface water	Rain-/stormwater management policies

Source: Own compilation





3.6 Conclusions

In general, the climate of the regions, except Hamburg, is categorized as humid continental climate which is characterized by mild summer, cold winters and longer frost periods. The climate of Hamburg is categorized as oceanic temperate climate which is characterized by warm dry summer and cool winter. There is more average annual precipitation in Germany, Latvia, and Estonia compared to Finland and Sweden. Due to climate change there is a general trend of increasing the variability and occurrence of extreme stormwater events, increasing winter precipitation in all the Baltic Sea regions. This will increase urban stormwater runoff in cities during winter causing flooding and deteriorating the quality of freshwater resources by carrying pollutants from increasing impermeable surfaces in the urban areas.

The topography the Tallinn, Uppsala and Turku is characterized by flat terrain which proves difficult for the implementation of some stormwater management best practices such as bioswales which require some natural slope for effective application (EPA, 1999). The soil in the regions of Uppsala, Turku and Tallinn is characterized by impermeable clay soil which makes natural infiltration difficult.

Consideration of regional characteristics like climate, topography and soil is necessary to choose suitable and efficient urban stormwater management practices in a given area. Most regions are characterized by cold climate and therefore appropriate design and construction guidelines and procedures should be followed to increase the effectiveness of the decentralized urban stormwater management measures in cold climate regions. Moreover, infiltration based rainwater management systems in regions with impermeable soils should be implemented by integrating a more permeable soil layer during construction and by the use of underdrain below the stormwater management facility. An example can be the use of filter swales which are being implemented in Germany as street stormwater management methods (Ingvertsen et al., 2010).





PART A

4. Assessing the state of USWM Technologies in the BSR

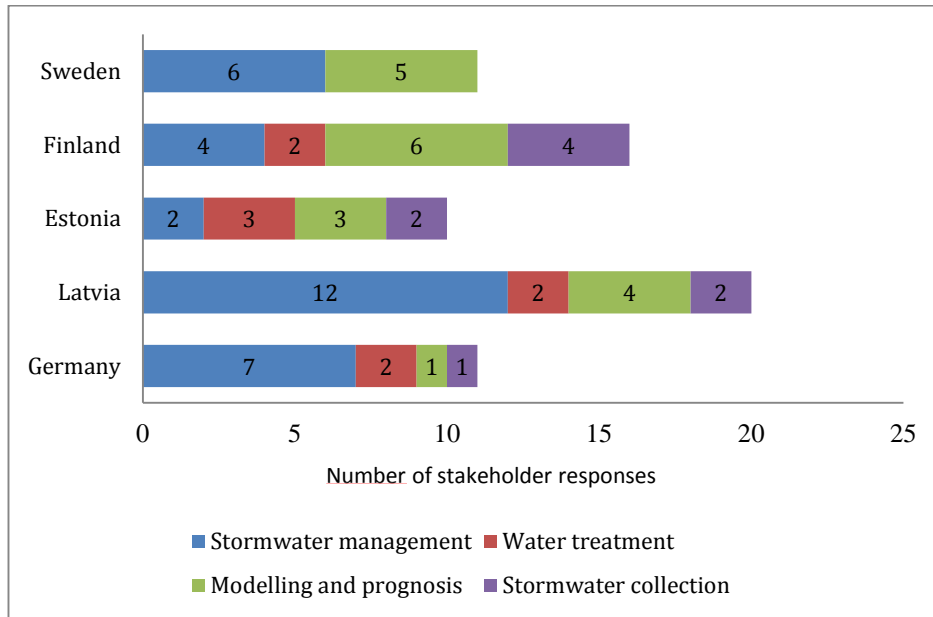
This part of the report identifies existing USWM practices in the Baltic Sea region, with special attention being paid to the BalticFlows partner regions, and seeks to evaluate selected USWM technologies. By means of a transnational survey, information on the current available technologies and practices related to urban stormwater management in the Baltic Sea regions was collected, amended with information from further regional reports and an in-depth literature review. With the help of a SWOT analysis, a structured planning method, four specific USWM technologies (green roof, porous pavement, bioretention basins and bioswales) were evaluated and their inherent strengths, weaknesses, opportunities and threats are highlighted in the following.

4.1 Current Decentralized Technologies

The main decentralized rainwater management techniques used in the Baltic Sea regions appear to be green roofs, rainwater collection from roof catchment and storage in underground storage tanks, retention basins, pervious pavements, open channel systems, natural infiltration systems and storage ponds (see more findings from regional reports in Annex 1). The BalticFlows project also produced a detailed directory of RTD capacities including technologies which is accessible via the project website (www.balticflows.eu). Findings are complemented by a survey of technologies, products or services related to USWM in the participating project regions, conducted in the frame of the BalticFlows project in 2014. The survey aimed at identifying distinctive regional technological capacities in the fields of rainwater monitoring and management in the Baltic Sea Region (Nõmm *et al.*, 2014). The specific technologies, products or services offered by the stakeholders under four urban stormwater management related categories: (i) Stormwater management, (ii) stormwater collection, (iii) modelling and prognoses, and (iv) water treatment, were assessed in the survey. Figures 6 and 7 show the distribution of identified technologies, products or services by sector and country. From all BalticFlows partner regions, Finland and Latvia can offer the highest number of technologies, products or services (see Figure 6). Figure 7 illustrates that stormwater management technology and services have the greatest share in USWM, followed by modelling and prognosis technologies and services.

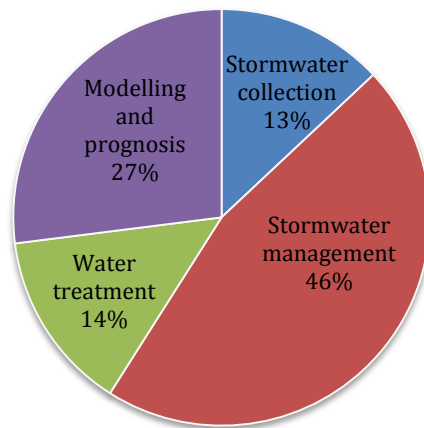


Figure 6: Distribution of UWSM technologies, products or services related to urban stormwater management in selected Baltic Sea regions by sector and country



Source: BalticFlows Survey, 2014; n = 68

Figure 7: Technologies, products or services related to urban stormwater management in selected Baltic Sea regions by sector



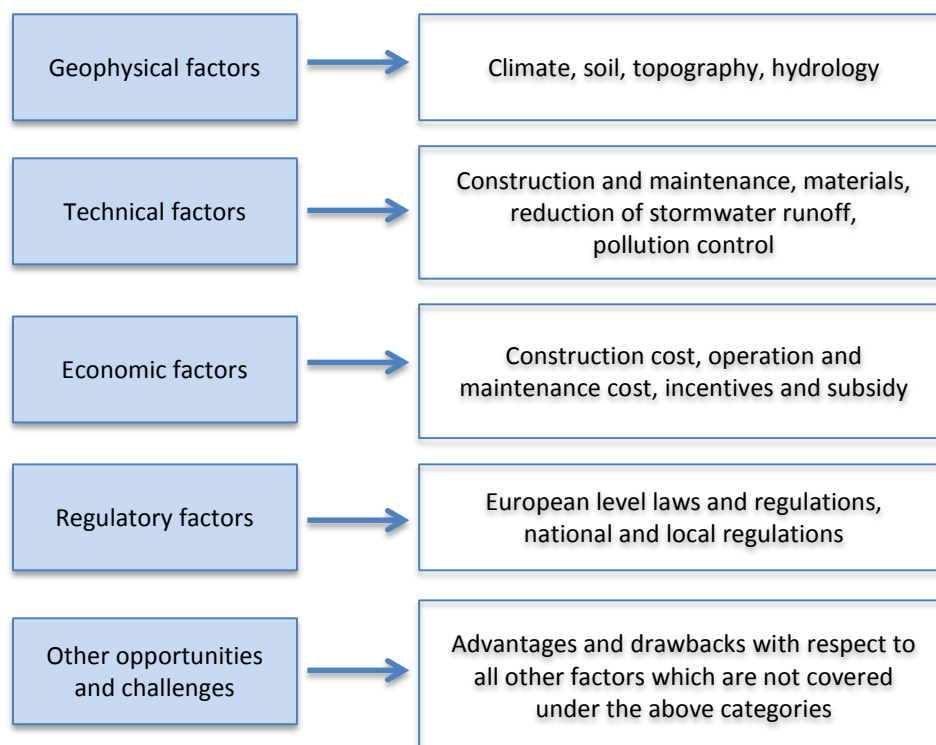
Source: BalticFlows Survey, 2014

4.2 SWOT Analysis of selected USWM technologies

Technical solutions, efficiency, economic considerations, urban planning, aesthetical and social characteristics are key aspects that need to be considered in the selection of technologies to manage stormwater in urban areas (Martin *et al.*, 2007). According to Barbosa *et al.*, 2012 five main factors affecting urban stormwater management can be categorized as geophysical (climate, soil, topography and vegetation), laws and legislations, social, economic and technical factors.

From the spectrum of those USWM technologies identified in the BalticFlows partner regions (see previous chapter), four technologies have been selected for an in-depth analysis. In order to evaluate these technologies in a structured manner, information was collected for each selected technology according to five categories. These categories and their main parameters are closer described in Figure 8.

Figure 8: Framework with parameters suitable for the characterization of USWM technologies



The before-mentioned parameters can be used to attribute certain dimensions to a USWM technology and illustrate distinctive strengths, weaknesses, opportunities and challenges, or threats for successful implementation. For this, a so-called SWOT analysis is used, i.e. a structured

planning method to evaluate the strengths, weaknesses, opportunities and threats that characterize an organization or a given product and is considered suitable for application for diverse activities (Coman and Ronen, 2009; Griffin, 2011). Such an analysis is usually represented by a matrix contrasting the internal with the external perspective. Both perspectives are directly connected to the entity that is evaluated. Here, the SWOT method will be applied to evaluate selected USWM management related technologies currently applied in the BSR. How the parameters that characterize USWM technologies fit into the SWOT structure is shown in table 3.

Table 3: General SWOT matrix with evaluation criteria used for the evaluation of selected USWM technologies

Strengths	Weaknesses
<ul style="list-style-type: none">- Geophysical factors- Technical factors- Economic factors- Social and biodiversity effects	<ul style="list-style-type: none">- Geophysical factors- Technical factors- Economic factors- Social and biodiversity
Opportunities	Threats
<ul style="list-style-type: none">- Regulations- Subsidy and incentives- Experience- Market competition- Resources	<ul style="list-style-type: none">- Regulations- Subsidy and incentives- Experience- Market competition- Resources

Note: Some parameters can represent strengths and weaknesses at the same time when the category comprises several parameters that have opposite impacts.

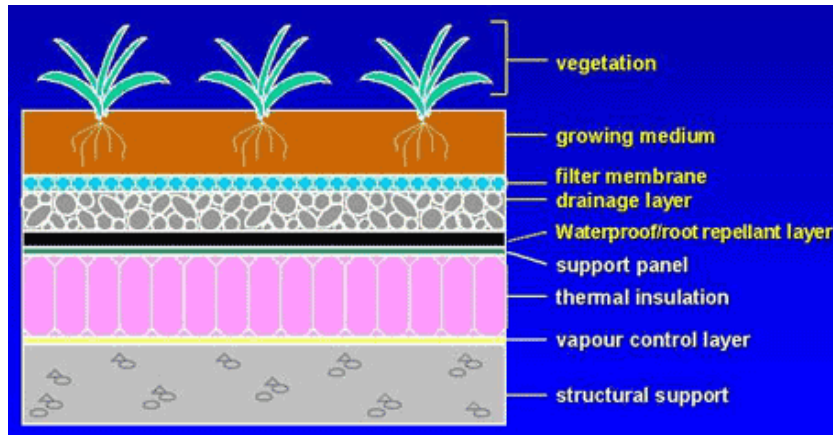
The four USWM technologies to be assessed in the following are green roofs, porous pavements, bioretention systems and bioswales.

4.2.1 Green Roofs

A green roof system (also referred as: rooftop garden, vegetated roof or eco-roof) is a vegetative layer grown as an extension of an existing roof. It is built on new and existing roof structures which need to be prepared to fit this special purpose. For example, it needs to have a good waterproofing and root repellent system, it needs to include a drainage layer and a filter cloth, a mulch layer and lightweight growing medium and plants (DPLG, 2010). See Figure 9 for an exemplary configuration of a green roof system.



Figure 9: Schematic representation of principal green roof components



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Among the Baltic Sea regions, green roofs are commonly used in Germany and Sweden (Buccola *et al.*, 2008). Germany is well known for its modern day green roofs, with a green roof industry growing 10 to 15% annually (Getter and Rowe, 2006). Here, an estimated 14% of all flat-roofed buildings are covered with green roofs (Köhler and Keeley, 2005). Currently, ten german-speaking institutions are represented in the European Federation of Green Associations, together with Austria and Switzerland (EFB, 2014). The 'Guidelines for the Planning, Construction and Maintenance of Green Roofing' contain relevant regulatory information on the construction and maintenance of different types of green roof systems (FLL, 2014).

As an example of how countries make progress with green roof technology, the city of Hamburg plans from 2015 onwards to cover at least 70% of newly constructed flat or low-pitched roofs with green roof according to the city's new green roof strategy. Also, direct financial incentives will be available for voluntary construction of green roofs which covers up to 50% of the total cost, with specific values set as follows: For intensive green roofing up to 40 € per m², for simple-intensive green roofs up to 20 € per m² and for extensive roofs up to 15 € per m². Moreover, the stormwater management fee is reduced by 50% by implementation of green roof system (BSU, 2014; Bürgerschaft FHH, 2014).

Building upon the framework introduced in the beginning of this chapter, the following listing illustrates some characteristics of this specific USWM technology and certain features prevalent in the Baltic Sea region that may exert influence on the wider application of green roof technology.



Geophysical Factors

Climate:

- Green roofs more suitable for hot-humid tropical regions, but can also be effectively used in cold climates (Corden, 2011; Köhler et al., 2002);
- Stormwater performance affected by extreme weather conditions (such as seismic zones or windy places) and cool wet season climates (Schroll et al., 2011; Stovin, 2010)
- Performance decreases during high precipitation periods (Fioretti et al., 2010; Teemusk and Mander, 2007)

Soil and vegetation:

- The type of plant affects green roof performance, with variety of species composition reducing runoff significantly compared to monoculture vegetation (Dunnett et al., 2008)
- Sedum is the commonly used plant for green roofs due to its higher survival rate on a roof top in harsh conditions (Villarreal and Bengtsson, 2005)

Hydrology and hydrogeology:

- Return rainwater to the atmosphere; cannot recharge ground water (MAPC, 2014)

Technical Factors

Materials:

- Installation requires high technical skill (Freeman, 2008; DPLG, 2010)
- Properly designed and constructed green roof does not require much maintenance except initial and occasional watering, fertilization and weed removal (Freeman, 2008; DPLG, 2010; MAPC, 2014)
- Does not require extra land for implementation

Stormwater runoff:

- Reduce stormwater runoff volume, reduce and delay peak runoff rates (Mentens et al. 2006; Köhler et al. 2002; Carter and Jackson, 2007; Bengtsson, 2005)
- Annual precipitation, roof type, and depth of substrate layers are factors significantly affecting stormwater retention in green roof (Mentens et al. 2006)
- Germany – 5 and 12 cm depth green roof retained 60 to 80% of the annual precipitation (Köhler, 2005); 65% (Centgraf and Schmidt, 2005)
- Sweden - extensive sedum moss roof retain 64% annual precipitation (Bengtsson, 2005; Villarreal, 2007)
- Extensive roof in Estonia stormwater retention for 2.1 mm rainfall is 85.7%, for heavy rain the green roof can only delay the runoff without runoff volume reduction (Teemusk and Mander, 2007)

Pollution control:

- Reduction of pollutants in rainwater runoff (Köhler et al. 2002), but the performance depends on the characteristics of the rain, climate and materials in the substrate layer (Berndtsson, 2010; Palla et al., 2010)
- Nitrate nitrogen and phosphate reduction (Köhler et al., 2002); removal of various metals (Steusloff, 1998; Köhler et al., 2002)

Economic Factors

Cost:

- High initial investment but the cost can be recovered within the design period considering the saving on other expenses (like providing insulation and hence energy saving, extended lifespan of water proofing layer) (Breuning, 2014; Banting et al., 2005)





- In Germany: extensive green roofs cost 25-35 € /m² (DDV, 2014)
- In USA: \$108 - \$269 / m² in USA (Freeman, 2008); \$62,9 - \$449/m² with lifetime of 50 years (Thurston, 2012)
- Moderate maintenance requirement (Freeman, 2008); \$13 – \$21/m² (Peck and Kuhn, 2003)

Incentives and subsidies:

- Direct financial incentive is available in Hamburg for implementation of green roofs (BSU, 2014; Bürgerschaft FHH, 2014; Romoe, 2014)
- In Hamburg indirect financial incentive in the form of reduced stormwater management tariff (Hamburg Wasser, 2014a, 2014b).
- No incentives in Finland (Nurmi et al. 2013)

Regulatory Factors

EU, national, regional support:

- The Water Framework Directive (WFD) 2000/60/EC (WFD) establishes an EU-wide regulatory framework for the protection of inland surface waters and groundwater (Baumgartner, 2008; EC, 2000).
- Decentralized stormwater management practices are preferred methods in Germany (Berendes 2010), Sweden (Uppsala kommun, 2014)
- Green roofs are integrated in regulation in 35% of German cities (Romoe, 2014)
- No supportive regulation in Finland (Nurmi et al. 2013)
- In Germany, the Federal Nature Conservation Act (BNatSchG) establishes the general framework for the impact mitigation regulation on nature and landscape and it encourages the implementation of stormwater management practices that mimic natural flows (Article 8)(BNatSchG, 2009)
- In Hamburg, the division of stormwater and sewage charge promotes decentralized natural rainwater management by offering indirect financial incentive (Hamburg Wasser, 2014a, 2014b).

