Integrated Resource Management Concept For A Zero Emission Hotel In Berlin, Germany

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EXECUTIVE SUMMARY

New and innovative urban infrastructures, which are based on the integrated management of resources, such as water, waste and energy, can contribute significantly to the reduction of resource consumption and related emissions as well as to the sustainable development of cities. Such infrastructure systems are based on decentralized measures, which are either integrated in existing - or in newly developed infrastructure systems. In opposed to centralized systems which are based on linear resource flows and often don't allow effective management of resources, so-called "measures at the source" with decentralized infrastructure systems allow the appropriate treatment, reuse, and recycling of resources. Furthermore such measures facilitate the creation of synergies between different sectors, such as water, waste and energy.

An example for an integrated resource management concept, including water, waste and energy, is developed for the new construction of an international youth hostel in the city centre of Berlin, Germany. In the framework of an integrated planning process for the building construction and the building service engineering, the architects Wahl & Bauer and the HATI GmbH develop a so-called "ZERO-Emission-Hotel" for the building owner, the incorporated association "Ludwig-Wolker-Haus e.V.". The building concept is based on the principles of sustainability, which will be evaluated with life cycle assessment tools and certified with the system of the DGNB (German Green Building Council - Deutsche Gesellschaft fuer Nachhaltiges Bauen). Sustainable sanitation systems and a resource flow management system will be integrated in the building. The aim is to enhance the performance of urban energy, water and wastewater management systems regarding sustainability criteria. The main elements of the integrated concept are amongst others:

- Significant reduction of the buildings service energy demand and water consumption for the transport of waste products, for example by the use of state of the art technology, such as water saving appliances, cascade uses and reuse and recycling measures.

- Separation of water-, resource-, and energy flows for efficient treatment and recycling. (Including: rainwater, greywater from bathrooms and kitchen, blackwater, organic waste, hot water production, heating, cooling and ventilation)
- Utilization of rain- and greywater for adiabatic cooling of the building, and restoration of the natural water balance, such as the enhancement of the local micro-climate by evaporation, reduction of runoff and recharge of groundwater.

INTRODUCTION

Since the mid nineteenth century urban sanitation in industrialized countries has been characterized by centralized sewers, which carry excreta away from areas of inhabitation. This system has become such an established standard that both the reasoning behind its development and its suitability and sustainability in the twenty-first century has long gone unquestioned. However the history of urban sanitation did not begin in the nineteenth century.

Many traditional agricultural societies recognised the value of human waste for soil fertility and practising the collection and reuse of excreta. This enabled them to live in communities in which nutrients and organic matter contained in excreta were returned to the soil from where they came. Excreta reuse was practiced widely in Asia (e.g. in China, Japan and in Korea) as well as in Arab and ancient American cultures. In Central Amazonia ancient cultures, which lived in permanent settlements, collected urine and faeces separately. Through processing charcoal, organic wastes and faeces in a special way they produced a so-called “terra preta” (black soil), which allowed over centuries the sustainable fertilization of forest gardens for agricultural production as well as the conservation and enhancement of soil fertility in the hot and humid climate of the tropics (Pieplow, 2008). Even as the world become increasingly more urbanized, the nutrients in excreta from urban sanitation systems were still used in many societies as a resource to maintain soil fertility despite high population densities. The practice of using the nutrients in excreta and wastewater for agriculture continued in China into the middle of the nineteenth century, and the marketing of fertiliser derived from excreta and organic waste was a thriving business (Brown, 2003).

Infrastructures for energy and water supply, as well as waste and wastewater management in contemporary cities are based on complex centralized supply, collection as well as discharge and disposal systems. Among the well-known advantages, they have system immanent disadvantages, which are barriers for effective integrated resource management. Hence measures for enhancing the efficiency of centralized systems cannot cope with the basic problems. In opposed to that the decentralization and integration of infrastructure systems can contribute to a sustainable development. After briefly introducing the problems of conventional infrastructure systems for sewage and waste management and resource management systems, this paper discusses approaches for the sustainable supply and integrated management of resources with decentralized infrastructures, which can be applied in new urban developments, as well as in urban renewal projects. Recent developments in cities of Hamburg and Berlin are used as examples to discuss the possibilities and tendencies of integrated resource management with decentralized urban infrastructures.

