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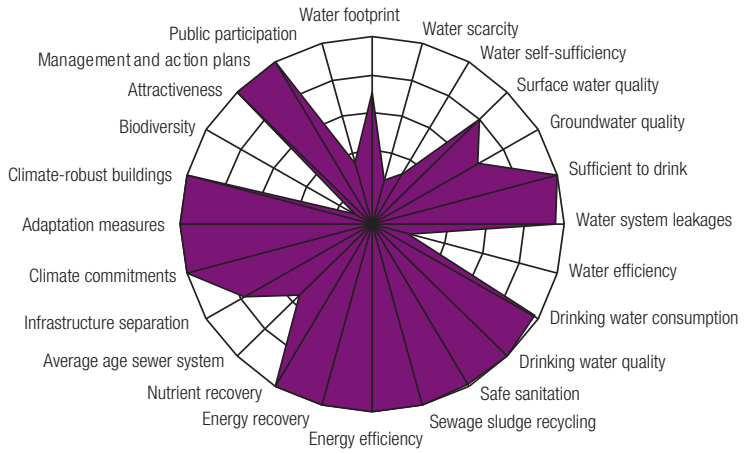
Baseline and best in urban water cycle services

Megatrends (e.g. demographic changes, water scarcity, water pollution and climate change) pose urgent water challenges in cities. This is highlighted in the European Union (EU) project TRUST (Transitions to the Urban Water Services of Tomorrow; www.trust-i.net/index.php). The main objective of TRUST is to support water authorities and utilities in Europe in formulating and implementing appropriate urban water policies as well as new technology and management solutions in order to enhance urban water cycle services. Baseline assessments of the sustainability of Urban Water Cycle Services (UWCS) have been made for eleven cities [1]. Hamburg performed well and had a high Blue City Index. This is in line with previous studies performed by Siemens [2]. In 2011, the city of Hamburg was awarded the title “European Green Capital” by the European Commission because of its ambitious targets in sustainability, climate and environmental protection. In order to improve the sustainability of UWCS in cities it is essential that cities share their best practices, for instance via a dedicated website. In this way cities can learn from each other in their transition towards more sustainable UWCS and become part of the solution!

assessment practices in the city of Hamburg.

Urbane Gebiete sind heute starken Veränderungsprozessen im Wasser-Sektor unterworfen, die nach neuen Antworten und Lösungen verlangen. Demografischer Wandel, Wasserknappheit, Wasserverschmutzung und Klimawandel sind nur einige dieser Herausforderungen. Vor diesem Hintergrund fördert die Europäische Union das Projekt TRUST (Transitions to the Urban Water Services of Tomorrow; www.trust-i.net/index.php). Die Hauptaufgabe von TRUST ist die Entwicklung von Hilfsmitteln, Technologien, Management-Methoden und Richtlinien, die die Städte und die Wasserver- und -entsorgungsunternehmen (Urban Water Cycle Services, kurz UWCS) in die Lage versetzen, sicher auf die Veränderungsprozesse der Zukunft zu reagieren. Zur Beurteilung der Nachhaltigkeit und Zukunftsfähigkeit städtischer Wasserunternehmen in Europa wurden im Rahmen von TRUST für elf Städte und Regionen Daten erhoben [1] und hieraus der Blue City Index ermittelt. Die Freie und Hansestadt Hamburg schnitt hierbei mit einem sehr guten Blue City Index ab. Dies stimmt mit verschiedenen Studien z. B. von Siemens [2] überein. 2011 wurde Hamburg der Titel „European Green Capital“ von der EU-Kommission auf Grund der besonderen Anstrengungen und Ziele der Stadt hinsichtlich Nachhaltigkeit, Klima- und Umweltschutz verliehen. Um die Nachhaltigkeit von Urban Water Cycle Services zu verbessern, ist es wichtig, dass Städte und Regionen bereit sind, voneinander zu lernen und ihre jeweiligen Stärken im Sinne von Best Practice miteinander auszutauschen. So können sie die nötigen Veränderungsprozesse rechtzeitig beginnen und anderen Partnern bei der Lösungssuche helfen.