Other Opportunities and Challenges

Experiences:

- Very good experience and well established green roof industries in Germany (Oberndorfer et al. 2007; Köhler, Keeley 2005); good experience in Sweden (SGRI 2014)
- Comprehensive guideline for planning, construction and maintenance of green roofing is available in Germany (FLL, 2014)
- Can be incorporated into new construction or added to existing buildings during renovation or re-roofing
- Create opportunity for re-using secondary aggregate (EFB, 2014)

Sustainability Aspects:

- Increased durability of flat roofs (Köhler et al. 2002)
- Increase urban green space and provide habitat for biodiversity (Li and Yeung, 2014)
- Improve human living and working environments (FBB 2014)
- Reduction of building energy consumption (Santamouris et al., 2007)
- Improvement of local microclimate by reducing urban heat island effect through evaporation of water with results in cooling and increased humidity (Miller, 2008; FBB, 2014)
- Improvement in air quality (Miller, 2008)





- Suitable for areas where infiltration is difficult due to tight soils or shallow bedrock, or on sites where infiltration is undesirable due to existing soil contamination (MAPC, 2014)

Disadvantages:

- Need stronger building structure to support the extra load of green roof layer
- Less competition in some Baltic Sea regions (only three green roof suppliers in Finland (Nurmi et al. 2013), Little experience in Latvia (Kara 2013)
- There is a need for watering to maintain the growth of vegetation during dry periods.
- Leakage can occur due to incorrect installation practices.

By means of the following SWOT table, the strengths, weaknesses, opportunities and threats that may have an impact on the wider application and implementation of green roof technology are highlighted. From the analysis, it appears as if green roof technology has indeed a great potential for application in the BSR region, as strengths and opportunities outweigh weaknesses and threats.



Table 4: SWOT analysis of green roof technology for application in the BSR

Strengths	Weaknesses
<p>Geophysical factors</p> <ul style="list-style-type: none"> - Can be applied in various climatic regions (Köhler et al. 2002; Corden 2011). - Help to maintain local hydrologic cycle by returning rainwater to the atmosphere through evaporation and evapotranspiration - Offers a possibility to use various vegetation type to increase the performance depending on the local condition <p>Technical factors</p> <ul style="list-style-type: none"> - Can reduce stormwater runoff volume by 60 to 80% in Germany - (Köhler, 2005; Centgraf and Schmidt, 2005); 87% in Estonia - (Teemusk and Mander, 2007) - Delay peak urban stormwater runoff (Mentens et al., 2006; Köhler et al., 2002) - Reduce pollutants in stormwater runoff (Köhler et al., 2002; Berndtsson, 2010; Palla et al., 2010; Steusloff, 1998) - Reduction of building energy consumption (Santamouris et al. 2007) - Increased durability of flat roofs (Köhler et al. 2002) - Properly designed and constructed green roofs doesn't require much maintenance (Freeman, 2008; DPLG, 2010) - Does not require extra land for implementation - Performance can be increased by varying the type of plant used, the type and thickness of the substrate layer affects green roof performance (Dunnett et al., 2008) - Can be incorporated into new construction or added to existing buildings during renovation or re-roofing <p>Economic factors</p> <ul style="list-style-type: none"> - Costs can be recovered within the design period if monetary values of the various benefits are considered (Banting et al., 2005; Breuning, 2014) <p>Social and biodiversity aspects</p> <ul style="list-style-type: none"> - Improve human living and working environments (FBB 2014) - Increase urban green space and provide habitat for biodiversity (Li and Yeung, 2014) - Reduction of building energy consumption (Santamouris et al., 2007) - Improvement of local microclimate by reducing urban heat island effect through evaporation of water with results in cooling and increased humidity (Miller, 2008; FBB, 2014) - Improve air quality (Miller, 2008) 	<p>Geophysical factors</p> <ul style="list-style-type: none"> - Performance decrease during extreme weather conditions and in cool wet season (Schroll et al., 2011; Stovin, 2010) - Performance decreases during high precipitation periods (Fioretti et al. 2010; Teemusk, Mander 2007) - Cannot recharge groundwater - Suitable for areas where infiltration is difficult due to tight soils or shallow bedrock, or on sites where infiltration is undesirable due to existing soil contamination (MAPC 2014) <p>Technical factors</p> <ul style="list-style-type: none"> - Require high technical skill for installation (DPLG, 2010) - Need stronger building structure to support the extra load of green roof layer - There is a need for watering to maintain the growth of vegetation during dry periods - Leakage can occur due to incorrect installation practices <p>Economic factors</p> <ul style="list-style-type: none"> - High initial investment cost, in Germany installation of extensive green roofs cost 25-35 €/m² (DDV 2014) - Moderate maintenance cost (Freeman 2008; Peck, Kuhn 2003)





Opportunities	Threats
<ul style="list-style-type: none"> - Supportive regulation at European level – the Water Framework Directive (WFD) (Baumgartner 2008; EC 2000). - Decentralized stormwater management practices are preferred methods in Germany (Berendes 2010), Sweden (Uppsala kommun 2014) - In Germany, the Federal Nature Conservation Act (BNatSchG) establishes the general framework for the impact mitigation regulation on nature and landscape – promoted green roof application (Article 8)(BNatSchG, 2009) - In Hamburg division of stormwater and sewage charge promotes decentralized natural rainwater management (Hamburg Wasser, 2014a, 2014b). - Availability of direct financial incentive in some Baltic Sea regions, for example in Germany (BSU, 2014; Bürgerschaft FHH, 2014; Romoe, 2014) - Very good experience and well established green roof industries in Germany (Oberndorfer et al. 2007; Köhler, Keeley 2005), good experience in Sweden (SGRI, 2014) - Comprehensive guideline for planning, construction and maintenance of green roofing is available in Germany (FLL, 2014) - Opportunity to re-use of secondary aggregate (EFB, 2014) - Reduction of cost of drainage (Breuning, 2014) 	<ul style="list-style-type: none"> - No incentives and supportive regulation in Finland (Nurmi et al., 2013) - Little market competition in some Baltic Sea regions (only three green roof suppliers in Finland (Nurmi et al. 2013); Little experience in Latvia (Kara 2013)





4.2.2 Porous Pavements

A characteristic of a porous pavements system, which is either a permeable or consists of another stabilized surface, is that it allows stormwater runoff to infiltrate through its surface, into the groundwater (MDT, 2005). Permeable concrete segmental paving emerged in Germany and Austria in the 1980s as a means of flood mitigation (Shackel and Pearson, 2006). In Germany, porous pavement has been installed with increasing frequency, with approximately 18,000,000 m² porous pavement installed per annum in 2009 – more than any other country in the world (van Diemen, 2009). A car and bus parking area at the Hannover World Expo 2000 site is one of the largest porous pavement systems in the world. The system allows the majority of water to be stored and infiltrated into the sub-grade soil and the excess water flows through a rubble filled swale trench system 2 m wide and 1.8 m deep (van Diemen, 2009). Porous pavements are also used commonly in Sweden to reduce runoff to sewer systems, reducing overflow frequency and volumes (Pitt, 2005).

Building upon the framework introduced in the beginning of this chapter, the following listing illustrates some characteristics of this specific USWM technology and certain features prevalent in the Baltic Sea region that may exert influence on the wider application of porous pavements.

Geophysical Factors

Climate:

- Suitable for both cold and warm climates (UNHSC, 2012), however during surface freeze in winter the effectiveness of porous pavements may decrease (Barrett & Shaw 2007; EPA, 1999)

Soil:

- Effective application needs deep permeable soils (EPA, 1999)
- Affect underlying soil bearing capacity (EPA, 1999)
- On the long-term, it may contribute to soil pollution with heavy metal and mineral oil (Dierkes and Geiger, 1999; Legret et al., 1999)

Hydrology and hydrogeology:

- Helps to recharge groundwater (EPA, 1999)

Technical Factors

Materials:

- Permeable pavements require frequent maintenance by vacuum sweeping in order to prevent pollutants from clogging the pores (Virginia DCR, 2011)

Stormwater runoff:

- Reduces stormwater runoff (Shackel, Pearson 2006).
- In Sweden: 50 to 81% annual stormwater runoff reduction (Stenmark, 1995)
- Reduces peak flow by 30% and delays peak flow by 5 to 10 min (Pratt et al. 1989)

Pollution control:

- Improved water quality by prevention of pollutants entering to water bodies (Scholz, Grabowiecki 2007); 90% removal of TSS by most permeable pavements (Shackel,





Pearson 2006); 80 – 90% reduction in chemical oxygen demand (Baladès et al., 1995); total phosphorous reduction by 80% (Dreelin et al., 2006); reduction of Lead by 90 – 95% (Baladès et al., 1995); copper, cadmium, and zinc reduction by 57 – 85% (Legret et al., 1999)

Economic Factors

Cost:

- Investment in Germany: 10 - 18 €/m² (Gartenbau, 2012)
- Investment in USA: \$6 - \$108/m² (Virginia DCR, 2011); \$17.8 – \$107.4/m² (Thurston, 2012); \$30.14/m² for porous asphalt pavement compared to \$24.22/m² for standard asphalt (UNHSC, 2012)
- Operation and maintenance: USA: \$0.5/m² (Virginia DCR, 2011)

Incentives and subsidies:

- In Hamburg, indirect financial incentive in the form of reduced stormwater management tariff (Hamburg Wasser, 2014a, 2014b).

Regulatory Factors

EU, national, regional support:

- The Water Framework Directive (WFD) 2000/60/EC (WFD) establishes an EU-wide regulatory framework for the protection of inland surface waters and groundwater (Baumgartner, 2008).
- Decentralized stormwater management practices are preferred methods in Germany (Berendes 2010), Sweden (Uppsala kommun 2014)
- In Germany, the Federal Nature Conservation Act (BNatSchG) establishes the general framework for the impact mitigation regulation on nature and landscape and it encourages the implementation of stormwater management practices that mimic natural flows (Article 8)(BNatSchG, 2009)
- In Hamburg, the division of stormwater and sewage charge promotes decentralized natural rainwater management by offering indirect financial incentive (Hamburg Wasser, 2014a, 2014b).

Other opportunities and challenges

Sustainability Aspect:

- Benefits the aquatic ecosystem by preventing pollutants from entering to water bodies (Tillmanns, 2013)

Disadvantages:

- Shorter life span compared to impermeable pavement (Shackel et al. 2008; Scholz, Grabowiecki 2007)
- Application restricted to low traffic area (EPA, 1999)

By means of the SWOT table, the strengths, weaknesses, opportunities and threats that may have an impact on the wider application and implementation of porous pavement technology are highlighted. From the analysis, it appears that strengths and weaknesses need to be closely assessed in relation to the respective local conditions and capacities in order to seize its inherent potential.



Table 5: SWOT Evaluation - Porous Pavements

Strengths	Weaknesses
<p>Geophysical factors</p> <ul style="list-style-type: none"> - Suitable for both cold and warm climates (UNHSC, 2012) - Enables the recharge of local aquifer (EPA, 1999) <p>Technical factors</p> <ul style="list-style-type: none"> - Can reduce stormwater runoff volume by 50 - 80% in Sweden (Stenmark, 1995) - Reduces peak flow by 30% and delays peak flow by 5 to 10 min (Pratt et al. 1989) - Improves water quality by prevention of pollutants entering to water bodies (Dreelin et al., 2006; Legret et al., 1999; Scholz, Grabowiecki 2007; Shackel, Pearson 2006) <p>Economic factors</p> <ul style="list-style-type: none"> - Cost savings by avoiding cost of managing pollution in water bodies, and also avoiding cost for the construction stormwater infrastructure associated to standard pavement (UNHSC, 2012) <p>Social and biodiversity aspects</p> <ul style="list-style-type: none"> - Benefits the aquatic ecosystem by preventing pollutants from entering to water bodies (Tillmanns, 2013) 	<p>Geophysical factors</p> <ul style="list-style-type: none"> - Frozen surface in winter decreases the effectiveness of porous pavements (Barrett & Shaw 2007; EPA, 1999) - Performance affected by increased frequency of stormwater events - Underlying soil bearing capacity can be affected (EPA, 1999) - Potential long-term soil pollution with heavy metal and mineral oil (Dierkes and Geiger, 1999; Legret et al., 1999) <p>Technical factors</p> <ul style="list-style-type: none"> - Require high technical skill for the construction (EPA, 1999) - Require frequent maintenance by vacuum sweeping in order to prevent pollutants from clogging the pores (Virginia DCR, 2011) - Shorter life span compared to impermeable pavement (Scholz and Grabowiecki, 2007; Shackel et al., 2008) - Application restricted to low traffic area (EPA, 1999) <p>Economic factors</p> <ul style="list-style-type: none"> - High investment as well as operation and maintenance cost (Virginia DCR, 2011), in Germany porous pavement cost 10 - 18 €/m² (Gartenbau 2012)
Opportunities	Threats
<ul style="list-style-type: none"> - Supportive regulation at European level – the Water Framework Directive (WFD) (Baumgartner 2008; EC 2000). - In Germany, the Federal Nature Conservation Act (BNatSchG) establishes the general framework for the impact mitigation regulation on nature and landscape – promoted green roof application (Article 8)(BNatSchG, 2009) - In Hamburg, the division of stormwater and sewage charge promotes decentralized natural rainwater management by offering indirect financial incentive (Hamburg Wasser, 2014a, 2014b). - Decentralized stormwater management practices based on infiltration are preferred methods in Germany (Berendes 2010), in Sweden (Uppsala kommun 2014) 	<ul style="list-style-type: none"> - Increased frequency of storm events may exceed the maximum water storage capacity of permeable pavements - Pose a potential risk for polluting groundwater and soil





4.2.3 Bioretention Systems

Bioretention systems are landscaped depressions with vegetation to which stormwater runoff is diverted and stored. Once in the depression, the landscaped trees, shrubs, and other vegetation help to remove the water through uptake, while the runoff infiltrates into the soil below. The underlying soil may consist of the original soil or it may be non-native soil such as sand that is installed during construction. Also, depending on the permeability of the underlying soil, a bioretention system may include a perforated underdrain which collects and removes infiltrated water (Weiss and Gulliver, 2005). Bioretention systems can be designed in different shape and size and also can support different types of vegetation, allowing their adaption to be adapted in different landscapes and urban spaces (Hoyer *et al.*, 2011).

Building upon the framework introduced in the beginning of this chapter, the following listing illustrates some characteristics of this specific USWM technology and certain features prevalent in the Baltic Sea region that may exert influence on the wider application of bioretention systems.

Geophysical Factors

Climate:

- Performance is affected in cold climate where the soil may freeze (Hunt et al., 2008)
- Increased winter rainfall and increased frequency of storm events affect the performance of bioretention systems (Tillmanns, 2013)

Soil:

- Not suitable where the soil is impermeable (EPA, 1999)

Hydrology and hydrogeology:

- Help to recharge groundwater
- Not appropriate if the ground water table is high (within 1.8 m of the ground surface) (EPA, 1999)

Technical Factors

Materials:

- Requires 5% land area 5of impervious watershed (EPA, 1999)
- Maintenance: annual or twice a year inspection of filter media, the trees and shrubs; frequent observation of inlet from impervious surfaces; landscaping and replacement after 5 to 15 years (Bawden, 2009; EPA, 1999)

Stormwater runoff:

- Promote infiltration of stormwater and reduce stormwater runoff and decrease peak stormwater flow (Roy-Poirier et al., 2010)
- Reduce mean peak runoff flow by 49 to 58 % and delay peak runoff by a factor of 5.8 to 7.2 (Davis et al., 2009)

Pollution control:

- Improved water quality by prevention of pollutants entering to water bodies (Tillmanns, 2013)





- 90 – 91% total suspended solids removal (Hsieh and Davis, 2005); 63% BOD removal (Hunt et al., 2008); 45 – 80% total nitrogen removal (Davis et al., 2006; Hunt et al., 2006); 70 – 85% phosphorous removal (Davis et al., 2006); 54.5-99.8% reduction of pathogens (Rusciano and Obropta, 2007); fecal coliform and E. coli reduction of 69% and 71%, respectively (Hunt et al., 2008); 90% reduction of polycyclic aromatic hydrocarbons (DiBlasi et al., 2009)
- Relatively low efficiency in heavy metal removal (Roy-Poirier et al., 2010; Davis et al., 2006)

Economic Factors

Cost:

- Investment: USA: \$376/m² (Herrera, 2012) ; \$39,7 – \$52.7/m² (Thurston, 2012)
- Operation and maintenance: USA: 11.84/m² (Herrera, 2012); 0.7–10.9% of construction cost (Weiss et al., 2007)

Regulatory Factors

EU, national, regional support:

- The Water Framework Directive (WFD) 2000/60/EC (WFD) establishes an EU-wide regulatory framework for the protection of inland surface waters and groundwater (Baumgartner, 2008).
- Decentralized stormwater management practices are preferred methods in Germany (Berendes 2010), Sweden (Uppsala kommun 2014)
- In Germany, the Federal Nature Conservation Act (BNatSchG) establishes the general framework for the impact mitigation regulation on nature and landscape and it encourages the implementation of stormwater management practices that mimic natural flows (Article 8)(BNatSchG, 2009)

Other opportunities and challenges

Pros:

- Improves aesthetics and multifunctional landscaping (Bawden, 2009)
- Creates potential habitats for birds and insects, and may attract wildlife species, such as, deer, butterflies and raccoons, which increases the local species biodiversity and enhance aesthetic appearance (Tillmanns, 2013)
- Decreased runoff pollutants that flow into water bodies can improve water quality, which benefits the aquatic ecosystem

Cons:

- During dry periods, especially in long dry summer seasons, water shortage may affect the vegetation in bioretention system, nitrogen leaching may occur due to plant die-off during this period (Bawden, 2009)

By means of the SWOT table, the strengths, weaknesses, opportunities and threats that may have an impact on the wider application and implementation of bioretention technology are highlighted. From the analysis, it appears that strengths substantially outweigh the weaknesses but that opportunities and threats need to be closely explored in relation to the respective local conditions and capacities.