Disadvantages of conventional centralized infrastructure systems

Conventional contemporary sewer systems have improved the public health situation in towns, cities and countries that can afford the massive installation, operation and maintenance cost. However they have also caused severe problems, like polluted and squandered fresh water resources, broken nutrient cycles, impoverished soils, and high monetary cost. For almost half of the world's population, the estimated 2.6 billion people who do not have access to adequate sanitation today (WHO/UNICEF JMP, 2005), it is expected that the so-called "end-of-pipe" systems remain unaffordable.

Water and waste management in today's cities is generally not based on integrated resource management. Clean drinking water is produced from raw water, which is either extracted from aquifers or surface water bodies. Used water with different ingredients and pollutant levels is mixed with each other, often with drained rainwater, discharged in centralized sewer systems, and finally in surface water bodies, such as rivers. In the best-case rainwater, sewage as well as solid wastes are collected separately and are conveyed to appropriate treatment processes, which facilitate the reuse, recycling or safe disposal of specific fractions. While the separation and recycling of solid wastes is practiced to an extended degree (for example organic material, paper, glass, metal and plastics), sewage and waste streams with different characteristics and noxiousness are mixed in conventional sanitation and wastewater treatment systems, and nutrients are either eliminated or discharged in water bodies. Leakages in the sewage system, overflows of mixed sewers and effluent discharge, lead (even after treatment) to the contamination of ground- and surface water systems with pollutants. A major reason for the degradation of natural watercourses relates to the poor management of excreta and treatment. None of the established sanitation systems have been successful on a global scale at controlling the discharge of organic waste into the environment. It is estimated that more than 90% of sewage in the developing world is discharged directly into rivers, lakes, and coastal waters without treatment of any kind. According to the EU Commissions' 2007 report on wastewater treatment, only 61% big cities of Europe (population greater than 150,000) complied with the treatment requirements of the Urban Waste Water Treatment (UWWT) Directive (UWWT, 2007).

Conventional water and sanitation systems incur high costs and the lock-up of capital for long periods of time (even decades) and they are not safe against catastrophes, such as flooding. Their adaptation to changing demographic structures, user behaviour, changing precipitation patterns as well as new technologies for sanitation involves high constructive and financial effort, because the required infrastructures for urban water supply and sewage discharge are designed for specific quantities. For instance, water supply and sewage discharge systems are designed for the transport of specific volumes. If these volumes are exceeding specific maximum or minimum limits, the systems do not work properly and have to be adjusted. These adjustments, which are required for both, growing and declining urban populations, and related changes in consumption, require investments in infrastructure systems. Such investments can cause significant economical burden for the society, particularly in case of a declining urban population. The supply of only drinking water also bears significant disadvantages because comparable big quantities of high-quality drinking water have to be produced and distributed for uses, which don't require such a good water quality. (Schuetze, 2005)

Energy is generally transported in form of non-renewable liquid or solid energy carriers (such as oil, coal, gas), to consumers via pipelines, waterways, roads or rail networks. These fossil fuels are burned for the production of heat and electricity. Electricity for cities is generally produced in centralized power plants, which are located in suburban or rural areas. The resulting heat from the combustion process is generally not reused on site. Hence it has to be either released in the environment or has to be transported over long distances to consumers. The electricity is also transported over long distances, which includes significant transmission and distribution losses. As a result only a comparable small portion of the primary energy used for the electrical energy production is reaching the consumers in form of electrical energy. The production of electricity and heat are the most important forms of secondary energy produced worldwide. The energy lost in their transformation represents approximately 70% (IEA, 2004) of the total energy lost in secondary energy production. The energy balances between primary energy demand for the production of usable end energy in world average is even worst: Only 11.6 of the consumed primary energy was for instance used effectively in 2005. All other energy is wasted or lost by entropy. (Cullen & Allwood, 2010) Furthermore centralized power plants and electrical energy supply systems are sensible against malfunctions and blackouts. In case of malfunctions or catastrophes, such as flooding, centralized water and energy supply systems can be damaged and fail to work.

Towards integrated system approaches and zero-emission concepts

In conventional infrastructure systems generally no sustainable synergies between the water, waste and energy management were created in the past. However there are exceptions, such as the anaerobic digestion of sewage sludge and the combined heat and power generation with the produced gas. The burning of the processed sludge is on the one hand contributing to energy production, but on the other hand it is eliminating precious organic material. The remaining residue form the combustion process is highly contaminated ash. (Hamburger Stadtentwässerung, 2000) A reuse of the processed sludge, for instance in agriculture, is practiced internationally to a declining degree due to the potential contamination of mixed sewage sludge. However 36% of the sludge from sewage treatment plants in Europe is still used in agriculture (Rosemarin, 2010).