Wastewater treatment plant in Hamburg for biogas production: zero CO_2
Source: HAMBURGWASSER



Source: Leeuwen/Bertram

Fig. 1: *City Blueprint of Hamburg*

The goods-and-services that cause the highest environmental impacts through their life cycles have been identified as housing, food and mobility. Agriculture accounts for more than 70 percent of global water use [3]. The necessity of Urban Water Cycle Services (UWCS) adapting to future stresses calls for changes that take sustainability into account. Megatrends (e.g. population growth, water scarcity, water pollution and climate change) pose urgent water challenges in cities [4, 5, 1]. This is highlighted in the European Union (EU) project TRUST (Transitions to the Urban Water Services of Tomorrow; www.trust-i.net/index.php). The main objective of TRUST is to support water authorities and utilities in Europe in formulating and implementing appropriate urban water policies in order to enhance urban water cycle services. TRUST's aim is to deliver knowledge to support UWCS transitions towards a sustainable and carbon-efficient water future without jeopardising service quality. It will do this through research-driven innovations in governance, modelling concepts, technologies, decision support tools, and novel approaches to integrated water, energy, and infrastructure asset management. To this purpose, TRUST is collaborating with ten pioneering city utilities and regions which represent a broad spectrum of living conditions in Europe and are determined to consider approaches that are different from the past. Before developing tailored roadmaps of possible interventions and transition pathways in these cities, a baseline assessment of the current situation in these city utilities was needed.

Table 1: Short summary of the methodology for the baseline assessment of the sustainability of UWCS of the city of Hamburg

Goal	Baseline assessment of the sustainability of UWCS of cities
Indicators	Twenty-four indicators divided over eight broad categories: 1. Water security 2. Water quality 3. Drinking water 4. Sanitation 5. Infrastructure 6. Climate robustness 7. Biodiversity and attractiveness 8. Governance
Data	Public data or data provided by the (waste)water utilities and cities based on a questionnaire for UWCS
Scores	0 (concern) to 10 (no concern)
BCI	Arithmetic mean of 24 indicators which varies from 0 to 10
Stakeholders	Water utility, wastewater utility, water board, city council, NGOs
Process	Interactive with all stakeholders involved early on in the process

Source: HAMBURGWASSER/KWR

This document presents the baseline assessment or quick scan of the sustainability of UWCS of one of the TRUST cities, i.e., the city of Hamburg. Hamburg, in the north of the country, is Germany's second largest city. The city situated on the banks of the river Elbe is a port city and a major industrial and commercial location. The port of Hamburg is the second largest in Europe, after Rotterdam, and is of key significance for the German economy [2].

Materials and methods

The assessment of the sustainability of the UWCS of the city of Hamburg has been carried out according to the methodology described in van Leeuwen [1]. In short, the baseline assessment of Hamburg was based on a questionnaire and supplemented with additional information for water security, public participation and regional or national estimates for local environmental quality (surface water, groundwater and biodiversity). This information has been used to make short reports of the cities and regions of TRUST, as well as the City Blueprint, i.e. a set of 24 indicators to assess the sustainability of the UWCS. The overall score of the sustainability of the UWCS of the city is expressed as BCI (Blue City Index). The method is shortly summarized in **Table 1**. We followed the definitions and terminology of the International Water Association (IWA) [6, 7].

Results of the baseline assessment

The results of the baseline assessment based on the completed TRUST questionnaire together with some additional information are summarized in **Tables 2** and **3** and **Figure 1**. Table 2 provides the general information whereas Table 3 summa-

rizes the key data for the drinking water and wastewater system of the city of Hamburg. Based on the FAO Aquastat database (www.fao.org/nr/water/aquastat/main/index.stm), the Total Renewable Water Resources (TRWR) available for Germany is 154 km³ per year. This is equivalent to a TRWR per capita of 1,871 m³ per year. Most of the water withdrawal is by industry (27 km³) and for municipal purposes (5 km³). The total withdrawal per capita per year is 391 m³. This is a considerable amount leading to a total freshwater withdrawal in Germany of 21 percent of TRWR (Table 2).

Environmental quality

The environmental quality (surface water quality, groundwater quality) is reasonable but the biodiversity of aquatic ecosystems according to information provided by the European Environment Agency is very low [8]. Most water bodies have a less than good ecological status or potential. This has been scored with a 1 in Figure 1. Despite this, the attractiveness of the city of Hamburg has been scored very high (10; see Fig. 1).