Table 6: SWOT Evaluation of Bioretention Systems

Strengths	Weaknesses
<p>Geophysical factors</p> <ul style="list-style-type: none"> - Enable the recharge groundwater (EPA, 1999) <p>Technical factors</p> <ul style="list-style-type: none"> - Promotes infiltration of stormwater and reduces stormwater runoff (Roy-Poirier et al., 2010); Davis et al., 2009) - Decreases peak stormwater flow (Roy-Poirier et al., 2010; Davis et al., 2009) - Improves water quality by prevention of pollutants entering to water bodies (Tillmanns, 2013; Hsieh and Davis, 2005; DiBlasi et al., 2009; Hunt et al., 2008) - Have moderate land requirement – 5 % of impervious watershed (EPA, 1999) - Does not require high technical skills for the construction and has moderate maintenance requirement (Bawden 2009; EPA, 1999) - Can be applied at a range of scales and shapes and therefore provide flexibility for locations within a development (Bawden, 2009) <p>Economic factors</p> <ul style="list-style-type: none"> - Relatively low investment, operation and maintenance cost (Thurston, 2012) <p>Social and Biodiversity</p> <ul style="list-style-type: none"> - Benefits the aquatic ecosystem by preventing pollutants from entering to water bodies (Tillmanns, 2013) - Improves aesthetics and multifunctional landscaping and can be used as a recreational area (Bawden, 2009) - Create potential habitats for birds and insects, and may attract wildlife species, such as, deer, butterflies and raccoons, which increases the local species biodiversity and enhance aesthetic appearance (Tillmanns, 2013) 	<p>Geophysical factors</p> <ul style="list-style-type: none"> - Increase in winter rainfall and increased frequency of storm events affect the performance of bioretention systems (Tillmanns, 2013) - Not appropriate if the ground water table is high (with in 1.8 m of the ground surface), soil is impermeable; not suitable for high slope (> 20%) (EPA, 1999) - Performance is affected in cold climate during period of soil freeze (Hunt et al. 2008) <p>Technical factors</p> <ul style="list-style-type: none"> - Relatively low efficiency in heavy metal removal (Roy-Poirier et al. 2010; Davis et al. 2006) - During dry periods, especially in long dry summer seasons water shortage may affect the vegetation in bioretention system, nitrogen leaching may occur due to plant die-off during this period (Bawden, 2009)





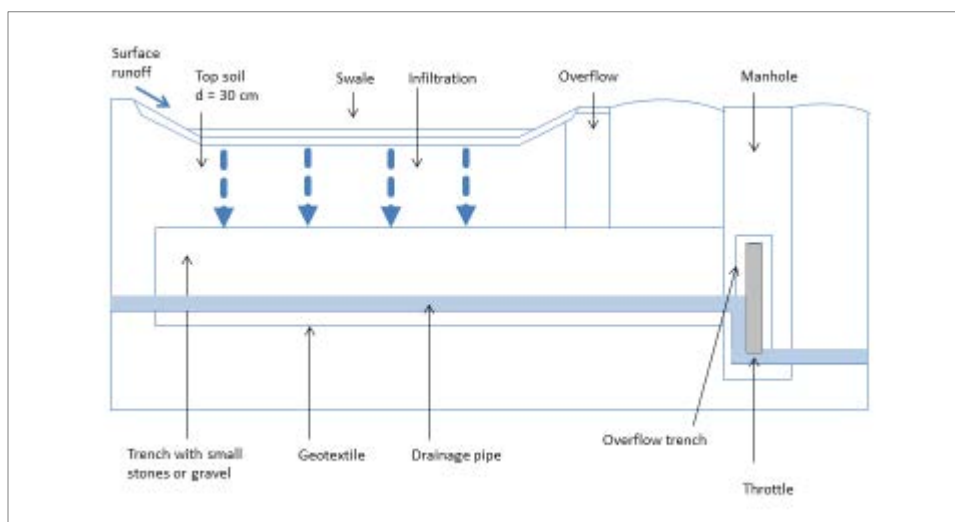
Opportunities	Threats
<ul style="list-style-type: none">- Supportive regulation at European level – the Water Framework Directive (WFD) (Baumgartner 2008; EC 2000).- In Germany, the Federal Nature Conservation Act (BNatSchG) establishes the general framework for the impact mitigation regulation on nature and landscape – promoted green roof application (Article 8)(BNatSchG, 2009)- Decentralized stormwater management practices based on infiltration are preferred methods in Germany (Berendes 2010), in Sweden (Uppsala kommun 2014)	<ul style="list-style-type: none">- Increased frequency of storm events may exceed the maximum capacity of bioretention systems- Pose a potential risk for polluting groundwater and soil



4.2.4 Bioswales

A bioswale, or alternatively called vegetative swale, is a broad, shallow channel (see Figure 10). A dense stand of vegetation covers its side slopes and its bottom. Bioswales receive stormwater runoff laterally through gentle side slopes and convey this stormwater downstream by way of longitudinal slopes that are typically less than 5% (EPA, 1999). Deletic and Fletcher (2006) consider bioswales, which can improve water quality, to be among the simplest and most cost-effective form of stormwater control measures as they slow down runoff from hard surfaces. In particular, the vegetated cover on sloped applications slows the overland flow to allow greater opportunity for infiltration into the soil, intercepting and filtering pollutants while also providing an opportunity for nutrient uptake through the root system (Weiss and Gulliver, 2005). There are generally two main types of swales: 1) grassed or densely vegetated swales with natural soils below; or 2) swales with filter media or porous soils whose major treatment mechanism is infiltration. The type of swale selected depends on-site physical conditions (soils, slopes, land use, water table depth, depth to bedrock), contaminants of concern and maintenance infrastructure (Boogaard *et al.*, 2014). If combined with other stormwater management systems such as bioretention basins or infiltration trenches, bioswales prove most effective, especially if the length of land, allowing enough retention time for pollutant removal, is limited (Jurries, 2003; UF, 2008).

Figure 10: Schematic diagram over the swale-trench (Mulden-Rigolen) systems at Glinder Strasse, Hamburg



Source: Adapted from Ingvertsen *et al.*, 2010



Building upon the framework introduced in the beginning of this chapter, the following listing illustrates some characteristics of this specific USWM technology and certain features prevalent in the Baltic Sea region that may exert influence on the wider application of bioswale technology.

Geophysical Factors

Climate:

- Can be applied in a range of climatic condition (Bawden, 2009)

Soil:

- Suited to a wide range of soil conditions, including low hydraulic conductivity 'clay' soils (Bawden, 2009)
- The type and compactness of the local soil affects the design of bioswales (Jurries, 2003)
- Recommended soil infiltration rate in Germany 1×10^{-6} - 1×10^{-3} m/s (Ingvertsen et al. 2010)

Hydrology and hydrogeology:

- Help to recharge groundwater

Technical Factors

Materials:

- Requires land area of 10-20 % of impervious watershed (EPA, 1999)
- Requires maintenance in order to prevent the bioswales from becoming clogged or polluted. Leaf waste and litter are removed and the overflow drains pumped clean twice yearly and the drainage system is hosed clean once per year (Boogaard et al., 2014).

Stormwater runoff:

- Increases infiltration and reduces total volume of stormwater runoff (UF, 2008)
- Able to handle the design storm if properly maintained and able to reduce peak discharges by 10 to 20% (Boogaard et al. 2014)
- Mean volume reduction 30 to 47% (Barrett 2005; Deletic, Fletcher 2006)

Pollution control:

- Reduces pollutants by combined treatment using soil, vegetation and microbes (UF, 2008)
- Able to reduce total suspended solids, heavy metals, phosphorous and nitrogen compounds (Bäckström 2003; Barrett 2005; Barrett et al. 1998; Schueler 1994; Weiss and Gulliver, 2005)
- Effectiveness depends upon maintenance and retention time of the stormwater in the bioswale. The longer the retention time, generally, the higher the pollutant removal efficiency (Jurries, 2003).

Economic Factors

Cost:

- Investment: \$3.2 - \$5.4/m² (Thurston, 2012); €0,37/m² - a rainwater sewer is 50% more expensive than a bioswale system (Boogaard et al., 2014)
- Operation and maintenance: 5%- 7% of construction cost (EPA, 1999); 4.0%-178% of construction cost (Weiss and Gulliver, 2005); € 0,27/m² (Boogaard et al., 2014)





Regulatory Factors

EU, National, regional support:

- The Water Framework Directive (WFD) 2000/60/EC (WFD) establishes an EU-wide regulatory framework for the protection of inland surface waters and groundwater (EC 2000; Baumgartner 2008).
- Decentralized stormwater management practices are preferred methods in Germany (Berendes 2010) and Sweden (Uppsala kommun 2014)
- In Germany, the Federal Nature Conservation Act (BNatSchG) establishes the general framework for the impact mitigation regulation on nature and landscape and it encourages the implementation of stormwater management practices that mimic natural flows (Article 8) (BNatSchG, 2009)

Other opportunities and challenges

Pro:

- Enhance the aesthetics of the local landscape and improve biodiversity (Bawden, 2009)

Cons:

- Leaching from swale vegetation may release trace metals and nutrients to the environment
- Infiltration through the swale may carry pollutants to ground water
- Standing water in swales may present safety concern, generate odor and can be a breeding place for mosquitos
- Their application is limited by availability of land
- Impractical in areas with flat or very steep topography, in wet and poorly draining soils
- Not suitable if peak discharge exceeds 0.14 m³/s and if the velocity exceeds 1 m/s (EPA 1999).

By means of the SWOT table, the strengths, weaknesses, opportunities and threats that may have an impact on the wider application and implementation of bioswale technology are highlighted. From the analysis, it appears that strengths may substantially outweigh the weaknesses, EU level legislation supports its application but this technology is not suitable in areas with high ground water tables, flat or steep topography or poorly draining soils.





Table 7: SWOT Evaluation of Bioswales

Strengths	Weaknesses
<p>Geophysical factors</p> <ul style="list-style-type: none"> - Can be applied in a range of climatic conditions (UF, 2008) - Enable the recharge of local aquifer (EPA, 1999) - Suited to a wide range of soil conditions, including low hydraulic conductivity ‘clay’ soils (Bawden, 2009) - Help to recharge groundwater (UF, 2008) <p>Technical factors</p> <ul style="list-style-type: none"> - Promote infiltration of stormwater and reduce stormwater runoff (Boogaard et al. 2014) - Decrease peak stormwater flow (Barrett 2005; Deletic, Fletcher 2006) - Able to reduce total suspended solids, heavy metals, phosphorous and nitrogen compounds (Bäckström 2003; Barrett 2005; Barrett et al. 1998; Schueler 1994; Weiss and Gulliver, 2005) - Requires moderate maintenance in order to prevent the bioswales from becoming clogged or polluted. Leaf waste and litter are removed and the overflow drains pumped clean twice yearly and the drainage system is hosed clean once per year (Boogaard et al., 2014). - Performance can be increases by appropriate maintenance and increasing retention time of the stormwater in the bioswales (Jurries 2003). <p>Economic factors</p> <ul style="list-style-type: none"> - Present low-cost alternative for decentralized stormwater management (Thurston, 2012) - Cost saving by avoiding cost of managing pollution in water bodies <p>Social and biodiversity</p> <ul style="list-style-type: none"> - Benefits the aquatic ecosystem by preventing pollutants from entering to water bodies - Provide landscape features in an urban development to improves aesthetics (Bawden, 2009) 	<p>Geophysical factors</p> <ul style="list-style-type: none"> - Not appropriate if the ground water table is high - Impractical in areas with flat or very steep topography, in wet and poorly draining soils (EPA, 1999) <p>Technical factors</p> <ul style="list-style-type: none"> - Have relatively high land requirement - 10-20 % of impervious watershed (EPA, 1999) - Not suitable if peak discharge exceeds 0.14 m³/s and if the velocity exceeds 1 m/s (EPA 1999).





Opportunities	Threats
<ul style="list-style-type: none">- Supportive regulation at European level – the Water Framework Directive (WFD) (Baumgartner 2008; EC 2000).- In Germany, the Federal Nature Conservation Act (BNatSchG) establishes the general framework for the impact mitigation regulation on nature and landscape – promoted green roof application (Article 8)(BNatSchG, 2009)- Decentralized stormwater management practices based on infiltration are preferred methods in Germany (Berendes 2010), in Sweden (Uppsala kommun 2014)	<ul style="list-style-type: none">- Leaching from swale vegetation may release trace metals and nutrients to the environment (UF, 2008)- Infiltration through the swale may carry pollutants to groundwater (UF, 2008)





4.2.5 Conclusions

By means of the SWOT table, the strengths, weaknesses, opportunities and threats that may have an impact on the wider application and implementation of four USWM technologies were explored. Local conditions affecting the physical implementation of decentralized stormwater management practices can be availability of land, soil permeability, local climate, but also local regulations and availability of incentives and subsidies.

From the analysis, it appears as if green roof technology has indeed a great potential for application in the BSR region, as strengths and opportunities clearly outweigh weaknesses and threats. Especially the very high stormwater runoff volume reduction (60 to 80%) the possibility to be applied in various climatic regions and the manifold social and diversity aspects need to be highlighted.

Regarding porous pavements, it may be suggested that especially its strengths and weaknesses need to be closely scrutinized in relation to the respective local conditions and capacities in order to seize its inherent potential. Whereas this technology is also assumed to be able to reduce stormwater runoff volume by 50 - 80% and to enable the recharge of local aquifers, high technical skill are required for the construction and the performance may be negatively affected by increased frequency of stormwater events.

Concerning bioretention systems, it seems that the strengths substantially outweigh the weaknesses of bioretention systems but that opportunities and threats need to be closely explored in relation to the respective local conditions and capacities. The technology has its strengths in a range of technical and social as well diversity aspects, e.g. It does not require high technical skills for the construction and has moderate maintenance requirement, it benefits the aquatic ecosystem by preventing pollutants from entering to water bodies and it may support the creation of potential new habitats for birds and insects, and may attract wildlife species, such as, deer, butterflies and raccoons, which increases the local species biodiversity.

The strengths of bioswales may substantially outweigh the weaknesses, EU level legislation supports its application but this technology is not suitable in areas with high ground water tables, flat or steep topography or poorly draining soils. Bioswales present a low-cost alternative for decentralized stormwater management which can be applied in a range of climatic conditions. It requires moderate maintenance, promote the infiltration of stormwater and reduce stormwater





runoff. Moreover, this technology benefits the aquatic ecosystem as it can prevent pollutants from entering to water bodies.

4.3 Technology Evaluation

The four most popular technologies identified in the region (i.e. green roof, porous pavement, bioretention basins, and bioswales) have been selected for further evaluation and applicability based on the characteristics of each technology and country-specific information which the BalticFlows partners have provided during the project.

4.3.1 Green roofs

Green roofs offer an option for decentralized management of rainwater falling on building roofs. It helps to reduce the volume of runoff, delays and reduces peak stormwater runoff flow rates and can reduce pollutants carried to water bodies through the runoff. Implementation of green roofs does not require additional land and therefore offers a decentralized urban stormwater management option in dense urban areas. Moreover, green roofs visually enhance the quality of life in cities. Accessible green roofs can even provide recreational areas. Although the initial investment cost of the green roof technology is higher than standard roofing, the costs can be recovered considering the monetary values of the different benefits ranging from the increased life of water proofing layer, cost saving from increased building energy efficiency, avoided cost for drainage infrastructure etc. Three factors have a major influence on the hydraulic as well as pollutant removal performance of green roofs: i. precipitation (duration, intensity); ii. substrate layers (type, thicknesses); and iii. the types of vegetation used in the green roofs. Using an appropriate design which integrates different technical options can prove useful to increase the efficiency of green roofs in different regions and under different climatic conditions. A well-established green roof industry in Germany, good experience in Sweden and relatively less experience and lack of market competition the other Baltic Sea regions offers an opportunity for transfer of technology and knowledge between the regions. The introduction of a regulatory framework as well as subsidy and incentive mechanisms for promoting green roofs in urban planning are key to a successful application as experiences from Germany show. To increase the efficiency of stormwater management measures, Villarreal (2007) suggests that green roofs should be implemented in combination with other best practices in stormwater management.





4.3.2 Porous Pavements

Porous pavements offer an option for decentralized stormwater management from areas including low-traffic roads, residential driveways, parking areas and sidewalks, reducing volume urban stormwater runoff, delaying and reducing stormwater runoff peak flow as well as reducing pollutants from stormwater flow. European level regulations, national and local legislations in the Baltic Sea regions encourage the implementation of infiltration based stormwater management systems of which one of the technologies is porous pavement systems. Porous pavements have higher initial capital cost than standard impermeable pavement however its overall cost can be lower considering the additional cost of the associated drainage infrastructure (curb, catch basins, piping, and ponds) for standard impervious pavements (UNHSC, 2012). Special design consideration may be required for increasing the performance of porous pavement in cold climate during winter, like durability against freeze-thaw cycles as well as designing of the sub-base drainage layers to avoid deformations due to frost heave of underlying soils (Kuosa and Holt, 2014). Although porous pavement can help to recharge groundwater, it may also pose risk for the pollution of groundwater and soil. Therefore, application of porous pavement requires the knowledge of the local soil and groundwater condition.

4.3.3 Bioretention Basins

Bioretention systems offer another efficient option for decentralized stormwater management. They reduce the volume of urban stormwater runoff, they delay and reduce stormwater runoff peak flow and reduce pollutants. Bioretention systems have relatively low construction and maintenance costs as well as low maintenance requirements. As mentioned before, European level regulations, national and local legislation in the Baltic Sea regions all encourage the implementation of such infiltration based stormwater management systems. Like other infiltration based stormwater management systems, their design and performance depends on the availability of permeable soil layer. Bioretention systems help to recharge groundwater, however they also pose a threat to pollute groundwater and soil if design guidelines are not followed properly.