According to recent researches and publications (Eawag, 2010), (Schuetze, 2005), (Schuetze 2008) new and innovative decentralized infrastructure systems, which are based on the integration of Environmental Sound Technologies (ESTs) have significant advantages compared to conventional centralized systems and are hence indispensable for sustainable (urban) developments. Such systems allow for example the separation of waste and wastewater streams with different characteristics, which allow an efficient treatment and high-quality utilization of nutrients, organic matter and water. The protection of ground- and surface water is achieved by the avoidance of wastewater, the decentralized collection, storage and treatment of different substances and wastewater streams respectively. The freshwater demand can be reduced by the reuse of recycled wastewater as service water. Decentralized management of rainwater facilitates the implementation of the concept of Integrated Water Resource Management (IWRM), as well as the European Water Framework Directive, even on comparable small scales. By saving majorly on canalization, the construction of alternative infrastructure systems for water, waste and energy systems only incurs capital lock-up for relatively short periods of less than 30 years. Required supply and discharge infrastructures can be provided for instance with flexible motorized transport systems which are based on electricity. Electricity can be produced effectively end efficiently with decentralized facilities such as photovoltaic generators, or combined heat and power generators (CHPs).

The application of integrated and decentralized energy systems with a high reliability in operation, and low maintenance requirements, allows the efficient use of generated energy at the place of origin, and the reduction of energy transfer losses. The application of building integrated components for the use of solar energy, such as specific solar thermal collectors or photovoltaic modules, which serve primary as part of the building skin and include therefore multiple functions, allow the significant reduction of the real cost for such energy systems. Therefore the application of solar energy systems is feasible, and realizable with comparable little additional costs to common components. Due to the comparable low energy demand of decentralized water systems, compared with the average end-energy demand of households in industrialized countries, the required electrical energy demand for those systems can be easily and with high reliability provided by decentralized systems which are based on renewable energies, particularly with photovoltaic.

CONCLUSION

New and innovative infrastructure systems, which include decentralized measures “at the source” offer manifold possibilities for the use of synergies between different sectors (such as water, energy and waste) as well as an integrated resource management towards a closed loop recycling economy and “zero-emission society”. The biggest challenges for successful implementation of such new and innovative infrastructures is the introduction of adapted operation and management structures for these new and innovative integrated systems. Decentralized systems, which are only based on comparable simple practically proven aspects, such as the utilization of greywater and rainwater, or the decentralized purification of wastewater and reuse for irrigation, are comparable easy to realize because operation and management structures can be adapted from existing good practice case studies in rural and urban areas. However there are significant differences in legal and institutional framework of specific regions and nations, which have to be considered during the planning of the specific systems.

A much promising zero-emission concept for an urban environment, based on the principles of sustainability and integrated resource management, is currently developed for a hotel in Berlin, Germany. In the framework of an integrated planning process for the building construction and the building service engineering, the architects Wahl & Bauer and the HATI GmbH develop a so-called “ZERO-Emission-Hotel” for the building owner, the incorporated association “Ludwig-Wolker-Haus e.V.”.

General aims of the zero-emission hotel

The building owner has formulated manifold general aims for the “ZERO-Emission-Hotel”. They include amongst others a holistic approach considering resource effectiveness, energy efficiency (including electricity, heating, cooling and hot water production), reduced building service costs, reduced operation failures and reduced demand for maintenance, as well as reduced time needed for remodelling in case that modifications of the building have to be carried out. Additional aims are climate protection, a high comfort level for the building users as well as a high urban and architectonic quality and a significantly reduced environmental impact. After the end of its lifetime it should be possible to remove the building, without any problems regarding social, economical or environmental criteria. Further aims are an integrated planning process, sustainable investment, life cycle assessment and certification of the building performance and the optimization of the risk management. The building should also be a best practice example with the potential to transfer the gained knowledge and the results to other projects. The building is co-financed amongst others by the German Research and Development program EnOB (Energie Optimiertes Bauen). The program provides subsidies for additional costs, caused by the integrated planning process, external scientific-technical consultancies, Investments for the pilot-applications of new technologies, expenditures for accompanying measurements and research, as well as expenditures for the optimization of services.

