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Integrated semicentralized supply and treatment systems face the challenge of growing infrastructure needs in fast growing urban areas. The smart integration of the infrastructure sectors water supply, wastewater treatment, waste and sewage sludge treatment offer synergy effects which increase the overall resource-efficieny and offer a higher flexibility and adaptability in infrastructure development.

Semizentrale – integrierte – Ver- und Entsorgungssysteme greifen die Herausforderungen für leitungsgebundene Infrastrukturen in Regionen mit schnellem urbanem Wachstum auf. Durch die intelligente Vernetzung der Sektoren Wasserversorgung, Abwasserreinigung, Abfallbehandlung und Klärschlammverwertung werden Synergieeffekte generiert, die zu einer erheblichen Steigerung der Ressourceneffizienz einerseits und einer Flexibilisierung und verbesserten Anpassungsfähigkeit der Infrastrukturentwicklung, entsprechend der räumlichen Entwicklung andererseits führen.

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ED SUPPLY and treatment systems

Quelle: claudiozacc – Fotolia.com

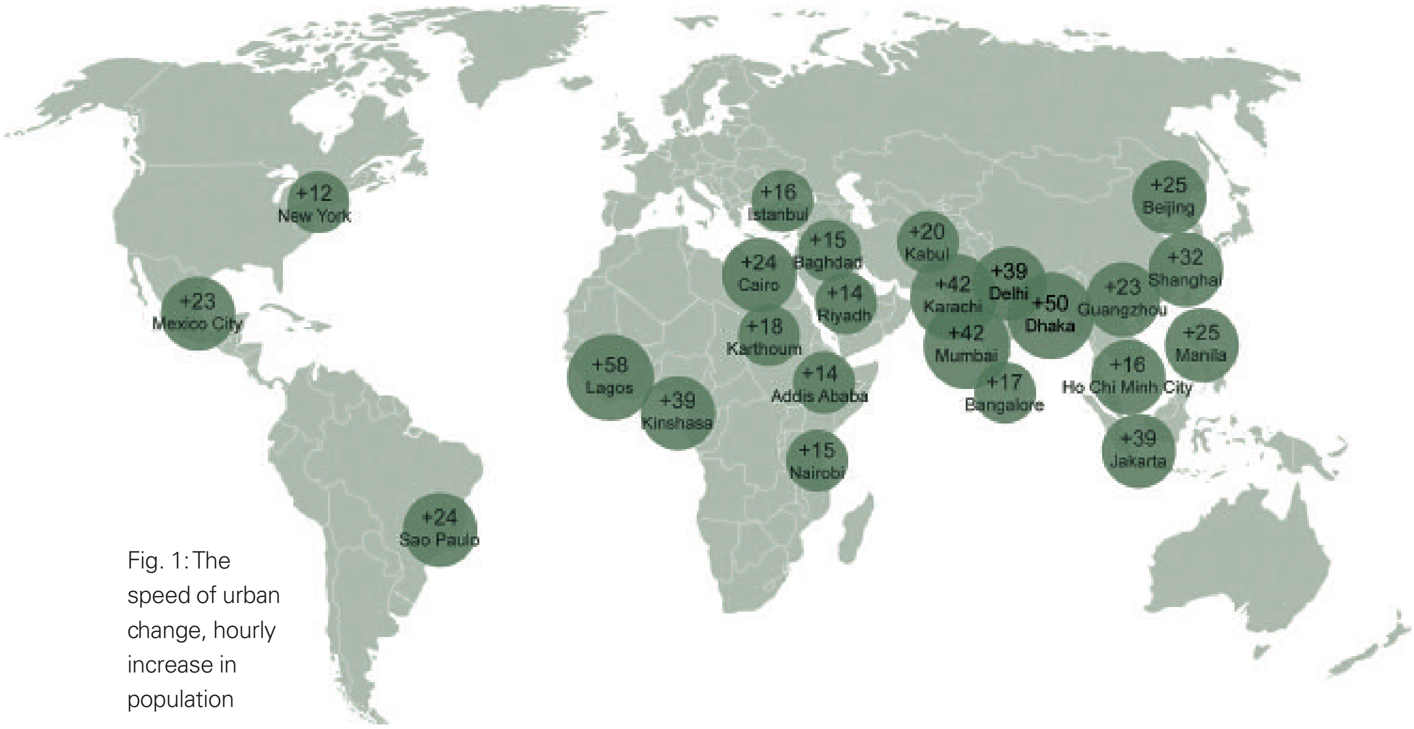


Fig. 1: The speed of urban change, hourly increase in population

Source: Bieker 2009, adapted from Burdett and Rhode 2007

Challenges of fast growing regions

In many fast growing cities in threshold and developing countries, local water resources do not suffice to supply the population with drinking water. At the same time, insufficient wastewater and waste treatment facilities lead to growing environmental and health problems. This situation is exacerbated by rising industrial needs on the one hand and by rapid population growth **(Fig. 1)** and rising living standards