4.3.4 Bioswales

Bioswales systems offer an efficient and low-cost option for decentralized stormwater management in terms of reducing volume urban stormwater runoff, in delaying and reducing stormwater runoff peak flow and reducing pollutants. Bioswale systems with underlying constructed porous layer and drainage can be used in areas where the soil is highly compacted or





impermeable. European level regulations, national and local legislations in the Baltic Sea regions encourage the implementation of infiltration based stormwater management systems of which one of the technologies is bioswales. However, their application is limited by availability of land and they may pose treat to groundwater pollution by leaching and also through infiltration. Furthermore, bioswales have limited applicability in flat topography area.

4.3.5 Conclusions

Sustainable urban drainage systems are characterized by an integrated water cycle management. The sustainable development of urban areas relating to impacts of climate variability and climate change implies that the adverse effects of urban stormwater runoff, i.e. increased urban flooding and deteriorating receiving water quality, are mitigated effectively. Best practice urban stormwater management will thus require the development of integrated measures, with each of them being designed to achieve specific targets related to urban stormwater problems. An example that demonstrates an integrated approach, i.e. implementation of different sustainable stormwater management practices for the decentralized management of stormwater, is Augustenborg, a housing district in Malmo, Sweden. In this project, different stormwater management systems including green roofs, bioswales, ditches, and ponds with regional wetland vegetation were applied. A Botanical Roof Garden, which covers an area of 9,500 m² is the largest green roof in Scandinavia and is the world's first botanical roof garden. All stormwater from the housing district is managed locally, and floods which were occurring frequently are prevented. Lessons can be learned from such examples in order to device integrated use of different sustainable urban stormwater management practices (Kazmierczak and Carter, 2010).

Which type of decentralized stormwater management technology is appropriate for application in a particular location depends on a set of different factors, including infiltration capacity, groundwater level, soil permeability and contamination, surface runoff characteristics, local climate, land availability and ground slope. For example, the application of infiltration based stormwater management practices in high groundwater table and impermeable soil areas is limited unless optimal locations are selected based on detailed geological investigations (Bockhorn *et al.*, 2013). In order to protect from groundwater pollution, the infiltration based stormwater management systems should carefully consider local conditions, especially the location of pollution hot spots and the seasonal groundwater table (UNHSC, 2012).





Among the main challenges identified in using decentralized stormwater management practices are the appropriate sizing of elements, cost estimates, understanding water dynamics, aspects of biodiversity promotion, dealing with the land administration and ownership issues (Backhaus et al., 2012). A thorough understanding of these factors is thus key to implementing efficient decentralized stormwater management measures.

The anticipated change in precipitation patterns due to climate variability and climate change is a vital factor affecting the performance of stormwater management systems. An increased frequency of storm events may exceed the design capacity of stormwater management technologies affecting their performance. For this reasons, the design of a given stormwater management system should therefore consider future changes at the very outset, besides the peak runoff volumes for flood control and the water quality volume for pollution control (Jurries, 2003). Of relevance to the Baltic Sea Region is the melting snow, which in cold climate zones, makes up a considerable part of annual stormwater runoff in addition to the proportion of rainfall runoff from urban surfaces.

4.4 Life Cycle Assessment

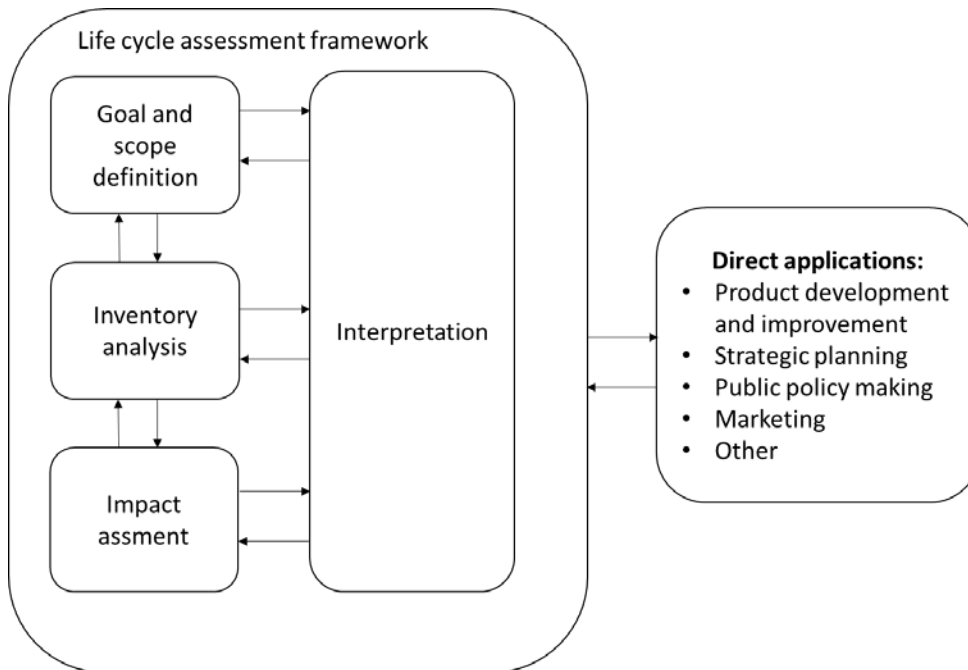
In a current study undertaken in the frame of the BalticFlows project (IFU 2016), a Life Cycle Assessment (LCA) has been used for the evaluation of Trench Through Systems. Trench Through Systems is a popular approach to manage the quantity of stormwater runoff. In this report, the results of this study are used to support the identification of best management practices by providing a holistic assessment that includes a variety of environmental impact categories over the whole life cycle of the product systems. After a brief introduction of LCA, the application of the LCA method for trench systems will be further elaborated.

4.4.1 Introduction to Life Cycle Assessment

A Life Cycle Assessment considers environmental aspects and potential environmental impacts over the entire lifetime of a product, from acquisition of raw materials through the production, use and final treatment (from cradle-to-grave). The LCA is structured as follows: First, the goal and scope are defined and then the inventory analysis takes place. Before finally interpreting the results, the impact assessment phase takes place. The four phases are presented in the Figure 11 (ISO, 2006).



Figure 11: Phases of LCA



Source: ISO, 2006

The first phase of an LCA is the “goal and scope definition”. It includes decisions relevant for the following phases and the final result. What shall be addressed includes the use of the results (inside an organization or public); the aim of the study (documentation or decision support), geographic, temporal and technical area of application; data quality requirements; financing and the object to be investigated (Baumann and Tillman, 2004). One core piece of a LCA is the functional unit, which defines the investigated object. It serves as a reference value, depends on the goal definition and is also used as value for comparisons. This unit can be based on the product or the services resulting from the product. Every single use of resources as well as every emission of substances to the environment during the LCA will be calculated in relation to the functional unit. In the ISO 14044, the functional unit is defined as “quantified performance of a product system for use as a reference unit” (ISO, 2006).

In addition to the functional unit, those environmental impacts that shall be considered during the interpretation must be defined. System boundaries are being set to describe the scope. Such boundaries describe which of the pre-chains have to be considered and which ones to neglect. For example, if the product that shall be analyzed is being transported during its life cycle, the emissions that are linked to the transport activities should be considered. (Schmidt *et al.*, 2009)



The second phase of a LCA, the life cycle inventory (LCI), describes the composition of resources consumed through the product or production system and the emissions to the environment. ISO 14044 describes the LCI as “phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle” (ISO, 2006). A product model system, which shall be analyzed, is being designed and fed, if possible, mostly with primary data. Primary data includes data that was measured or collected in the specific process system. Such data forms the foreground system. Secondary data from literature or generic data sets taken from databases in order to model unknown or repeating processes forms the background system.

In practice, separating the product system that shall be analyzed into foreground and background model has proven to be quite useful. The foreground includes the known processes for which real and specific process data can be collected. The background system, on the other hand, assesses the unknown upstream processes such as materials, energy and transport services. Due to the fact that often no real and specific data is given for such processes, generic LCI data from appropriate databases is being applied here (ILCD, 2010). When modeling, foreground and background systems are combined. The overall product system consists of numerous processes that are needed for producing the product and that are linked to one another. Energy and material flows for each process must be included. Balancing all energy and material flows in relation to the functional unit is the foundation for phase three of the LCA, the life cycle impact assessment (Schmidt and Schorb, 1995).

During the third phase, i.e. during the life cycle impact assessment (LCIA), the environmental impacts of the elementary flows from the LCI are being assessed. The ISO 14044 defines the LCI as “*phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product system throughout its life cycle*” (ISO, 2006). In order for the results to serve the purpose of communication and decision support, they can be concentrated as well as weighted or prioritized (Frischknecht and Jungbluth, 2007). The type of weighting is already decided upon in the first LCA phase (goal and scope definition). LCIA applies evaluation models, which include indicators for different impact categories.

LCI databases usually include the possibility to use various LCIA methods. The advantage of using such a ready-made method is, that it is not necessary to go very deep into the different impact assessment steps, such as classification and characterization, because the environmental information for the different pollutants and resources is already aggregated to a characterization



indicator or a single number index. Different environmental loads are assessed on a common scale and each method has a particular measurement principle. (Baumann and Tillman, 2004)

Life cycle impact assessment methodologies help to analyze life cycle inventory results by connecting the single results to the corresponding environmental impacts through the mentioned characterization factors. (Humbert *et al.*, 2012)

The final phase of an LCA is interpretation of the results. An LCA is an iterative method. Hence, the interpretation may lead to an adaption of the goal and scope definition and improvement of the models. Interpretation includes a discussion of the hotspots, characteristics of the study and oftentimes recommendations.

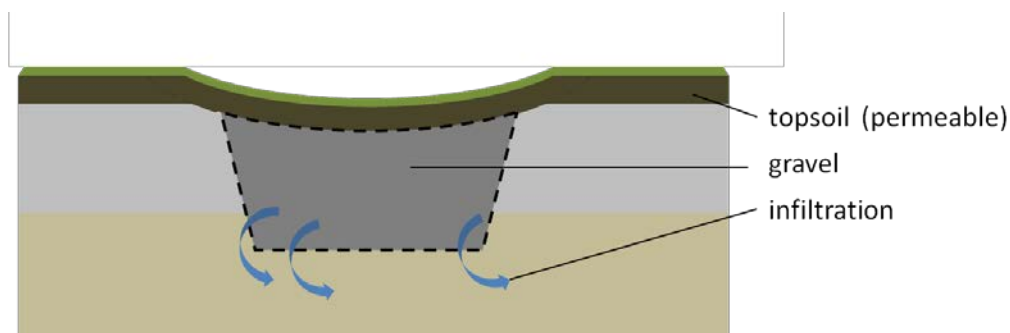
4.4.2 Setup of the LCA for Trench Systems

In general, trench systems store runoff water before letting it infiltrate into the ground, delayed in time. For the LCAs in the BalticFlows project, two kinds of trench systems will be assessed.

- The first system considered will consist of gravel, surrounded by PP-geotextile. Figure 12 illustrates the concept. Runoff water is stored in the gravel's pore volume before infiltrating.
- The second system consists of half-pipe plastic shells with wholes.

Like conventional systems, these two kinds of trench systems retain the run-off to infiltrate it to the ground slowly. As the plastic system is hollow, more water can be stored compared to a gravel system of the same size. Therefore, plastic systems require less space than gravel trenches (Emscher Genossenschaft, 2007).

Figure 12: Gravel Trench System



Source: IFU



In the BalticFlows study (IFU 2016), a Life Cycle Assessment has been conducted to compare environmental performance over the entire lifetime of the two systems.

The entire life cycle, i.e. from raw materials to decommissioning (cradle-to-grave), was included. The LCA has been conducted using the software solution Umberto® NXT LCA, which enabled a visualization of the entire life cycle, including all phases and calculating the results. Data on the materials were attained through LCI databases such as ecoinvent v3.1 (Ecoinvent, 2014). A selection of impact categories from the impact assessment method ReCiPe was used. In addition, the valuation method ecological scarcity (2006) was used as this is one of few methods accounting for sand and gravel as resources that impact is allocated to. The functional unit applied to the BalticFlow Project's LCA resembled a certain volume of retention that can handle the runoff of a certain area, the roof of a single-family home. Both systems were dimensioned for the same conditions.

Generally, trench systems are quite robust and therefore can have a very long lifetime of around 100 years. If the infrastructure is not going to be changed because of size or to include other technologies, such systems are not considered to be removed at all. However, the researchers considered a lifetime of 50 years and a decommissioning phase. The gravel was calculated to be brought to a recycling centre, the plastic components including geotextiles would need to be transported to a disposal site.

Concerning maintenance, trench system, both gravel and plastic, are expected to require only small effort. Despite of thorough research and consultation of several experts in the field of plastics, no reference points indicating negative impacts by the polypropylene and polyethylene on the soil surrounding the system were found that need to be included into the assessment. The polypropylene systems used does not contain any softeners. Pure propylene is chemically inert and very stable. Strong acids or certain organic aromatic chemicals may cause corrosion but exposure to these is not the use case.

To set up the models, information obtained directly by a producer of plastic trench systems was used. The production site of the elements is located in central Germany. Spread over Europe, plenty of these trench systems are installed. The plastic trench system and the gravel trench system were modeled in Umberto with the system boundaries cradle-to-gate.



4.4.3 LCA Results

Table 8 summarizes the results of the LCA described above for the evaluated impact categories. All impact categories except natural resources (from the method ecological scarcity) were calculated using the method ReCiPe. The results show higher impact for the gravel system in all impact categories.

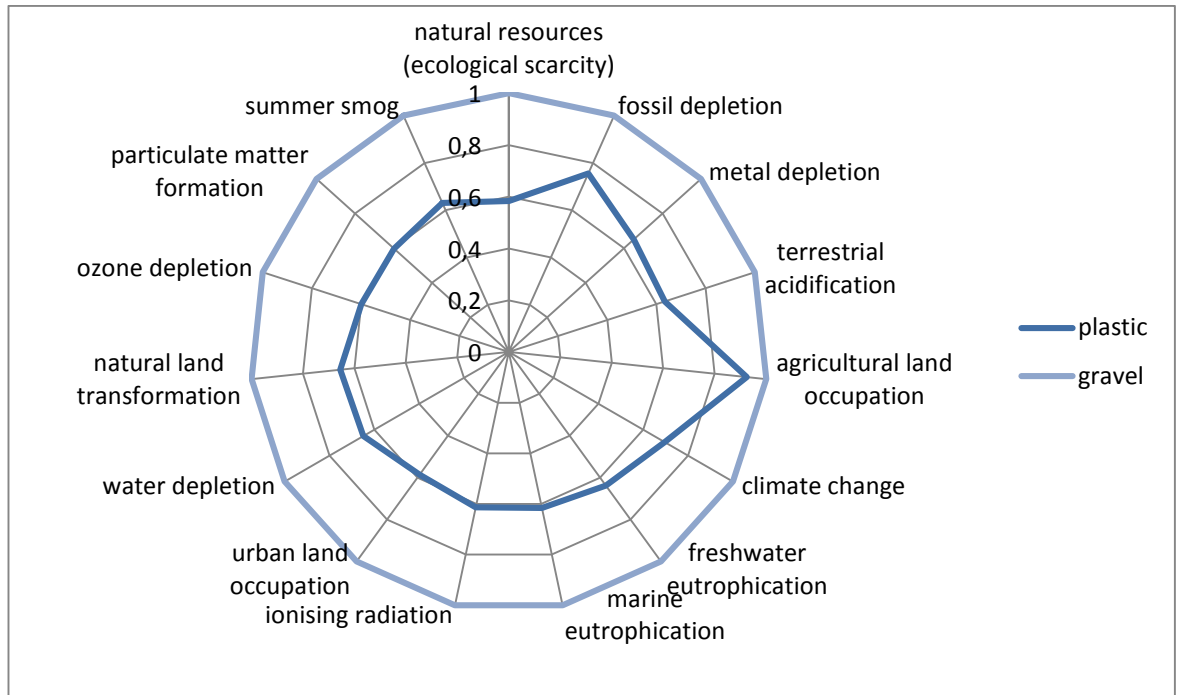
Table 8: Results of the LCA for the different impact categories

impact category	unit	plastic	gravel
natural resources (ecological scarcity)	UBP	539395	924718
fossil depletion	kg oil-Eq	231	306
metal depletion	kg Fe-Eq	40	62
terrestrial acidification	kg SO ₂ -Eq	3,5	5,5
agricultural land occupation	kg SO ₂ -Eq	25	27
climate change	kg CO ₂ -Eq	585	840
freshwater eutrophication	kg P-Eq	0,02	0,03
marine eutrophication	kg N-Eq	0,14	0,22
ionising radiation	kg U235-Eq	36	59
urban land occupation	m ² a	30	51
water depletion	m ³	1,3	2,0
natural land transformation	m ²	0,06	0,09
ozone depletion	kg CFC-11-Eq	8,E-05	1,E-04
particulate matter formation	kg PM ₁₀ -Eq	2,7	4,4
summer smog	kg NMVOC	4,1	6,5

Source: own compilation

Figure 13 shows a normalized Fingerprint diagram. For each impact category, the higher value was set to 1 and the other value scaled down accordingly.

Figure 13: Results as a fingerprint



Source: IFU 2016. All impact categories calculated with the LCIA method ReCiPe except when indicated in brackets.

4.4.4 Conclusions

Despite the fact that the plastic trench system includes a plastic tunnel, it also contains gravel and sand. Both are major contributors to the overall impacts of this option. The difference in the results is strongly influenced by the tunnel systems avoidance of gravel. As for the strong influence of the gravel: big amounts need to be extracted and transported over long distances, and ecosystems get destroyed or damaged severely in this process. Peduzzi et al (2014) claim that sand and gravel use exceeds their natural renewal rates by far. In LCA, ecosystem damage can be depicted by different elementary exchanges in various impact categories while use of resources can only be considered if this information is attached to the material itself. We found that these materials are only included in few evaluation systems; they are not included in any of the frequently used ones.

The results of the LCA show that under the preconditions of the analyses the plastic system is superior to the conventional gravel system in all evaluated impact categories.