Drinking water

Drinking water is prepared from borehole sources (100 percent) and there is 100 percent population coverage. The total water consumption (52.6 m³ per person per year) ranks amongst the lowest of the TRUST cities. This has been the result of a long campaign in Hamburg to save water. This is also the explanation for the relatively low score (score = 2) of Hamburg for the indicator 8 (water efficiency). For Hamburg water efficiency is not a high priority anymore as water efficiency has been improved considerably over the last decades. The quality of the supplied water is excellent (Table 3 and Fig. 1). The average age of the distribution system is 43 years and the number of main failures is about average. The water losses in the system are extremely low (4.4 percent).

Wastewater

The wastewater system is a collection, transport and treatment system. The percentage of the population covered by adequate wastewater collection and treatment is 99 percent. There is a system of combined sewers, sanitary sewers and stormwater sewers and the separation of this infrastructure is 76 percent (score 7.6; Fig. 1). Despite the fact that the average age of the wastewater is relatively high (46 years), the number of sewer blockage per 100 km is relatively low. The energy costs for the wastewater system are relatively low (Table 3). Wastewater is effectively treated and energy is recovered. All sewage sludge is thermally recycled. This leads to a score of ten in Figure 1.

Governance

The city of Hamburg shows a very high level of commitment to sustainable solutions. This is reflected in high scores for sustainable urban water management, energy-efficient building [9]

Table 2: Basic data for the water service area of Hamburg

Resident population	2.05 Mio.
Household occupancy	2.0
Supply area (drinking water) km²	1,200
Catchment area (wastewater) km²	1,400
Annual average rainfall (mm)	773
Daily average air temperature (°C)	9
Population density (inhab/km²)*	230
TRWR per capita (m³/year)*	1,871
Total freshwater withdrawal as percent of TRWR*	21

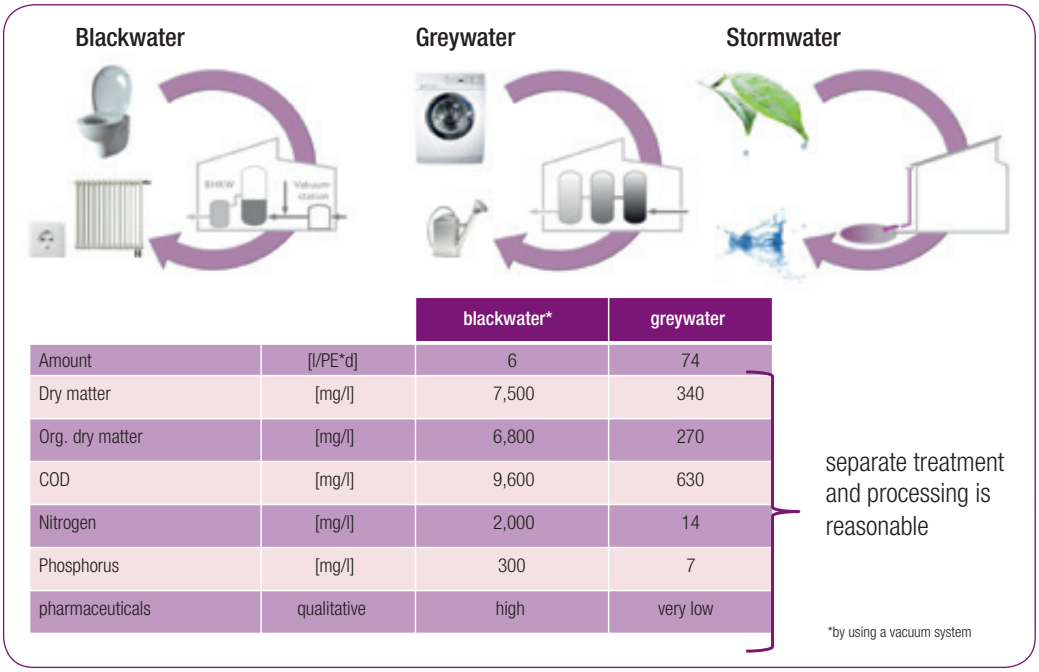
* National data according to FAO Aquastat