The integrated overall concept for the ZERO-Emission-Hotel includes different sub-concepts, respectively sub-systems, which contribute on the one hand individually to the reduction of resource flows. On the other hand the products and emissions of specific sub-systems are used as input or resources for other sub-systems. The specific systems and there inter-relations will be briefly described subsequently and are schematically illustrated in Figure 1: Schematic section drawing of the integrated water and sanitation system in the “ZERO-Emission-Hotel” in Berlin (Zeisel, 2010). They include for example “adiabatic cooling”, “building component activation”, “waterborne technologies and resource-effective installation systems”, “heat recovery from greywater and processing for regenerative cooling”, “urine/ yellowwater collection”, and “sludge drying for the production of terra preta”.

Water saving sanitation technologies

A comparably low water consumption in households without loss of comfort and without changing behaviour of the users can be ensured by the application of water saving fittings (so called flow rate delimiters), water saving appliances (for instance washing machines and dish washers) as well as water less urinals and water saving toilets. Such toilets have cleaning flow rates of about 2 litres (for flushing after urination) and respectively 3.5 litres (for flushing after defecation), such as the “GreenGain” by Villeroy & Boch. With these measures the water consumption can be reduced with minimal investment costs, minimal operating costs and without loss of comfort by approximately one third. Examples for the successful application of such water saving technologies can be found for instance in the city of Hamburg, where all conventional urinals in public toilets and buildings have been already replaced with water less urinals. Also water saving “GreenGain” toilets have been already successfully applied, used and monitored in highly frequented public toilets. As a result of these pilot projects it is planned to replace also all conventional toilets in public buildings with the water saving “GreenGain” toilets. The motivation behind these measures is the saving of precious drinking water and the collection of concentrated urine, respectively blackwater for appropriate treatment and reuse.

Water saving showerheads with flow-rates of 8 l /min, as well as taps with flow rates of 6 l/min are currently state-of-the-art technologies. However there are also already comfortable technologies available, which allow very low-flow rates of 4.5 l/min and less for showerheads, as well as 3 l/min and less for taps. The advantages of such water saving technologies are not only savings of precious drinking water resources but also the enhancement of the overall efficiency of the specific applied sanitation systems. Waterless technologies facilitate the reuse or resources, such as undiluted urine. Water saving technologies allow the efficient collection, storage and processing of potential resources, such as greywater and blackwater. Due to lower supply and discharge quantities also smaller supply and discharge pipelines, tanks and treatment facilities can be installed. Therefore the application of water saving technologies also contributes to overall material efficiency of the project.

Drinking water substitution & heat recovery from greywater

Additional savings in drinking water consumption can be achieved through the substitution of drinking water with so-called “service-water”. In the ZERO-Emission-Hotel greywater from the shower- and bathtubs is collected separately, is purified in an aerobic membrane bioreactor and is temporarily stored (in a service water storage tank), before it s used as service water for cleaning, toilet flushing or adiabatic cooling of the building. The occurring sludge from the purification process is collected and drained to the blackwater collection and sludge sedimentation tank for further treatment. The drainage, collection, treatment and storage of greywater take place in a thermally insulated system. After the purification process the remaining heat is extracted from the purified greywater by means of a heat pump. The heat gain is used for the production of hot water. The heat recovery from greywater is a comparable simple and very effective measure to reduce the energy demand for hot water production, which makes up a comparable big portion of the overall heat demand of an energy efficient building. This is particularly true for hotels, in which the resource consumption (water and energy) for showers is very high, compared with other uses.

Groundwater recharge, adiabatic cooling and building component activation

A potential surplus of purified greywater (collected in the cooling water supply tank) as well as the collected rainwater can be used for irrigation or infiltration on the property and the augmentation of groundwater. The building is equipped with a greened roof, which is intensively irrigated with collected rainwater and purified greywater. The intensive irrigation contributes significantly to enhanced evaporative cooling of the roof surface area, with positive effects on the urban microclimate and the buildings indoor temperature during hot periods in the summer. Furthermore the photovoltaic modules, installed on the intensively irrigated greened roof, are expected to have a higher efficiency of 8 -10% during hot summer days in comparison with modules which are installed on conventional roofs (without evaporative cooling). The collected rainwater and purified greywater are also used during the hot summer months for the activation of building components with cold water. The required piping systems for cooling or heating (the same system can be used during the cold winter months for heating) are integrated in the prefabricated concrete slabs. The piping layers are located under the reinforcement layer of the slabs and have therefore only a very small vertical concrete cover, which facilitates comparable short handling times and provides good radiation properties for heating and cooling.