The results of the LCA were heavily influenced by the contribution of sand and gravel. Both analyzed systems are used as decentralized measures and hence, no conclusion can be drawn from this





analysis whether decentralized management practices are more beneficial than centralized system. However, the contribution to the results by the materials gravel and sand was in a range of scale which implies to consider any avoidance of them to be beneficial. Centralized structure drainage systems tend to use large quantities of sand and gravel. Hence, when decentralized structure methods can be used instead of centralized structures, this is likely to be preferable.

The tendency to avoid the use of sand and gravel where when possible, could be identified. As management practices for runoff water are very site- and case-specific, so are the LCA results. The method LCA should therefore be applied to specific projects. Finally, it needs to be added that, as part of this report, the LCA approach has been included here for demonstrative purposes, serving as one example of a method that can be used to calculate and compare different drainage systems and options.





PART B

5. Overview of Regional Capacities in the BSR

This part of the report focuses on assessing the capacities that are a relevant precondition and enabler of USWM in the BSR region. From this perspective, policy and regulatory aspects which support the introduction and implementation of USWM practices are reviewed for those countries participating in the BalticFlows project. Moreover, the current state of UWM implementation is identified. Further, the sources information and knowledge networks such as relevant databases and associations, main actors for RTD related to urban stormwater management, financial stakeholders as well as current economic development and mentoring for capacity building in the regions are highlighted.

5.1 Policy and Regulation

In the following, characteristic features of the institutional and regulatory environments of the respective BalticFlows partner countries Estonia, Finland, Germany, Latvia, and Sweden are briefly described, complemented with relevant EU level directives, national and regional level policies.

5.1.1 Institutional and Legal Framework

The institutional framework for the protection, planning and management of water resources in Germany is imbedded in the general political, legislative, and governmental structure that, in addition to the European Union, is characterized by three primary levels of authority: the federal republic; the federal states; and the municipalities (Kampa *et al.*, 2003; Nickel *et al.*, 2013). The German Association for Water Management, Wastewater, and Waste (DWA) and the German National Urban Development Policy Initiative play important roles in national policies and legislations.

In Latvia, rainwater management is regulated by the national legislation in the field of environment, construction and land drainage, enforced at the local (municipal level) through construction control (mainly during the process of technical design). Maintenance of the rainwater management infrastructure is mainly ensured by local municipalities or municipal water companies. The research and development policy framework is largely defined by the Ministry of Education and Science in





the policy papers “General principles of science and technology development 2009-2013” and “General principles of science, technology development and innovation 2014-2020”. State level actors, mainly research institutions, local municipalities and private companies are working at learning and adapting best international practice in the field of rainwater management, as well as developing their own innovative and cost-efficient approaches.

The responsibility for flood prevention and protection lies with Finland’s environmental administration and the Finnish rescue service authorities. Regional environment ELY-Centers are mostly involved in flood management, whereas regional rescue services are engaged mostly cases relative to hazardous floods. The Finnish Environment Institute (SYKE) conducts flood research, supports regional authorities and supplies tools for flood prevention and protection. The organization is responsible for national hydrological monitoring and flood forecasting. Concerning governance of flood damage and prevention in urban and rural areas, the Finnish municipalities are the corresponding authorities directly in charge managing water resources at the regional level (Ymparisto 2016).

In Sweden, water regulation takes a top-down approach. Water management and monitoring is then divided between numerous water authorities representing regional and municipal governments, including the Parliament and central government, the Swedish agency for marine and water management, the county administrative board, and the municipalities.

For Estonia, the Ministry of Environment is the main body engaged in the management of water resources. Different sub-sectors including The Environmental Board; The Environmental Inspectorate; the OÜ Estonian Environmental Research Centre; the Geological Survey of Estonia; the Estonian Environment Agency (ESTEVA); and the Technology Centre of the Ministry of the Environment (KEMIT) are the main bodies involved in the water management and regulatory aspects of the region.

5.1.2 European, National and Regional Level Policies and Legislations

European level policies and legislations related to urban stormwater management in the Baltic sea regions have been identified by the BalticFlows project as follows:

- Water Framework Directive 2000/60/EC (WFD);
- Groundwater Directive 2006/118/EC;





- Floods Directive 2007/60/EC;
- Marine Strategy Framework Directive 2008/56/EC;
- Urban Wastewater Directive (91/271/EC);
- Environmental Quality Standards Directive (2008/105/EC);
- Bathing Waters Directive (2006/7/EC)

The Water Framework Directive 2000/60/EC (WFD) forms the heart of European Water Law. In 2000, it established an EU-wide regulatory framework for the protection of inland surface waters and groundwater. Its primary goals are the maintenance and improvement of the aquatic environment, the reduction of discharge of hazardous substances in waters, the set-up of general principles, the indemnity of a good surface water and groundwater status as well as the prevention of deterioration of waters (Baumgartner, 2008; EC, 2000).

The EU Flood Directive 2007/60/EC requires EU Member States (MS) to assess if their water courses and coast lines are at risk from flooding. Moreover, MS are to map the extent of flooding and relevant assets and humans at risk in these flood prone areas, and subsequently take adequate and coordinated measures in order to improve flood risk management. The directive shall be carried out in coordination with the European Water Framework Directive (EU-WFD), i.e. by implementing flood risk management as well as river basin management plans, and through coordination of the public participation procedures in the preparation of these plans. All assessments, maps and plans are to be publicly accessible (EC, 2007; Santato et al., 2013). Furthermore, the EU Groundwater Directive prohibits any actions that may deteriorate groundwater quality, possibly affecting the application of infiltration based stormwater management practices (EC, 2006).

National level policies and legislations in Germany include the German Federal Water Management Act (Wasserhaushaltsgesetz), Wastewater Charges Act (Abwasserabgabengesetz), the German Federal Building Code (Baugesetzbuch) and the Federal Nature Conservation Act (Bundesnaturschutzgesetz). The German Federal Water Management Act is the fundamental law in regard to water management which came into force on 1st March 2010. It recodified Germany's water legislation on the basis of the extended legislative powers granted to the Federal Government under the Federalism Reform of 2006 (UBA, 2010). Specifically, it lays down the basic aims for water management, it aims to establish legal requirements for an organized regulation according to quantity and quality of surface and underground water, and it governs human impacts on waters (Berendes, 2010). Policies and legislations at Federal State level in Hamburg are the Hamburg Water





Act (Hamburgisches Wassergesetz), Ordinance on the permit-free infiltration of rainwater on residential properties, Water Protection Area Ordinance, The Hamburg Wastewater Act (Hamburgisches Abwassergesetz), the Hamburg Building Code (Hamburgische Bauordnung) and Wastewater Charges Acts of Hamburg.

Latvian national level legislations include Water Management Law, Cabinet of Ministers (CM) 31.05.2011 regulation No.418, "Regulation on water bodies at risk", CM 20.12.2007 regulation No. 830 on Approval of the National Programme for Flood risk assessment and management for 2008-2015, CM 24.11.2009 regulation No. 1354 on Initial flood risk assessment, flood maps and flood risk management plan, CM 25.06.2009 regulation on river basin district management plans and programmes of measures, Daugava, Gauja, Lielupe and Venta river basin district management plans, CM 12.03.2002 regulation No.118 "Regulation on surface and groundwater quality", CM 22.01.2002 regulation No.34 "Regulation on pollutant emissions to water", Latvian construction norm LBN 223-99, "Sewerage outer networks and constructions", Latvian construction norm LBN 224-05 "Land drainage systems and hydro technical constructions". Moreover, at the end of 2015, river basin management plans and flood risk management plans 2016-2021 were adopted by the Ministry of Environmental Protection and Regional Development of the Republic of Latvia for the four largest Latvian rivers (Daugava, Lielupe, Gauja, Venta). The newest piece of legislation is the Cabinet of Ministers 22.03.2016 regulation No. 174 Regulations on public water services and use. It guides procedures to provide, use and eliminate public water management services, to connect real estate to the centralized water supply and sewerage system, lists the requirements for the meter for the commercial hub and states the procedure for public water service accounting and settlement.

In Finland so far stormwater management has no special law, but provisions in a number of different laws and regulations exist such as: the Land Use and Building Act, Water Management Act, Water Act, Flood Risk Management Act and Environmental Protection Act.

National level legislation in Sweden include: Water Quality Management Ordinance, Law on Public Water Services, The Food Act, The Swedish Environmental Code and The Planning and Building Act.

For Estonia, national legislations include: HELCOM recommendation 23/5 on Reduction of discharges of urban areas, Local Government Organization Act, Public Water Supply and Sewerage Act, Environmental Monitoring Act, Estonian standard EVS 848:2013 Sewer system outside





buildings, Tallinn Development Plan 2009-2027, Tallinn Development Plan 2014 – 2020, Tallinn Stormwater Strategy and Tallinn Water Supply and Sewerage Development Plan 2010-2021.

5.2 Stakeholders

In the following, only a selection of relevant RTD actors in the BalticFlows partner countries are listed and their roles in urban stormwater management briefly sketched. Readers are recommended to visit the BalticFlows website at www.balticflows.eu to access a comprehensive repository of stakeholders active in urban stormwater management and diffused load monitoring.

5.2.1 Public and Private RTD Actors and Their Role in USWM in the Regions

The main national actor in Germany related to urban stormwater management is the Federal Ministry of the Environment, Nature Conservation, and Nuclear Safety (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit – BMUB). Federal State level actors for RTD in urban stormwater management include e.g. the Hamburg State Ministry of the Environment and Energy - (Behörde für Umwelt und Energie – BUE) which has different departments directly involving urban stormwater management issues like the department of Construction and Service, the department of Environmental Protection and the department of Emission Control and Enterprises. Other important RTD actors in Hamburg include the Hamburg Water Inc. group, the agency of roads, bridges and waters (LSBG), the Hamburg Chamber of Commerce (Handelskammer Hamburg), and the universities, among them, for example, the Hamburg University of Technology, the HafenCity University and the Hamburg University of Applied Sciences.

In Latvia the main national level RTD actors for USWM are the Latvian Environment, Geology and Meteorology Centre. Regional level RTD actors in Latvia include Riga city council traffic department, Riga Water company, Jūrmala water company, Riga city council housing and environment department, Riga city council executive administrations, Land owners, Latvia University of Agriculture, Riga Technical University, University of Latvia and Latvian Institute of Aquatic Ecology.

Among the main RTD actors in Finland are the Finnish Environment Institute (SYKE), regional ELY-Centers and municipalities. Also several universities have research projects related to stormwater management. In addition, some of the regional councils have an active role in stormwater and flood risk management.





In Sweden, RTD actors include the Ministry of the Environment, the Swedish Water and Wastewater Association, the Swedish agency for marine and water management, Uppsala University and Swedish University of Agricultural Sciences also play a role. Meanwhile, in Estonia, the list of RTD actors include: the Ministry of the Environment, the Environmental Board, Tallinn City Government, Estonian Association of Water supply and Wastewater, the Estonian Water Works Association, Estonian Water Association, State-owned company Estonian Environmental Research Centre, Marine Systems Institute (MSI) at Tallinn University of Technology, The Estonian Environment Agency, Tallinn University of Technology, and the Estonian University of Life Sciences. Table 10 provides a compact summary of those public and private RTD actors, differentiating between national and regional level.

Table 9: Regional public and private RTD actors related to USWM in the Baltic Sea Regions

REGION	PUBLIC AND PRIVATE RTD ACTORS	
	NATIONAL	REGIONAL
Hamburg, Germany	Ministry of the Environment, Nature Conservation, and Nuclear Safety (BMUB)	State Ministry of Urban Development and Environment Hamburg - (BSU); District Authorities of Hamburg, Hamburg Water Inc. group, Agency of Roads, Bridges and waters (LSBG), Hamburg Chamber of Commerce (HK) and Universities
Turku, Finland	Finnish Environmental Institute (SYKE); John Nurminen Foundation	Regional ELY-Centers, regional councils, University of Turku, and Turku University of Applied Sciences
Riga, Latvia	Latvian Environment, Geology and Meteorology Centre	Riga city council traffic department; Riga Water company; Jūrmala water company; Riga city council housing and environment department; Riga city council executive administrations; Land owners; Universities
Uppsala, Sweden	Ministry of the Environment, the Swedish Water and Wastewater Association, Swedish Agency for marine and water management	Universities
Tallinn, Estonia	Ministry of the Environment; The Environmental Board; The Estonian Environment Agency	Tallinn City Government; Estonian Association of Water supply and Wastewater; The Estonian Water Works Association; Estonian Water Association; State-owned company Estonian Environmental Research Centre; Universities

Source: own compilation





5.2.2 Financial Actors Relevant to RTD and Innovation in the Regions

The European Union is the main financial actor relevant to RTD and innovation in urban stormwater management for all the Baltic Sea regions. Other actors vary from national government ministries to research foundations. In Germany national government ministries, regional state ministries, municipalities and local districts and research foundations are the key financial actors.

In Latvia, the Latvian National funding for RTD is the main financial actor. For Finland, the relevant financial actors are divided into three levels of actors. Regional level actors are Centre for Economic Development, Transport and the Environment (ELY Centre) of Southwest Finland, LOURA (collaboration forum for cities of Turku, Uusikaupunki, Rauma, and Pori) and Regional Council of Southwest Finland. Organisation and agencies such as the Finnish Funding Agency for Technology and Innovation (Tekes), Academy of Finland and governmental ministries provide funding in national level. There are also private funding actors e.g. John Nurminen Foundation and Nordic Environmental Financing Corporation (NEFCO). National government ministries and research funding agencies are the main financial actors in Sweden.

In Estonia, the financial actors include Ministry of Environment and the foundation Environmental Investment Centre (EIC), the Local governments and water enterprises. The main regional financial actors relevant to RTD and innovation in the Baltic Sea regions are summarized in table 30.

From a stakeholder survey undertaken in the frame of the BalticFlows project in 2014, it appears that public sector organizations were mainly financed by local municipalities whereas private sector organizations relied on private capital. Only academic institutions were financed by respective national budgets. Moreover, the European Union plays a significant role in the financing of private sector organizations and academic institutions.

5.3 Databases, Data Availability and Logging Systems

There are different databases available in the Baltic Sea region countries which contain information related to USWM. These databases can be categorized into the following groups (see table 11):

- i) water resources, infrastructure and environmental monitoring databases;
- ii) database of institutions, companies, experts; and
- iii) other databases (meteorological, spatial, hazard, infrastructure and research projects databases).



Most of the databases can be accessed free of charge, whereas others need special subscription and rights for one to gain access to their information.

Table 10: Databases related to urban stormwater management in the Baltic Sea regions

REGION	TYPE OF DATABASES		
	WATER RESOURCES AND ENVIRONMENTAL MONITORING	DATABASE OF INSTITUTIONS, COMPANIES, AND EXPERTS	OTHER DATABASES (METEOROLOGICAL DATA; SPATIAL DATA; HAZARD DATA; INFRASTRUCTURE AND RESEARCH PROJECTS)
Hamburg, Germany	<ul style="list-style-type: none"> - GERONIMUS - ZTEIS - ETOX 	<ul style="list-style-type: none"> - DWA - FBR - GWP - Online Portal for Water Research in Germany 	<ul style="list-style-type: none"> - DWD - UFORDAT – database of research projects
Riga, Latvia	<ul style="list-style-type: none"> - LEGMC - Water-2 database Database of the Latvian Agricultural University - Latvian Institute of Aquatic Ecology 	<ul style="list-style-type: none"> - Latvian Environment, Geology and Meteorology Centre - Latvian water supply and sewerage company association - Riga Planning Region - Cleantech Latvia 	<ul style="list-style-type: none"> - Latvian Geospatial Information - Rainwater management infrastructure, land drainage
Turku, Finland	<ul style="list-style-type: none"> - Hertta – open database (e.g. surface water quality, follow-up of water pollution control and conservation, data for WFD reporting) - Hydrological database (HYDRO) (incl. Hertta) - Groundwater database (POVET) - PATO – database for dam safety - VELVET – water supply and sewerage system database - VAHTI – database for water supply and sewage facilities (incl. discharges) 		<ul style="list-style-type: none"> - Finnish Meteorological Institute - Finnish Environmental Institute’s and Finnish Meteorological Institute’s flood center



	sourced from wastewater treatment plants) - Watercourse database - Riverbed database - Waterway model database - Database for water construction		
Uppsala, Sweden	- VISS		- SMHI Waterwebb - GIS service of the Uppsala County - Swedish Natural Hazards Information System
Tallinn, Estonia	- Environmental Register - EELIS		- Tallinn Spatial Database

Source: own compilation





5.3.1 Databases on Water Resources, Infrastructure and Environmental Monitoring

In the following, the type of information contained in the first group of databases is described in more detail per country:

Germany:

- ETOX database of the German Federal Environmental agency (UBA) (contains guidelines on various national and international environmental quality parameters)
- GERONIMUS database of the Ministry of Urban Development and Environment (BSU) (contains data on regional surface and groundwater quantity and quality)
- ZTEIS database of the State Ministry for Health and Consumer Protection (BGV) (contains drinking water quality data)

Latvia:

- LEGMC database of the Latvian Environment, Geology and Meteorology Centre (contains precipitation, hydrology, water quality and water pressures databases)
- Water-2 database (water users and polluters are obliged to provide data on flood-prone areas)
- Database of the Latvian Agricultural University (contains river basins for precipitation, hydrology, land cover etc.)
- Database of the Latvian Institute of Aquatic Ecology (contains data on sea monitoring)

Finland:

- Hertta database (cluster of open access or partly open access databases used for load monitoring, water resource and environmental management as well as nature conservation and planning of land-use in Finland. Information (including GIS-data) gathered from and produced by environmental authorities and other parties can also be found in the Hertta database and its sub-databases)
- Watercourse database (contains GIS and water resources data)
- Waterway model database (contains data for drainage areas bigger than 10 km², in addition to the drainage database by Finnish Environment Institute (SYKE))
- Waterway model database (comprehensive national database managed by SYKE used for making predictions on water levels, water flows, groundwater levels, nutrient loads into the Baltic Sea and snow loads)
- VELVET (regional and national database, which gathers data from water supply and sewerage facilities)

Sweden:

- VISS-Water Information System Sweden, providing maps of all of Sweden's major lakes, rivers, groundwater and coastal waters; information on status classification, environmental monitoring, quality standards, and protected areas involved in water management, and water-related measures

Estonia:

- Environmental Register (<http://register.keskkonnainfo.ee>) with Estonian Nature Information System EELIS-data of resource, natural heritage and environment state including monitoring results and environmental factors.