Source: HAMBURGWASSER/KWR

Table 3: Key data for drinking water and wastewater for the city of Hamburg

Drinking water		Wastewater	
System input volume (million m³ per year)	118	Number of properties connected	700,000
Population coverage (%)	100	Collected sewage (m³/inhabitant per year)	75
Authorised consumption (million m³ per year)	108	Length of combined sewers (km)	1,216
Consumption (m³ per person per year)	52.6	Length of stormwater sewers (km)	1,710
Service connections x 1000	660	Length of sanitary sewers (km)	2,224
Water losses (m³) per connection and year	7.2	Wastewater treated (million m³)	150
Water losses (%)	4.4	Total sludge produced in STPs (ton DS per year)	46,900
Quality of supplied water	99.97	Sludge going to landfill (ton DS per year)	0
Average water charges (€/m³)	1.77 excl. VAT	Sludge thermally processed (ton DS per year)	46,900
Mains length (km)	5,412	Sludge disposed by other means (ton DS per year)	0
Average mains age (y)	43	Energy costs (million €)	7.7
Number of main failures	525	Average age of the sewer system (year)	46
Main failures per 100 km	9.70	Sewer blockages	144
Asset turnover ratio	0.44	Sewer blockages per 100 km	2.8

Source: HAMBURGWASSER/KWR



		blackwater*	greywater
Amount	[l/PE*d]	6	74
Dry matter	[mg/l]	7,500	340
Org. dry matter	[mg/l]	6,800	270
COD	[mg/l]	9,600	630
Nitrogen	[mg/l]	2,000	14
Phosphorus	[mg/l]	300	7
pharmaceuticals	qualitative	high	very low

separate treatment and processing is reasonable

*by using a vacuum system

Source: HAMBURGWASSER

Fig. 2: HAMBURG WATER Cycle®. An innovative wastewater concept based on source separation

and the way the external collaboration is organized. Hamburg has explored green options and answers to its metropolitan challenges, shared its experiences and practices as the European Green Capital of 2011. Hamburg has set ambitious climate protection goals such as reducing its CO_2 emissions by 40 percent by 2020 and by 80 percent by the year 2050.

Water-related highlights of Hamburg

An important result from this baseline assessment of the TRUST cities and regions was that cities can learn from each other. With an active exchange of "highlights" or "best practices", cities can significantly improve the sustainability of UWCS of other cities. Below you will find the highlights of the city of Hamburg.

Rain Infra Structure Adaption

The project RISA (Rain Infra Structure Adaption) aims at developing adequate responses concerning rainwater management in order to avoid flooding of basements, streets and properties as well as water pollution from combined sewer overflow and urban/street run-off. The goals of the RISA project are:

- flood protection and inland flood control
- water body conservation and
- near-natural water balance.

The project focuses on the identification of technological requirements and the creation of conditions that enable a forward-looking and sustainable rainwater management. The main objective is to maintain the actual drainage comfort and to guarantee/improve water protection and inland flood protection. Moreover, the project seeks to integrate water management measures into urban and regional planning and to adapt the institutional setting accordingly. Project results will support the development of a structural plan for rainwater. This is a guidance document for administrations, experts and property owners for new rainwater management in Hamburg. Therewith, the project RISA contributes to the climate protection concept and climate change adaptation strategy of the senate of Hamburg. The measure addresses the fact that rainwater management is a municipal joint task. The project was funded by the State Ministry of Urban Development and Environment of Hamburg (Behörde für Stadtentwicklung und Umwelt) in co-operation with HAMBURG WASSER, the municipal Water Supply and Wastewater Disposal Company in Hamburg in September 2009. Further information can be found on: www.risa-hamburg.de/index.php/english.html

Unity in diversity – the Jenfelder Au

"Unity in diversity" is the slogan selected to represent the social and environmental standards incorporated into the Jenfelder Au neighbourhood, located in the eastern part of the city of Hamburg. The Jenfelder Au will be the first neighbourhood in Hamburg where the HAMBURG WATER Cycle® will be incorporated into newly constructed buildings. The neighbour-

hood, which also incorporates other efficient approaches for energy production, comes very close to fulfilling the vision of a neighbourhood with a completely self-sufficient energy supply. Additionally, the space-efficient development plan ensures affordable access to townhouses with gardens in Jenfeld. The individuality of the approximate 2,000 future residents is also not sacrificed. It incorporates a variety of house and apartment styles with individual aspects which harmonize to form one neighbourhood which truly manifests the motto, "unity in diversity". Further information can be found on: www.hamburgwatercycle.de/index.php/the-jenfelder-au-quarter.html