Resource flow management and nutrient recovery

The sanitation facilities of the ZERO-Emission-Hotels conference, restaurant and office areas are equipped with waterless urinals, which facilitate the undiluted collection of urine. The urine is collected in removable yellowwater collection containers, which are regularly exchanged and replaced with empty containers. The full containers are transported for further treatment, for instance for the production of “terra preta”, or direct use as liquid fertilizer for public green, such as flowering - and useful plants, but not for food production. The separated collection of urine with waterless urinals has manifold advantages. Beside significant savings in water consumption, a big part of the nutrients and micro pollutants generally contained in mixed domestic sewage can be separated with the urine, which contains approximately 85% of nitrogen, 50% of the phosphorous, 90% of the potassium and 50% of the micro pollutants. Compared with other wastewater fractions, such as blackwater, concentrated urine can be easily treated and processed; nutrients can be extracted and micro pollutants can be eliminated (Larsen & Lienert 2007). Even a partly separation of urine can contribute significantly to the optimization of treatment processes of the remaining sewage streams, particularly through the reduction of the nitrogen and phosphorous load. The separated collection of urine could turn a wastewater treatment plant from an energy consumer into an energy producer: Instead of 11 watt per person being consumed, 2 watt of primary energy per person could be generated, as the energy efficiency of many processes could be increased and the energy in wastewater could be better exploited (Wilsenach & Loosdrecht 2006).

The water saving toilets, which are installed in the ZERO-Emission-Hotel facilitate the comparable concentrated collection of blackwater, which consists of flush water, urine, faeces and anal cleansing material (toilet paper). The blackwater is collected together with the sludge from the purification of greywater in a black water collection and sludge sedimentation tank. The sludge is extracted from the tank and drained mechanically. The remaining liquid fraction of the blackwater is discharged in the centralized sewer system (According to the regulations in Berlin all existing and new buildings have to be connected to the cities public sewer network). There are three different basic methods to separate the solid and liquid blackwater fractions: the “filter bag”, the “mutec-system” and the “TeceBASIKA-filter”. In the “filter bag” method the sewage is drained through a filter bag. While the solids are kept in the bag, the liquid fraction can pass through the pores of the filter bag. The disadvantage of this method is that the solids are always drained with the discharged blackwater and that nutrients are washed out. In the “mutec-system” the collected sludge is pumped in an aerated “thick-matter-storage”. The storage is filled from the bottom. Hence the drainage of the collected solid matter can be avoided, and contained nutrients are not washed out. The dried sludge can be regularly extracted and processed to terra preta. The third method, the “TeceBASIKA-filter”, is used in the ZERO-Emission-Hotel: The blackwater is separated in liquid and solid fractions by means of a slit strainer. A spiral conveyor transports the separated solids automatically to a storage tank. The drained sludge is collected together with organic waste from the hotel kitchen and with a specific portion of bio-char in removable containers, which are regularly exchanged and replaced with empty containers. The full containers are transported for further treatment, for instance for lactic acid fermentation and the production of “terra preta”, to a treatment facility, which is located outside the hotel property.

The required electricity for the failure free operation of the described decentralized resource management system as well as for the transport of the collected resources is produced on the building by means of photovoltaic generators.