on the other hand. In 2011, the threshold of seven billion people living on earth was passed. More than 50 percent of the world population is already living in cities. By 2030, this number will have increased to more than 60 percent, equaling almost 5 billion people – related to a world population of 8.32 billon people in 2030 (UNDP 2011).

Below, the impact this development will have on technical infrastructure systems will be demonstrated, taking the city of Shanghai as example: Shanghai shows an increase in population of 32 persons per hour. For Asia, this is an average, not a top value (Fig. 1). In Shanghai, the daily water consumption per capita is approx. 140 l/(C · d), which is also the daily amount of wastewater. The specific amount of accumulating waste is approx. 1 kg/(C · d). Due to the annual increase of approx. 280,000 inhabitants, there will be a significant increase in the additionally required capacities in the field of water processing as well as wastewater and waste treatment **(Tab. 1)**.

Consequently, there is an enormous need for action in fast growing urban regions in infrastructure planning and development. In order to meet the already existing great challenges, concepts are needed that increase the resource efficiency. The common centralized approach that is approved in developed countries, focuses on sector separation and therefore lacks intra-sectoral flexibility and adaptability.

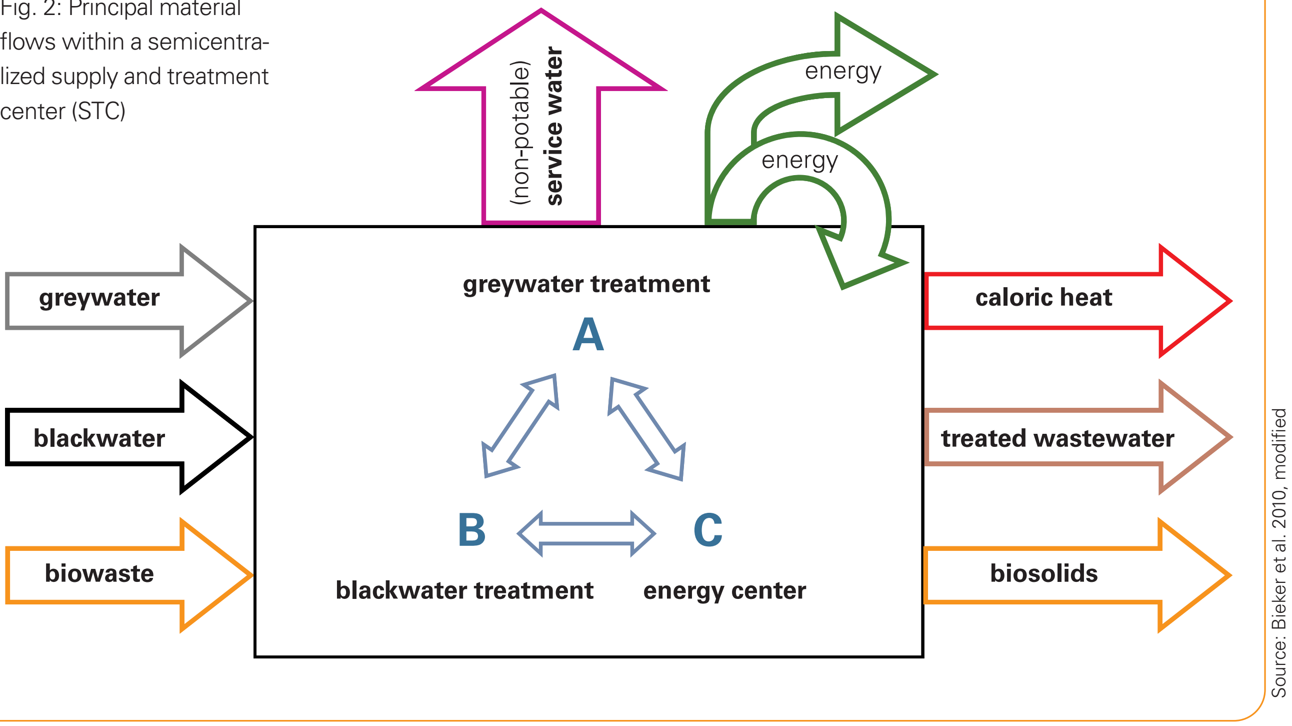
Worldwide, urban growth and increasing consumption have tremendous effects on the infrastructure of supply, treatment and disposal of water, wastewater, and solid waste. In many regions, the environment is seriously stressed by deficient or missing wastewater and waste treatment plants.