5.3.2 Database on Institutions, Companies and Experts

In the following, the type of information contained in the second group of databases is described in more detail per country:

Germany:

- Online portal for Water Research in Germany
- DWA database of the German Association for Water, Wastewater and Waste
- FBR database of Association for Rainwater Harvesting and Water Utilization
- GWP database of German Water Partnership

Latvia:

- Database of the Latvian Environment, the Geology and Meteorology Centre (database of stakeholders in river basin management planning)
- Database of Latvian water supply and sewerage company association (database of members)
- Database of the Riga planning region (database of rainwater management and monitoring sector stakeholders)
- Database of Cleantech Latvia (database of members)

5.3.3 Other Databases

In the following, the type of information contained in the third group of databases is described in more detail per country

Germany:

- UFORDAT database of the German Federal Environmental agency (UBA) (contains information on research projects related to environmental issues)
- DWD database of the Germany's National Meteorological Service (contains meteorological information)

Latvia:

- Database of the Latvian Geospatial Information Agency (spatial database including information on geodesy, construction, administration/settlement, topography, water bodies, land use/land cover, transportation and utilities)
- Databases of the Ministry of Agriculture Real Estate (for rainwater management infrastructure, land drainage, sewerage condition by water companies and traffic department and drainage on agricultural land)

Finland:

- Database of the Finnish Meteorological Institute (open database is for the weather and sea water level observations and climate change predictions)
- Database of the Finnish Environmental Institute and Finnish Meteorological Institute flood center (includes a flood map service and contains information on national flooding predictions and upholds assessments of the ongoing water level and flooding situation)

Sweden:

- SMHI Waterwebb of the Swedish Meteorological and Hydrological Institute (mission to manage and develop information on weather, water, and climate to provide knowledge and advanced decision-making data for public services, the private sector and the general public)





- Swedish Natural Hazards Information System (database managed by the Swedish civil contingencies agency with documentation of the causes, events, management and lessons learned from past natural disasters in Sweden)

Estonia:

- Tallinn Spatial Database, a GIS-service of the Uppsala County Administrative Board.

5.4 Smart Specialization Strategies, Cluster Policy and Initiatives in the BSR

The project BalticFlows supports a network of five research-driven European countries with the intent to promote and develop regional clusters that can lead to a Smart Specialization Strategy (S3) in USWM for the Baltic Sea Region. Smart specialization refers to a policy framework combining industrial, educational and innovation policies. Referring to the EU2020 growth strategy, this approach suggests that countries or regions identify and select a limited number of priority areas for knowledge-based investments, focusing on strengths and comparative advantages (EU, 2014). The following is a compilation of the current smart specialization, cluster policies and, initiatives characterizing the project's Baltic Sea Regions.

In Hamburg, cluster policies are part of Hamburg's innovation and technology strategies. The main economic sectors of Hamburg are grouped into four well established clusters: logistics, media and IT, life science and aviation as well as four newly established clusters: creative industry, renewable energies, maritime and healthcare (Craston, 2011). The experience in cluster based economic development policies can provide an opportunity to facilitate cluster formation on rainwater management and monitoring in the Baltic Sea region through the 'BalticFlows' project.

Latvia has five fields of smart specialization available: knowledge-intensive bio-economy; biomedicine, medical technologies, biopharmacy and biotechnologies; smart materials, technologies and engineering systems; smart energy; information and communication technologies. The smart specializations most relevant to rainwater management and monitoring are knowledge-intensive bio-economy and smart materials, technologies and engineering systems. Moreover, five research areas are set as priority: environment, climate and energy; innovative and improved materials and smart technologies; public health; research and sustainable use of local resources; state and community sustainable development.

Furthermore, two cluster initiatives exist in Latvia related to rainwater management:





a. The Rainwater management and monitoring cluster developed by Riga Planning Region within the BalticFlows project. The cluster initiative will be integrated in the following Riga planning region development planning documents:

- Sustainable development strategy 2014-2030
- Development programme 2014-2020

Moreover, within the BalticFlows project, a "Rain water management and monitoring plan" for the Riga Planning Region has been developed. It is based on the BalticFlows Joint Action Plan and elaborates locally adapted and targeted actions. It is linked to the national level and Riga region development planning documents and focuses on the municipalities and regional target territories (Riga metropolitan area, coastal, urban, rural areas).

In particular, the document describes Latvian situation regarding management and monitoring of flowing rain waters and implementation options of Action Plan (institutional, socio-economic, environmental aspects) and gives recommendations for governance, business, research sectors and citizen engagement actions.

b. CleanTech Latvia, which is a non-governmental cluster organization launched to foster and promote Latvian Cleantech companies, organizations, joint ventures, research and educational institutions, some of which are active in the water sector.

In Finland smart specialization strategies are being developed in the region; however, not yet completed. The following are areas of R&D linked with rainwater management technologies:

- PURE – PURE, a project on urban reduction of eutrophication
- Waterpraxis, eco-efficient and sustainable practices to improve the status of the Baltic Sea, with the aim at improving the status of the Baltic Sea by assisting in the implementation of river basin management plans in the region
- LOURA network (a cooperation agreement between the cities of Uusikaupunki, Pori, Rauma and Turku) with the aim to bring together actors willing to find new sustainable growth from water
- Green Net Finland is a cleantech business network on environmental monitoring and energy efficiency for the urban environment

In Sweden, the fields of smart specialization include Life Science, Green Tech, Engineering, tourism and ICT. Green Tech includes district heating, geothermal heating, solar cells and energy storage,





sewage recycling, technical solutions for stormwater management such as water parks and cleaning methods. The Regional Development Strategy of the Uppsala Regional Council outlined goals for more investment in R&D sector, innovation, establishment of more companies in the region and those who can export (URC, 2014).

In Estonia, the smart specialization strategy was developed by the Estonian Development Fund in 2013 (EDF, 2013). The strategy identified Estonian business sectors with a higher-than-average growth potential and added value. The Development fund also identified three activities which are of critical importance and will add to the economic growth potential of Estonia:

1. Information and communications technology (ICT) horizontally via other sectors. It is important to note that the development of this sector around the world has reached a stage where bigger opportunities can be found in the application of ICT technology in other sectors. Sub-sectors:

- a) use of ICT in industry (incl. automation and robotics);
- b) cyber security;
- c) software development.

2. Healthcare technology and services. Demand for healthcare services is growing globally as the population ages. Estonia has the greatest potential in:

- a) biotechnology (a strong scientific basis);
- b) e-health (use of IT for the development of medical services and products).

3. More efficient use of resources. The increasing global population is likely to increase the need to use resources more efficiently. Estonia's potential in this area is greatest in:

- a) materials science and industry;
- b) development of the 'smart house' concept (IT solutions and more efficient construction of houses (passive house));
- c) food that supports health.

Rain- and stormwater management themes are not specifically included in the strategy, but are still covered by the theme of efficient use of resources as well as using ICT in water management technologies.





Smart specialization clusters in Estonia include ICT, health technology, effective use of resources, agriculture and biotechnology (Nõmm et al., 2014).

5.5 Economic Development Policies, Strengths and Opportunities

The identification of the economic potential and financing mechanisms currently being used in the participating Regions, and for the implementation and management of USWM, are part of the main objectives of the BalticFlows project that aim at achieving a high level of technological expertise strategic planning. The following is a description of the current economic environments for each of the participating regions.

The Hamburg region has strategic sustainable urban planning objectives which combine economic growth, quality of living, and environmental protection strategies. The city has the highest annual economic output per capita and the highest retail spending capacity compared to other states in Germany (HMG, 2014). The city was awarded the title 'European Green Capital 2011' by the EU Commission for its high environmental standards and development goals. In 2013, the city of Hamburg held a six month International Building Exhibition (IBA Hamburg) which exhibited the potential of green technologies for companies and residents including innovative technologies for decentralized urban rainwater management (IBA Hamburg, 2013). The port of Hamburg, which is the second largest in Europe and the eleventh largest worldwide, contributes to making the city, the wholesale and foreign trade center of Germany and a strong logistic sector for the distribution of goods (HPA, 2014). The strong drive towards environmentally sound sustainable technologies for different aspects of resource management in Hamburg offers the opportunity to develop innovative technologies for urban stormwater management and get support for implementation, production and marketing.

The Southwest Finland area has a remarkable cooperation zone, a combination of high level industry and know-how as well as a unique and distinctive cultural and diverse natural environment. With its five ports and two international airports, the South-West of Finland has a very good networking experience. It is the gateway between east and west with connections to the markets in Scandinavia, the European Union and Russia as well as Asia. Southwest Finland offers co-operation, investment and trade possibilities to all kinds of companies. Finland is also the only country in Scandinavia using the EURO as currency, contributing to making businesses accessible to the Scandinavia market and to other European Union countries.





The county of Uppsala is a part of the capital region in Sweden and Mälardalen, an expansive region crucial to the further economic growth in Sweden. Strong clusters include ICT, life sciences, and financial and business services. The region's strategic development plan is to create an attractive region in the future that appeals to businesses and top talent. A reliable source in highlighting the economic development strengths in the region is the 2009 'Regional Development Strategy' document prepared by the Uppsala Regional Council which has set goals like developing a world-class sustainable society, to become a smart player on the global stage by being at the forefront of global competition (URC, 2014).

Tallinn is the economic capital of Estonia creating over half of the Estonian GDP (ESO, 2008). Smart specialization strategies include information technology, tourism and logistics. More than 25,000 economically active enterprises exist in Tallinn. Trade and business enterprises dominate in the structure of business (33%), followed by transportation, warehousing and communication (9.9%), construction (8.6) and processing industry (8.1%) (Tallinn City Council, 2008).

The Riga Planning Region generates the highest proportion of GDP in Latvia. In 2009 the region generated 66% of the total GDP. Creating of competitive and high value-added economy and promotion of international cooperation-oriented development strategy are among the priorities of Riga city long-term development strategy 2025 (W4T, 2012). Commercial services, trade and transport industry constitute the major economic development sectors in the Riga region. The geographical location of the region which is the center of both Latvia and the whole Baltic region makes it strategically important for market access to European Union and Eastern regions (Riga, 2005).

5.6 Mentoring for Capacity Building

The mentoring capacity of the participant regions is a strategy for the exchange of knowledge and technology transfer within the regions. European countries with transferring potential could offer their services and know-how to European and International regions where development and expertise is deficient. The different levels of expertise found in the participant countries of the BalticFlows project, will open possibilities for further development, supply, and demand of USWM technologies and practices. Table 11 is the summary of the existing expertise potential of the Regions, as well as gaps found where the need for further expertise from other regions is needed.



Table 11: Expertise existing and needed in the Baltic Sea regions

COUNTRY	EXISTING CAPACITIES	REQUIRED CAPACITIES
Germany	<ul style="list-style-type: none"> - Efficient but also economically feasible technologies in the field of rainwater management - Integrating rainwater management into urban landscape planning – Hamburg Water Cycle - Designing and implementing multifunctional spaces that adjust to the surrounding infrastructure and image of the city 	<ul style="list-style-type: none"> - Cooperating with the private sector - Technology and knowledge transfer from the other regions
Latvia	<ul style="list-style-type: none"> - River basin management Meteorological observations and managing of the meteorological data - Surface and ground water quality monitoring and modelling - Public involvement in water management 	<ul style="list-style-type: none"> - Best practice on rainwater tariffs; - Improvement of legislation and regulatory base for sustainable rainwater management; - Construction and maintenance of sustainable rainwater management systems; - Pollution reduction potential of different techniques, most cost-effective techniques for specific pollutants.
Finland	<ul style="list-style-type: none"> - Planning tools and methods - Flooding management caused by ice dam - Regional Spatial Data Infrastructure - Use of spatial data (geographical information) and map services - Interactive Visualization and Simulation of Flooding Scenarios 	<ul style="list-style-type: none"> - Liability issues regarding flooding - Development of infiltration and retention solutions suitable for cold climate conditions and impervious soil types - Practical utilization of harvested stormwater - Sea level rise and stormwater flow rate - Delay systems in densely built city areas
Sweden	<ul style="list-style-type: none"> - Integration of rainwater management to urban landscape planning 	<ul style="list-style-type: none"> - Technology and knowledge transfer from the other regions - Development of infiltration and retention solutions suitable for cold climate conditions

<p>Estonia</p>	<ul style="list-style-type: none"> - There is no expertise with regard to rainwater harvesting to provide from Estonia 	<ul style="list-style-type: none"> - Rainwater harvesting, near natural stormwater management in areas with existing combined or separate stormwater sewer systems. - Design standards for rainwater harvesting and near natural stormwater management, as well smart treatment technologies for cold climate conditions. - Monitoring, well-functioning in Estonian climate, both continuous automated runoff measuring systems and sensor based technology for evaluation of stormwater peaks and quality parameters - Also is very important to know about legislation and taxation related to stormwater in other countries.
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Source: own compilation

6. Evaluating Regional Capacities

Overall, there is a requirement for sound USWM across the Baltic Sea area and the need for site-specific technologies and strategies is significant. There could be ample opportunities for experts in the field to exchange knowledge and know-how and to expand market opportunities in the area.

The Baltic Sea countries could supplement each other with respect to the some of the demands and offers existing in the different regional countries. For example, the capacities offered in Hamburg and Uppsala regarding the availability of technologies, which could be integrated into urban planning and landscaping, could match demands of Estonia and Latvia who require additional know-how on technologies and best practices for sustainable rainwater management. For some of the distinctive demands, however, global best practices should be evaluated on their applicability and transferability to the Baltic regions². For example, underground stormwater delaying system can be a solution in densely populated urban areas, as demanded from Turku region, for which a good example can be found in Rotterdam (Mackenzie, 2014).

² See, for example, the [BalticFlows report on Analysis of Potential Regions for Mentoring in Urban Stormwater Management](#)





6.1 Policy and Legislation

Among the EU directives, the WFD, Flood Directive and Groundwater Directive are the most relevant to urban stormwater management in the Baltic Sea Regions. The WFD and the Groundwater Directives primarily aim at protection of freshwater bodies whereas the flood directive deals with prevention of flood in urban areas. The WFD is the main common regulation applied in all the Baltic Sea regions as they have to comply with its regulations. Enforcement of these directives in the Baltic Sea region countries implies the application of stormwater management measures should be in line with the provisions of these directives.

The Baltic Sea region countries also have national and local laws which support the implementation of decentralized stormwater management measures. The Federal Nature Conservation Act (Bundesnaturschutzgesetz) is one of the examples. The act encourages the implementation of stormwater management measures which doesn't alter the natural water flow behaviour, with the s called 'ecological compensation measures' (Ngan, 2004).

In comparison with other countries, the broad use of green roof construction in Germany can clearly be attributed to legislation that is linked to collective benefits, like subsidies in the form of direct financial incentives as well as indirect financial incentives which involve split wastewater fees and ecological compensation measures. The ecological compensation measure is based on the sections from the Federal Building Code and the Federal Nature Conservation Act (*BNatSchG §8 (1)*) (Ngan, 2004).

Governments and regional authorities should support the implementation of decentralized urban stormwater management practices either by direct financial incentives and subsidies, or in the form of indirect incentives like reduced stormwater management fee from properties that demonstrate local management of stormwater. The experience in split water tariff in Hamburg which encourages the implementation of local decentralized urban stormwater management measures can be followed in other regions as way of indirect incentive in the implementation of green roofs, reducing impervious surfaces in the new development by implementation of porous asphalt for example.

Moreover, mandatory regulations requiring part of new building development in certain urban areas to be green, like the German Biotop Area Factor which began in Berlin and Hamburg, can play important role for integration of sustainable decentralized urban stormwater management systems





to urban planning. This kind of regulation encourages the development of green space areas, like green roofs and vegetated rainwater infiltration systems like bioretention and bioswales, in densely built-up urban locations (Roehr et al., 2008; SSU, 2014). Adoption of such regulation in the other Baltic Sea regions can help for wider application of decentralized urban stormwater management measures.

6.2 Levels of Practice

The main current practice for managing urban stormwater in all the Baltic Sea regions is the use of separate and combined sewerage systems. Decentralized urban stormwater management practices are also being implemented in all the regions. Green roof, porous pavement, open channel stormwater management with retentions ponds, roof water collection by storage tanks, swales and bioretention systems are the common decentralized urban stormwater management technologies implemented in the regions. Green roofs particularly are very common in Germany and there is well established green roof industry in the country (Getter and Rowe, 2006; Köhler and Keeley, 2005).

It is generally observed that, while there are more decentralized urban stormwater management systems implemented in Germany and Sweden, the implementation of these systems is finally gaining momentum in Finland, Latvia and Estonia. Current policies and strategic plans in these countries encourage the use of decentralized measures including local infiltration, detention, retention or use, as part of the urban stormwater management strategy.

The introduction of regulatory framework and well as subsidy and incentive mechanisms for promoting green roofs in urban planning strategy plays a significant role for its successful application and the experience of Germany in general could provide valuable guidance in this regard.

6.3 Stakeholders

Stakeholders representing public sector, private sector and scientific sector play important role in the development of successful cluster for rainwater management and monitoring in the Baltic Sea regions. The institutional framework for the implementation of stormwater management technologies or practices is similar in the regional countries which go in parallel to the legal framework. Land-use planning including municipal stormwater planning is the responsibility of





municipalities in all the regions, however, the extent to which the municipalities act independently varies in the different regions. In Sweden municipalities are more independent to take measures for stormwater water management. On the other hand in Germany the state government a key player in the development of stormwater management practices.

6.4 Regional Information and Databases

Various regional databases are available in the Baltic Sea regions containing information and data on different stormwater management aspects including water resources, environmental monitoring, spatial data, organizations, projects and etc. However, most of the databases have limited accessibility and sometimes the information is limited or not easily available.