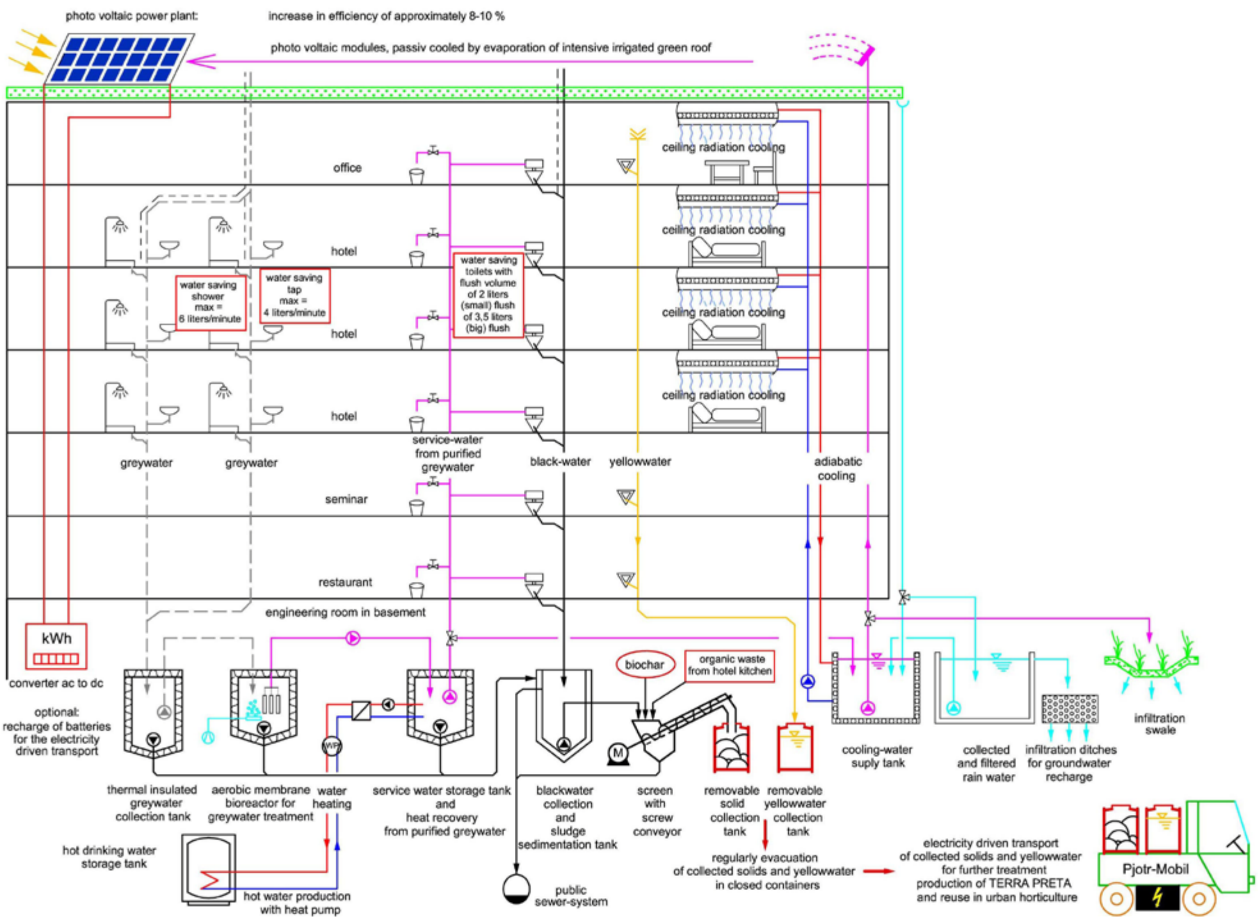

Figure 1: Schematic section drawing of the integrated water and sanitation system in the “ZERO-Emission-Hotel” in Berlin (Zeisel, 2010)

Outlook

Integrated Infrastructures for resource management can contribute significantly to sustainable urban developments, regarding economical, ecological and social criteria. The monitoring and evaluation of realized projects could proof that the specific integrated decentralized energy water and waste infrastructure systems are indeed flexible and facilitate sustainable urban developments and that they can provide the basic required services, such as electricity supply, drinking water supply, room heating, sewage treatment and waste management.

The decentralized treatment of sewage streams at the source of origin facilitates the use of more than one water quality (drinking and service water) and the appropriate treatment of sewage streams with different characteristics, because the investment costs for multiple pipeline and drainage are low, compared with the investment for centralized supply and drainage systems with long pipeline lengths. The separation and collection of different streams allows the reuse and recycling e.g. of energy, water and nutrients, and is therefore a basic condition towards a “zero emission” society and a closed loop recycling economy.

In the past, the lack of appropriate available technology, smart system designs, high investment and operation cost, and poor operational safety were arguments against the decentralization of infrastructures, particularly in urban areas with high densities. However past research findings show that integrated decentralized systems for water and sanitation can be realized without having the above described disadvantages and meeting the requirements for sustainable development, also in existing urban areas with high densities. These research findings form the basic condition for the described project and ongoing research, which aims to contribute to paradigm shift in urban infrastructure systems for water, sanitation and energy, from pipeline-bound systems to integrated decentralized systems due to the manifold advantages. According to findings in some European and Asian countries a high user acceptance of such systems can be expected, while stakeholders have more objections. The design, construction operation and accompanying research of real projects is crucial for the widespread application of the described systems in the near future as well as for sustainable urban developments and for the strengthening and support of the competence and innovation capacity in the sectors of Water, Energy and Waste. The construction, operation, monitoring and accompanying research of the integrated infrastructure systems of the ZERO-Emission-Hotel in Berlin contributes therefore significantly to the development of sustainable urban infrastructures.

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