The HAMBURG WATER® Cycle in the Jenfelder Au

The HAMBURG WATER Cycle® (HWC) will be implemented in the Jenfelder Au in approximately 630 residential units. This allows the development of a neighbourhood with climate-neutral residences with sustainable water drainage. The project is unique in its size and value as an example to spur future innovation in urban development and planning. For these reasons, the Jenfelder Au is a pilot project of the "National Urban Development Policy" of the Federal Ministry of Building and Urban Development (BMVBS) and the Federal Institute of Building, Urban Affairs and Spatial Development (BBSR). The HWC can vary on its scale of implementation. The most crucial feature is the separation of wastewater streams and the subsequent energy recovery from the wastewater. In the neighbourhood of Jenfelder Au, a feature is added, rainwater, which extends the creative possibilities of urban- and landscape-planners. In the open space design, rainwater becomes a creative element. The Jenfelder Au stormwater management concept decouples the rainwater flow from the sewer network, allowing the water to flow over the natural landscape back to the local waters. The landscape and urban planning concept is made possible through the use of open channels which allow rain to flow through streams and waterfalls to retention basins which are in the form of attractive ponds and lakes. Thus, the appearance of the residential area is enhanced, and the flood protection is optimized as the retention basins are designed to provide further storage potential in case of heavy downpours.

The HWC offers a new approach to wastewater management, which does not have much in common with the principles of conventional sewer systems. It entails the separation of the material flows of wastewater. Thus, the blackwater, which is generated from toilet use, is separated from the greywater (kitchen, bathroom and washing machine wastewater). The utilization of the wastewater is therefore adapted to the specific properties of black water, grey water and rain water to achieve results which are the most efficient and ecological. The high concentration of organic substances in blackwater makes it ideal for the production of biogas through fermentation. Through the addition of other sources of biomass to the blackwater, energy can be generated in the form of heat and electricity instead of energy being consumed as in the standard, energy-intensive wastewater treatment (Fig. 2). After the anaerobic treatment of this material, this material can then be further utilized to improve the soil quality or to create fertilizer. When greywater is not combined with blackwater, it can be cleaned easily with minimal energy requirements and then can be used as process water or returned back to the environment. Further information can be found on: www.hamburgwatercycle.de/index.php/the-hwc-in-the-jenfelder-au.html

Energy efficiency at HAMBURG WASSER

In 2011 the HAMBURG WASSER central wastewater treatment plant (WWTP) "Köhlbrandhöft" (2.7 million inhabitant equivalents) became carbon-neutral. Many projects had been necessary to reach this ambitious aim: Low temperature waste heat from the sludge incineration process is supplying via a district heating system a neighbouring container terminal. Two wind turbines (2.5 MW each, 140 m hub height, 100 m rotor diameter) at the WWTP Dradenau are generating 14,000 MWh p.a. to serve the WWTP with electric power. Surplus digester gas is purified and converted into BioMethane and feeds the gas grid of the

local gas supplier. More than 120 company's cars are powered by this gas, the new slogan of HAMBURG WASSER is "Your wastewater is our energy".

Discussion

In the assessment of cities and regions in the EU TRUST project, the city of Hamburg was excellent [1] and had a BCI of 7.7. According to the German Green City Index [2], Hamburg ranks above average in water. The total water consumption (52.6 m^3 per person per year) ranks amongst the lowest of the TRUST cities. This has been the result of a long campaign in Hamburg to save water. This is also the explanation for the relatively low score (score = 2) of Hamburg for the indicator 8 (water efficiency). For Hamburg water efficiency is not a high priority anymore as water efficiency has been improved considerably over the last decades. The quality of the supplied water is excellent (Table 3 and Fig. 1). The average age of the distribution system is 43 years and the number of main failures is about average. The water losses in the system are extremely low (4.4 percent). Biodiversity may be an area where further improvements are needed. The City of Hamburg was awarded the title "European Green Capital 2011" by the EU Commission because of its ambitious targets in sustainability, climate and environmental protection. The HAMBURG WASSER group is deeply involved in supporting activities to achieve these targets.

Advantages and limitations of the baseline assessment approach have been discussed previously [9, 10, 1]. The most important result from the assessment of Hamburg and the previous study is that the variability in sustainability among the UWCS of the cities offers excellent opportunities for short-term and long-term improvements, provided that cities share their best practices [2, 1]. Cities can learn from each other in their transition towards more sustainable UWCS. In this way, cities can become part of the solution! It also shows that even cities that currently perform well, such as the city of Hamburg, can still improve their UWCS. Of course, this would depend on many other factors, such as socio-economic and political considerations, and is ultimately the responsibility of the cities themselves.

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