Establishment of more open platform for sharing information regarding stormwater management technologies, their hydrologic and pollutant removal performance, technical data, cost and maintenance aspects will play important role to create more awareness to the public and promote best performing technologies.





PART C

7. Towards more sustainable USWM Practices

This final part C tries to give answers to the question of which kind of USWM solutions, i.e. decentralized practices, may truly offer sustainable solutions. As choosing the appropriate USWM technology needs to be grounded in economic considerations, a cost-benefit analysis, including a detailed example, is proposed in the end of this chapter as one method to support decision-making.

7.1 Growing need for sustainable practices

Frequent flooding events impacting cities worldwide may have a negative influence on water quality of adjacent water bodies. Unprocessed stormwater may negatively influence the quality of runoff³ and excessive rain during wet periods creates overflows in conventional systems as they received more runoff than their design capacity. For these reasons, extreme urban stormwater events are considered a threat to urban infrastructure, the local economy, urban resilience, and the ecosystem, when not planned and managed properly.

The traditional way of treating stormwater is that it should get diverted as quickly as possible away from the source and into adjacent rivers and lakes. Conventionally, the treatment of stormwater is handled through a combined sewerage system that collects wastewater and stormwater in one pipe network where the mixed stream is sent to a wastewater treatment plant, a water body or a separate sewerage system. Through this system, wastewater and stormwater are treated separately, where stormwater is discharged into the adjacent water body, while wastewater is sent to a treatment plant. The unsustainable nature of this traditional approach is accentuated by environmental issues that are characteristic of urban settings. For example, it can be observed that degraded and highly modified riparian ecosystems are impacted because of changes in the hydrology of catchments or pollution content in runoff. Urbanization can cause changes to catchment behavior where built areas lead to more impervious surfaces and where waterways

³ Runoff is the flow of water that occurs when excess water from rain, meltwater, or other sources flows over the earth's surface.





become channeled and piped, resulting in a reduction in catchment storages. Some of the main problems with the conventional USWM approach can be summarized as the following (Marlow et al. 2013):

- Reduction of the groundwater infiltration in city environment
- Reduction of water infiltration and evaporation which has a negative impact on local climate (e.g. Heat Island effect)
- Risk of overflow in conventional system may cause flooding during heavy rainfall periods especially in a conventional system receiving more runoff than its design capacity
- Inflexibility, conventional system designed only for performing under certain conditions

Because of the above mentioned issues, there is an obvious necessity to shift from the conventional way of dealing with stormwater to a more sustainable solution. On this issue, several concepts have been developed to tackle the unsustainability of the traditional approach like the Integrated Urban Water Management⁴ (Coombes and Kuczera, 2002; Mitchell, 2006; Maheepala et al., 2010; Burn et al., 2012), Total Water Cycle Management (Chanan and Woods, 2006; Najia and Lustig, 2006; Grant et al., 2010), Water Sensitive Urban Design⁵ (Wong, 2006; Yu et al., 2012), as well as Best Management Practices.

A common thread found in all those sustainable concepts relates to three core benefits when a shift is made away from traditional to more sustainable approaches:

- iv. a more 'natural' water cycle;
- v. enhancement of water security through local source diversification; and
- vi. water resource efficiency and reuse.

⁴ Integrated urban resource management (not only stormwater)

⁵ This approach aims to integrate decentralised stormwater management, understood as sustainable water management, into urban design.





7.2 Decentralized USWM Solutions

Decentralized' solutions are said to be complementary to existing centralized systems which can be adapted to local contexts, i.e. existing water sources and demands, and address social and environmental aspects (Cook et al., 2009; Gikas and Tchobanoglous, 2009; Sharma et al., 2010).

With the adoption of decentralized solutions, innovation and technology as well as a more efficient use of resources can be promoted, in addition also the amenity value of the landscape can be raised, thereby positively influencing community well-being and environmental protection (Kennedy et al., 2007; Biggs et al., 2009; Tjandraatmadja et al., 2009; Daniels and Porter, 2011; Hall, 2012). Decentralized solutions may also slow down the augmentation of existing infrastructure. For example, traditional water and wastewater pipe network design has to cater for peak demands, i.e. infrastructure needs to be large enough to handle peak loads. If decentralized solutions could mitigate these peak loads, i.e. provide additional local capacitance, investments could be deferred, resulting in a substantial reduction in capital costs (Speers and Mitchell, 2000). Current practices of decentralized solutions were taken under investigation in the following sections specifically through urban stormwater harvesting systems as USWM strategies that can collect and store stormwater to mitigate the impacts of flooding.

7.3 Urban Stormwater Harvesting

Harvesting systems can detain and store stormwater in cities and mitigate flooding. Through an extensive literature review, the following technologies were identified effective urban stormwater harvesting systems (Hoyer et al., 2011; US EPA, 2001; Dolowitz et al. 2012; Stahre and Urbonas, 1992):

- Permeable pavements (*Streets areas*)
- Green roofs (*Buildings*)
- Bioretention, bioswales (or vegetated swales), biotops, dry and wet detention ponds, wetland, gravel or sand filter (*Green spaces*)

Bioretention systems were chosen as suitable strategy for green spaces in this study, whereas dry and wet detention ponds (see, for example, Stahre and Urbonas, 1992) are considered as a part of sewerage system and therefore excluded here.





7.4 Regional Economic Development and Smart Specialization Strategies

Currently, across the Baltic Sea Region, existing regional smart specialization strategies do not yet include urban stormwater management as a component. Opportunities to build up on existing capacities thus bring forward a stormwater smart specialization strategy for the Baltic, needs to be supported by the responsible parties, stakeholders, and authorities with the decision-making power and willingness to create change.

Existing economic development policies and strategies, although not directly addressing rainwater management, can be utilized as instruments to lay down the foundation for future development and world-class excellence of rainwater management and monitoring clusters in the BSR. For this purpose, the project BalticFlows has collaborated with its regional and European partners to stimulate and build momentum enabling all regions to move towards a trans-national strategy in stormwater and smart specialization. On this issue, the regions have been able to capitalize on specific advantages like geographical location, business climate, and existing infrastructure, human and social capital of the regions. Cluster based economic development policy and strategies in the different countries, and complementary conditions which support economic activities, like the strategic location of the Turku region as a link to other countries; and the position of Hamburg's port as the third largest international port in Europe, are examples of kind of advantages that can help form a future strong Baltic Sea regional cluster in the stormwater field.

Activities of the past European Conference, Towards Smart Specialization in Urban Stormwater Management: Integrating Principles into Practice, organized by the BalticFlows project, explored the smart specialization potential in a European-Baltic urban context. Regional strengths, know-how, and capacities in the field were highlighted and it was concluded that in order to increase the uptake of current practices and technologies, cities and regions needed to:

1. Seek stronger regulatory and political support;
2. Move towards a diversification in the use of rainwater resources to boost innovation;
3. Procure synergies, partnerships and innovative financing opportunities

Further steps will require public-private sector cooperation, cluster building, and integration of research and technologies into an overall vision and future water for Europe.



7.5 Economic Evaluation of USWM solutions

The necessity to implement sensible urban stormwater practices has become increasingly clear in recent years and urgency will only grow with ongoing urbanization and a changing climate.

However, the choice of the most appropriate stormwater management technology does not only depend on technological feasibility, but also on economic considerations. If various options exist, it is crucial to make informed and sound decisions. These can be based on a number of methods like cost-benefit-analysis (CBA), cost-effectiveness-analysis and multi-criteria approaches. Below the first method will be introduced further.

The term cost-benefit-analysis (CBA) immediately implies that by using this method the costs (of a project, a measure, a policy instrument or program) shall be compared to the benefits, thereby identifying the most favorable option. Pearce et al. (2006) provide detailed insights into how to use this method. Nevertheless, it also makes sense to use CBA if there is only one option available in order to assess whether this option is appropriate or not. Accordingly, an important prerequisite is the comprehensive knowledge of all components factoring into costs and benefits. In the following discussion pertaining to CBA, the focus will remain on its applicability to urban stormwater management.

7.5.1 Assessing Urban Stormwater Practices

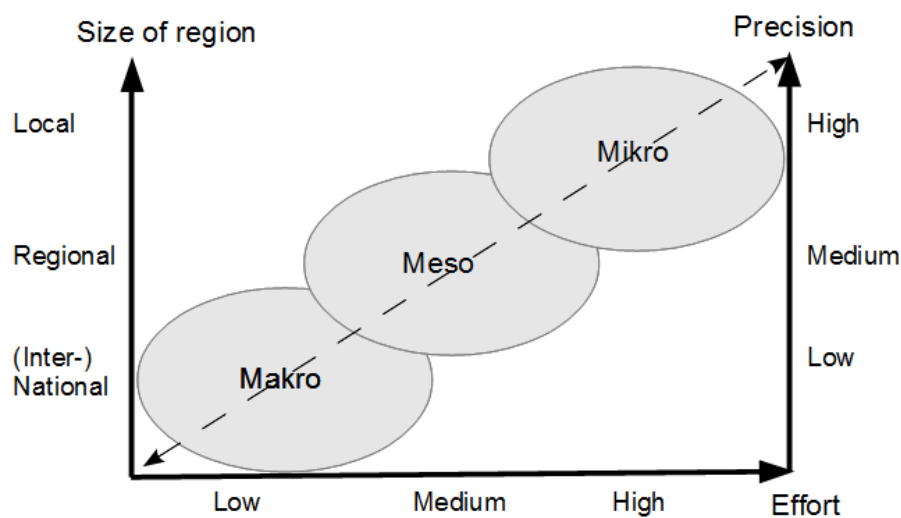
There is a large amount of literature on CBA in urban stormwater management, yet most of it either deals with specific (regional) case studies or technological solutions or a set of these respectively. This may be due to the fact that urban stormwater management is usually the domain of engineers and (urban) planners.

From an economist's perspective, two aspects need to be mentioned, which heavily influence the applicability of CBA and the underlying methods: Firstly, one has to differentiate roughly between measures in urban stormwater management on the one hand, and programs or instruments to regulate or incentivize especially private behavior on the other hand. Borrowing from the literature on adaptation to climate change (e.g. EEA, 2012) measures would include grey and green infrastructure approaches with a special attention on technical solutions, whereas programs or instruments would comprise soft approaches like dissemination of information or economic incentives.



Secondly, one has to be aware of the (geographical) scale of the problem at hand. As Reese & Markau (2005) point out, the smaller the space under scrutiny becomes, the higher the precision becomes but at the price of a vastly rising effort and possibly also methodological issues. This is illustrated in Figure 14. There is also a connection to the first aspect: Instruments and programs obviously address a larger geographical space, i.e. in our case the city as a whole, while measures usually relate to smaller geographical units.

Figure 14: Scale, effort and precision of CBA



Source: Reese & Markau, 2005

Turning to stormwater technologies, i.e. measures in particular, an economic evaluation of their costs is complex since costs are case-specific and can vary strongly. It is hardly possible to make general recommendations since factors like size and differing preconditions influence costs. Moreover, several technologies might offer extra benefits beyond the concrete aim of stormwater protection, which also need to be considered. Thus, an economic evaluation is necessary for each individual case. Nonetheless, broad characteristics and important evaluation criteria influencing technologies are presented in the following pages to give an overview of aspects that need to be considered.

Following the flood protection concept of the city of Hamburg, stormwater management technologies can be categorized into three dimensions of protection: preventive, technical and operational flood protection (LSBG, 2009). Preventive flood protection aims at reducing risks and damages by the communication of stormwater threats to citizens in order to create a sense for



individual risk precaution. Preventive stormwater management in the form of targeted land use and measures to enhance natural water retention can avoid flooding ex-ante. Technical flood protection covers constructional measures to control the drain of stormwater. Operational flood protection relates to measures taken directly before or during the flood event. Above all, the goals of these measures comprise warning systems and short-term measures to repel the flood water. In addition, the operation and maintenance, the inspection of constructional defense systems like dykes, and regular water monitoring are also a part of operational measures. Another very general differentiation can be made with regard to the actors who demand technologies. Several large-scale technologies might only be implemented by the public, because they apply to whole streets, areas or cities and can be considered a public good (e.g. dykes or sewer systems), while small-scale measures with direct benefits for only one household or firm (e.g. green roofs or protection of buildings) are mostly carried out by the respective private actors. In particular technologies like early warning systems might be demanded by both public and private actors.

Within the broad categorization and before evaluating the technologies, each technology's concrete aim should be specified to ensure comparison of measures with as similar purposes as possible. A prerequisite for the further selection and evaluation of technologies is their applicability. Several measures require conditions like the availability of large space, infrastructure connections or certain soil characteristics, similarly, some technologies require specific complementary technologies that might or might not be already in place. If they are not already present, additional costs result. Therefore, it is necessary to gather information about required complementary technologies before choosing possible options for detailed comparison.

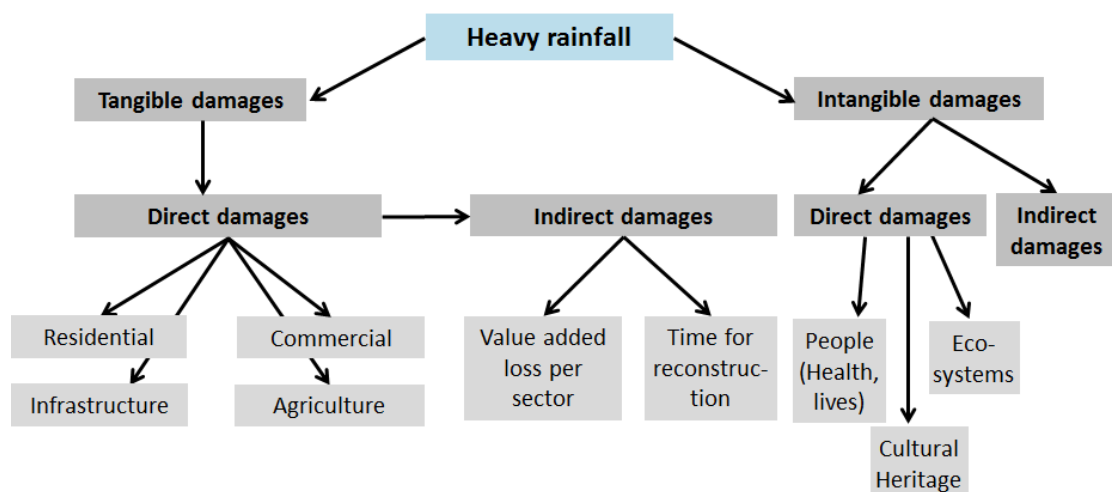
Regarding the assessment of costs, costs need to be divided into construction/installation costs and maintenance costs. Construction costs are one-time costs, while operational costs occur regularly during the existence period. Of course, the different durations of the technologies have to be taken into account when options are compared. In particular, construction costs depend on many influencing factors and can vary considerably. Therefore, it is only possible and meaningful to specify cost ranges within which case-specific actual costs probably lay. For this reason, minimum, average and maximum construction costs should be estimated to establish a foundation for evaluation. To facilitate a better approximation of actual costs, it is advisable to additionally determine the drivers of costs. So, for each application the specific extent of each influence factor can be identified to derive cost estimations. Typical drivers that affect construction or installation



costs are the size of the area of implementation, the choice of design and material, and preconditions like already existing protection measures, infrastructure connection (seal systems, logistics etc.), available space, terrain and soil characteristics, and legal requirements. The maintenance costs are usually less case-specific and can be indicated in average costs. Yet, here the frequency of cost occurrence is essential for comparison of technologies.

Opposing the costs are the benefits, which are mainly comprised by the damages avoided with the implementation of a technology. However, while it is common to approximate the extent of flood damages by estimating the so-called direct (tangible) damages their scope is much wider than that. This is illustrated in figure 15, where the whole set of possible damages is shown. This indicates that orthodox estimates are usually below the actual level of damages.

Figure 15: Types of flood damages



Source: adapted from Penning-Rowsell, 2003

However, the comprehensive estimation of these damages is an intricate procedure. Besides, these estimates can only be done either ex-post, i.e. after damages occurred or based on extensive models trying to forecast potential consequences and damages. This adds to the already existing uncertainty in the estimation process. Accordingly, for policy purposes or for the requirements of public planners, tools which allow manageable yet reliable estimates that can be used for decision-making are needed.

The difficulty in estimating the aforementioned damages differs according to the loss presented in figure 15. While tangible damages are easier to quantify, intangible damages are harder to put into





numbers. This especially holds true for all aspects where personal values of the scientist or normative assumptions play a role. Nevertheless, a crude approximation seems to be better than no quantification at all. Additionally, some technologies – very often from the category “green” – have co-benefits, which also have to be taken into account. Examples include aesthetic aspects, improved qualities of water or air, water harvesting, additional usable space for gardens, an increase in plants or animals (biodiversity), and various others. These specific extra benefits should as well be offset to the cost estimates. However, in most cases it is extremely complex to assign them a monetary value, so the existence of additional benefits might only be an essential decision criterion in case of options with roughly similar costs or if extra benefits are highly welcomed.

To summarize: The economic evaluation of urban stormwater management practices is a difficult but worthwhile task. Firstly, it is necessary to make clear what is under scrutiny, i.e. one specific technology in general, a comparison of different technologies to achieve a certain goal (in a pre-defined area), or a policy to promote urban stormwater management in general or a selected technology in particular. All these aspects influence the required method of evaluation. Secondly, our considerations show that the economic evaluation of stormwater management technologies is highly complex since it requires a high amount of case-specific data. Moreover, several costs and benefits are hard to put in numbers, in particular the value of human health, ecosystem changes or aesthetic aspects. At least they require normative assumptions which have to be made transparent. Therefore, it is necessary to collect as much information regarding the above presented criteria and their influence factors as possible to obtain a reasonable estimation of costs and benefits. Yet, general recommendations or one-size-fits-all best-practice technologies are impossible to derive, because of the case-specificity of each application’s costs and benefits. Finally, it has to be noted that other methods beyond CBA exist which in some cases could be more appropriate than pure CBA. For example, cost-effectiveness analysis sets an indicator of environmental effectiveness in relation to the respective costs (see Pearce et al., 2006). This relation of different units does not indicate whether the measure should be implemented or not if benefits are to outweigh costs. Yet, this ratio might be helpful to compare different alternatives. Another example is the multi-criteria analysis which combines various indicators of effectiveness that are allowed to have different units (Pearce et al., 2006). These are usually standardized and then aggregated, so that the resulting number is a weighted average of scores of indicators. Again, this is mainly a tool for comparing options that comes along with various subjective choices.





7.5.2 Case study: Assessing Greens Roof Policies and Measures

As shown above, the evaluation of stormwater management practices is complex as a large amount of information is required, and several assumptions have to be made which make the complete capturing of all costs and benefits a difficult task to achieve. Concrete evaluations can only be made in specific cases. To further explain, the case of green roofs will be discussed; however, no explicit application will be analyzed, but instead, green roofs will be investigated from a technology specific point of view as presented in the preceding section. In addition, it will be discussed which meso- or macro-scale practices can be implemented to support the use of technologies on the micro-scale.

The estimation of costs and impacts of green roofs largely refers to the literature on adaptation to climate change. Green roofs are a prominent example for an adaptation measure with various benefits (see e.g. Altvater et al., 2012). Regarding urban stormwater management, they can be considered as a preventive flood protection technology measure that enhances the local capacity of direct stormwater seepage and evaporation. They can be applied on buildings with appropriate provisions and roof slopes of up to 40°. Green roofs are typical applications implemented on private and public buildings alike.

Even on a micro-scale, construction costs vary strongly, so usually only cost ranges can be derived. Common estimates for the installation of green roofs (compared to a conventional roof) lie between 5 Euro/m² and 60 Euro/m² (see e.g. Mann, 2005; Altvater et al., 2012). Various factors, like the size of the roof, the extent of the planting and usage, and technical requirements influence the specific costs. The annual maintenance costs also vary with the extent of planting and usage, but not as much as the installation costs. In general maintenance costs are estimated to be quite low for green roofs, lying between round about 0.5 Euro/m² for extensive and 4 Euro/m² for intensive planting (see e.g. Mann, 2005; Altvater et al., 2012).

The benefits, opposing the costs of green roofs, are more complex to estimate. The benefits of green roofs consist of the avoidance of damages due to heavy rainfall. These damages can be tangible and intangible, direct and indirect. Especially, indirect damages are hard to estimate while intangible damages are complex to monetize. As explained before, damages can either be estimated ex-post to a stormwater event or ex-ante with the help of models. Both approaches have their difficulties. Moreover, benefits also are highly case-specific and vary with the surrounding conditions. In general green roofs are supposed to increase local seepage and evaporation, reducing or slowing down stormwater flows into the sewerage system (Matthews, 2011). Through





the implementation of green roofs, general stormwater system requirements and costs to avoid flood damages are lessened. But the reduction of stormwater flows is not the only benefit associated with green roofs. Extra benefits might be the longer life expectancy of green roofs compared to conventional ones; the filtration of air and rainwater; thermal insulation and reduction of energy consumption; aesthetic benefits; habitat provision for wildlife, usable space for recreation; and important aspects regarding climate change and the potential reduction of the urban heat island effect (e.g. Foster et al., 2011; Matthews, 2011; City of Portland, 2008).

Under the assumption that benefits outweigh the costs of green roofs as a stormwater management technology measure in the long-term, they should be implemented (for such results see City of Portland, 2008). Next to this kind of bottom-up consideration, urban stormwater management practices also encompass instruments on a larger scale, which can complement the technology measures chosen on the micro-scale. These are policy instruments and programs that can be applied at a city, state or country level to influence the behavior of people and the implementation of technologies. This kind of state intervention is usually used to correct market failures e.g. due to externalities (Commission of the European Communities, 2007). In the case of urban stormwater management these externalities clearly exist. Technology measures like green roofs do not only provide private benefits for the agent who implements the technology, but very likely also benefits the public due to the relief on the common sewage system and the mentioned extra benefits (City of Portland, 2008). Hence, often, the total benefits of such measures are commonly underestimated and their effective level of implementation falls short. Also, free-rider problems might occur in the way that agents do not implement measures because they expect others to do so. In these cases a state intervention is necessary to reach an optimal level of measure in stormwater management.

Basically, there are three types of policy instruments for interventions that differ with regard to their force. A mild kind of intervention, the communication and provision of information-e.g., regarding the cost and benefits of stormwater management measures, appeals to implement them or attempts to boost research and development of technologies to make them more attractive and less expensive. The actual implementation of technology measures is however voluntary in this category. Another type of policy instrument are market based instruments like taxes, fees and charges, indirect or direct subsidies or the establishment of a certificate system. These extra costs or grants should correct the cost and benefits of measures and thereby induce the effective level





of implementation. More importantly, citizens can still act voluntarily and can decide whether it is optimal to implement measures or not. This characteristic makes market based instruments an efficient policy instrument that yields a cost-effective level of implementation (static efficiency) and provides incentives for improvements and innovation (dynamic efficiency) (e.g. Kosonen and Nicodème, 2009; Commission of the European Communities, 2007). The third category covers regulatory instruments like laws and standards. These enforce the implementation of a certain level of stormwater management measures. Therefore, they are not necessarily considered to be cost-efficient. Yet, they definitely ensure the application of measures if the implementation can be effectively monitored. All these policy instruments might be combined with or applied to specific technology measures or it might be left open to all options.

Up to now, green roof policies are not very widespread. Yet, various different policy instruments have been applied in some areas globally. Often a combination of instruments or an embedding of green roof policies in more general policy programs for urban stormwater management or adaptation to climate change is employed. In the city of Hamburg for example, there is a combination of direct and indirect subsidies to foster the implementation of green roofs within the so called "Gründachstrategie". Direct subsidies are implemented in the form of grants for the construction of green roofs of up to 50 percent of the accruing costs (HH Senat, 2014). These are, like in most cities with such subsidies, only applicable for voluntary green roof constructions that are not induced by law (IGRA, 2014; HH Senat, 2014). The subsidy program is designed for the years 2015 to 2019 and provides 3 million euros in total (HH Senat, 2014). In addition to this direct financial incentive, the city of Hamburg also sets an indirect incentive through the reduction of the stormwater fee. In cases of implementation of green roofs with a substrate thickness of more than 5 cm, only 50 percent of the annual stormwater fee has to be paid (HH Senat, 2014). With this combination of direct and indirect subsidies the city aims at promoting the greening of 70 percent of the newly constructed and suitable roofs. Furthermore, the future use of regulatory instruments is being planned.

All in all, the implementation of green roofs and the promotion of them due to policy instruments might be a valuable option in various cities and regions. If the technology is applicable, benefits outweigh costs and efficient policy instruments are available, a policy induced expansion of green roofs might be an urban stormwater management best practice. Yet, it is essential to also analyze other technology measures and compare the results to find the best technology measure or





combination of measures. This ex-ante analysis of measures and policies then definitely requires an ex-post implementation monitoring to verify and update the previous estimates and resulting decisions.

8. Conclusions and recommendations

This report offers a comprehensive overview of best practices and knowledge in the field of urban stormwater management in five countries of the Baltic Sea Region. From a set of different perspectives, a comprehensive overview of the status quo of stormwater management as well as new knowledge on urban stormwater management technologies was presented. Drawing on insights from the five participating BalticFlows project partner countries, i.e. Germany, Latvia, Finland, Sweden and Estonia, short profiles of urbanized regions provided insights into challenges and current practice how urban rain- and stormwater can be dealt with in a changing climate.

A framework consisting of five main parameters that affect urban stormwater management, i.e. geophysical, legal and regulatory, social, economic and technical factors, has been applied to four prominent technologies identified in the BSR partner regions which were singled out for an in-depth assessment with the aim to explore the technologies' distinctive strengths, weaknesses, opportunities and threats in detail. It is recommended that, in order to identify and implement the effective, sustainable technology, one has to consider on a range of local conditions which will impact and influence the effectiveness of the respective USWM technology, i.e. aspects such as the availability of land, especially regarding decentralized solutions, soil permeability, local climate, but also local regulations and availability of incentives and subsidies.

For example, from the technologies evaluated, green roofs are considered to be less sensitive to certain site-specific conditions that influence performance. Because of the variety of applications and materials that continue to be improved, green roofs can be designed to fulfill a certain criteria or level of retention which makes them highly adaptable. In the case of porous pavements, bio retention basins and bioswales technologies, the local conditions of the site would require further consideration including attention to soil type and groundwater table considerations. The overall success in the implementation of a specific technology is; however, highly dependent on the attention that is given not only to performance standards of the given technology, but also to its





context and to the specific characteristics and constraints of the urban area on which each technology is designed to perform and react to.

Innovative methods and decentralized approaches to urban stormwater management in city planning, offer solutions to manage and control excessive loads- this contributing to build capacities in the areas of research, technology and water innovation. State-of-the-art technologies and best practices are opportunities that could help foster, economic, social, and environmental development while preserving the quality of BSR and European waters.

Drawing on the findings of the capacity assessment, there is a requirement for sound USWM across the Baltic Sea area, and the need for site-specific technologies and strategies seems significant. There seem to be ample opportunities for experts across the BSR to exchange knowledge and know-how and to expand market opportunities in the area, however, Baltic Sea countries could complement each other with respect to the some of the offer and demand currently existing in the different regions. For example, the extensive development in planning, products and technologies in the Hamburg and Uppsala regions, could very well match deficiencies in the regions of Estonia and Latvia where additional know-how could contribute to growth and further development. Competitive practices and technology development in this field could become a key factor and platform to open up opportunities for water innovation and further economic development if Baltic cities and regions.

The traditional approach to stormwater management – diverting water as quickly as possible away from its source and into adjacent rivers and lakes–requires innovative thinking. Cities are calling for a transformation in the way water resources and water efficiency are handle. Shifting from conventional ways of dealing with stormwater to more flexible solutions in an imperative in building urban residence and helping cities deal with flooding. Several concepts, many of them integrated approaches, already exist that could improve the overall sustainability of stormwater management systems.

Finally, it is hoped that this report offers some inspiration on how to promote sustainable stormwater management technologies and practices that can benefit the public while at the same time contribute to overarching efforts of maintaining a good quality that can preserve the state of Baltic Sea Region waters.





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Annexes

Annex 1: List of technologies, products or services related to USWM

List of technologies, products or services related to urban stormwater management based on survey questionnaire from organizations willing to further cooperate. Identified technologies, products or services related to urban stormwater management in the Baltic Sea regions taken from survey questionnaires and that included organization willing in further cooperation are listed below. Areas of know-how offered from various organizations is indicated in bracket after each technology, products or service (Source: BalticFlows survey).

Germany

- SUDS/BMPs like wadi systems (Mulden-Rigolen), urban water bodies, etc. (SIEKER – Stormwater experts mbH)
- Innolet, street runoff treatment (SIEKER – Stormwater experts mbH)
- Innodrain, street runoff management, (SIEKER – Stormwater experts mbH)
- Consulting and engineering (LEHNE - Environmental and construction engineering services mbH)
- Productive contour retention measures (Hamburg University of Technology, Institute of Wastewater Management and Water Protection)

Latvia

- Methods to determine Infiltrate, SUDS techniques (SIA Jūrmalas ūdens)
- Rainwater harvesting and management (SIA EkoStandarts Tehnoloģijas)
- Rainwater infiltration (SIA EkoStandarts Tehnoloģijas)
- Raineo - rainwater management system (SIA PipeLife Latvia)
- Stark and Pragma - piping systems for rainwater transportation (SIA PipeLife Latvia)
- Sustainable drainage concepts (SIA Grupa 93)
- Swales, bioswales (SIA apdALPS)
- Permeable pavements (SIA apdALPS)
- Rainwater reuse (SIA EkoStandarts Tehnoloģijas)





- Flood inundation modelling tool (Riga Technical University, Faculty of Computer Science and Information Technology)

Estonia

- Filtration and fuel/oil separation from water (Metternich Precision Instruments)
- Designing of rainwater systems (Entec Eesti OÜ)
- Ecohydrological processes of wetlands (Estonian Marine Institute)
- GIS systems and spatial analysis (University of Tartu, Faculty of Science and Technology)

Finland

- Designing stormwater management systems (FCG OY)
- Modelling stormwater and stormwater management systems (FCG OY)
- Design of stormwater management for cities, system level/ general plans (Ramboll OY)
- Design on hold up structures, collections networks including pumping station. Generally design of all related structures, operation and maintenance (Ramboll OY)
- Modelling (Ramboll OY)
- Rainwater management: landfill leach waters, agricultural runoffs, runoffs from municipal WWTPs (University of Turku / Biophysics)
- Oil and sand separator systems to clean rainwater (Wavin-Labko Oy)
- Plastic modules to store /attenuate rainwater (Wavin-Labko Oy)
- Stormwater pipes, fitting and chambers (Uponor Suomi OY)
- Stormwater management systems: infiltration, retention and harvesting (Uponor Suomi OY)
- Detailed design and modelling (Pöyry OY)
- Flood inundation mapping (University of Turku / Geography)

Sweden

- Design of stormwater treatment systems, such as wetlands (WRS Uppsala AB)
- Modelling land use and pollution impacts on water quality (Uppsala University Department of Earth Sciences)
- Stormwater management (Sweco AB)
- Water planning for streams and larger seas according to "water directive" from EU, advisory or recommendation (MNV Sverige)





Annex 2: Survey indicators

Source: BalticFlows survey

The main criterion used for the selection of the technologies, products or services is their categorization in the area of urban stormwater management. The specific technologies, products or services offered by the stakeholders under the four urban stormwater management related categories, namely, stormwater management, stormwater collection, modelling and prognoses, and water treatment were considered for selection. Rainwater management and monitoring related areas covered in the questionnaire are listed below. The selected categories are stormwater collection, stormwater management, modelling and prognoses and water treatment.

- Precipitation monitoring
- Runoff and load monitoring
- Stormwater collection
- Stormwater management
- Stormwater quality/quantity measurement
- Modelling and prognoses
- Water treatment
- Power generation from rainwater
- Thermal energy extraction
- Wastewater related technologies
- Others (consulting, ...)

All the specific technologies, products or services offered under the categories stormwater management and stormwater collection are included in the list of the stormwater management related technologies, products or services in the Baltic Sea regions. For the categories modelling and prognoses and water treatment only those technologies, products or services that are relevant to urban stormwater management are included in the list. For the water treatment category the selection includes runoff treatment, rainwater treatment and reuse systems. For modelling and prognoses category the selection includes design and modelling tools for rainwater management systems, flood risk assessment tools, design tools for rainwater systems, GIS systems and land use planning tools. Technologies, products or services offered by the organizations that are interested in further cooperation are presented in Annex 1.





Annex 3: List of identified USWM technologies from internal regional reports and currently applied decentralized USWM techniques in the BSR

List of identified urban stormwater management technologies from internal regional reports and currently applied decentralized urban stormwater techniques in the Baltic Sea regions from internal regional reports are listed below (Source: BalticFlows survey).

Germany

- Open channel system (Hamburg water cycle at Jenfelder Au) – enhancing attractiveness of landscape, local use of water for gardening...
- Rainwater collection from roofs and streets to flow in open channel (Trabrennbahn Farmsen)
- Green roof and rainwater harvesting in underground cisterns /Allermöhe)
- Multifunctional space as stormwater management strategy – use of traffic, recreations or other appropriate urban areas as flood control measures (Hamburg Wasser) –
- Use of school ground as multifunctional space, retention basins
- Underground infiltration drains, pervious pavements – elementary school Moorflagen
- Near surface collection and infiltration
- Rainwater collection from roof and storage ponds
- Soil filter systems and retention basin
- Green roofs, underground cisterns and storage ponds
- Roof collection and underground tank combined reuse in irrigation and air conditioning
- Green roofs, cisterns and pervious pavements
- Infiltration, decentralized and semi-decentralized retention, and controlled overflow

Latvia

- Separate rain water sewerage
- Combined sewerage
- Land drainage network (drainage ditches and ponds)
- Rain water treatment plants.





- Green roofs (Eastern Latvia creative services centre “Zeimuļs”, shopping centre “Olimpija” in Riga, apartment building “Tomsona terases” in Riga etc.);
- Surface drains in streets (towns of Līvāni, Talsi);
- Permeable pavements (various locations e.g. Daugavpils pedestrian promenade,)
- Ornamental swales – Kandava old town park;
- Ornamental retention basin with a fountain (Madona);
- Ornamental retention basin, roadside surface drains, raingardens in Talsi;
- Long-established, new and renovated retention ponds in many locations;
- Road-side swales in Tukums, Ozolnieki-Jelgava road;
- infiltration trench in Brankas, Ozolnieki municipalities;
- infiltration cassettes and water reuse solutions in private homes in Riga

Finland

- Most of the rainwater flows are directed either to separate rainwater drains or to combined sewers, which load down to wastewater treatment plants.
- New solutions that tend to decrease the rainwater flow in to sewers and - natural infiltration and retention systems are generally considered in Finland
- Rainwater management plan was made for Turku region – infiltration systems
- Open channel systems (Eco-Viikki neighborhood in Helsinki)
- Underground delaying systems and open channels (Vuores district)

Sweden

- Rainwater infiltration
- Green and permeable surfaces
- Drainage and open stormwater management to delay stormwater locally
- Open stormwater system for collection and treatment
- Stormwater collection and purifying ponds
- Permeable asphalt

Estonia

- Green roof
- Roof water collection with underground collection tank
- Settling pond for collection and treatment of stormwater of main roads





BalticFlows is a European Commission 7th Framework Programme research project which aims at creating a framework for future research cooperation in the management and monitoring of rainwater flow into Baltic Sea catchment areas by establishing common methods of managing and monitoring water quality and quantity and to have a common goal in protecting the Baltic Sea from further environmental degradation.

www.balticflows.eu

ISBN 978-3-00-052932-0



European Commission 7th Framework Workprogramme
Regions of Knowledge, Call: REGIONS-2012-2013-1
Project no. 319923 BalticFlows

"Monitoring and management of flowing rain water in Baltic Sea catchment areas"