Table 1: Additional annual infrastructure capacities needed, example of Shanghai

timeframe	hour	day	week	year	5 years
urban growth [C/a]	32	768	5,376	280,320	1,401,600
additional water and wastewater treatment capacities [m³/time]	4	108	753	39,420	197,100
additional waste treatment capacities [Mg/time]	0.03	0.8	5.4	280	1,401

Source: based on Burdett and Rhode 2007

Fig. 2: Principal material flows within a semicentralized supply and treatment center (STC)



The Semizentral approach of integrated infrastructure systems

The Semizentral approach has been developed to meet the described challenges – to overcome insufficient infrastructure systems that cannot keep up with rapid urban growth and increase the resource efficiency in water and material use. The basis of this approach is the integration of the infrastructure sectors water, wastewater, waste, and sewage sludge. As shown below, the approach is easily adaptable to changing boundary conditions and enables the use of different synergy effects and thereby increases the resource-efficiency considerably.

The integrated approach

Semicentralized supply and treatment systems offer a future-oriented and resource-saving alternative to conventional sectored infrastructures while adjusting on a modular design of wastewater, waste and sludge treatment modules **(Fig. 2)**. Module A comprises the greywater treatment. Wastewater from showers and washing machines is treated to be used as service water for toilet flushing. Hereby, nearly one third of the daily water usage can be saved by this intra-urban reuse. Module B assures the treatment of blackwater. Module C, the energy center, consists of the anaerobic (thermophilic) treatment of residual biowaste and sewage sludge from modules A and B. The resulting biogas is used for power generation. The emerging amounts fulfill the needs of all treatment processes within the so-called semicentralized supply and treatment center (STC), even generating a surplus for further purposes. The integrated treatment of different water and material flows in one complex offers new efficient solutions in order to save resources and energy.

To reduce the distance between the households (source of greywater and blackwater as well as consumers of service water) and the treatment location of the water flows to a minimum, the semicentralized supply and treatment center needs to be located close to urban housing areas. The contiguity of housing on the one and treatment modules on the other hand implies a small footprint of the STC due to land costs and development pressure. Therefore, compact treatment methods are of interest. Secondly, emissions need to be reduced to a minimum, odor as well as noise or air pollution. These requirements can be met best with an in-house solution.

Key elements of the integrated semicentralized concept and therefore the in-house solution in terms of the STC are the intra-urban reuse of water on the one and the integrated treatment of solid waste and sewage sludge on the other hand. It is not intended to determine certain treatment technologies – the choice has to consider the specific circumstances of the respective implementation case.

Scale and flexibility

As indicated above, the overall aim of semicentralized supply and treatment systems is to contribute to the improvement of resource efficiency while offering the best possible range of flexibility. Therefore, the system has to be adaptable to the specific situation of a given context.

A central issue concerning the design of semicentralized supply and treatment systems is the scaling. In accordance with the concept of adaptation to specific contexts, the actual size of the population supplied by one module has


Source: fstockfoto – Fotolia.com

to be assessed from case to case, but is to be guided by the principle "as small as possible as big as necessary" (Böhm et al. 2006). At the same time, the concept has to cope with the ambivalence of sustainability with regards to economic as well as social and ecological interests.

The comparison of different scales brought up the recommendation of a best suitable scale (according to ecological, sociocultural, and economic reasons) of 50,000 up to 100,000 capita in a fully integrated semicentralized supply and treatment system within fast growing urban areas in China (cp. BMBF 2005). This scale also offers the opportunity of heat recovery from greywater. Due to short transport distances, the water is still warm enough for heat recovery when entering the STC and the amounts accrue in relevant quantities.

Advantages of the Semizentral approach

In comparison to conventional (linear and sectored) centralized supply and disposal systems, integrated semicentralized solutions (closed-cycle systems) offer a wide range of advantages, such as

- water savings,
- energy self-sufficiency,
- higher flexibility and therefore higher planning certainty,
- decreased capital commitment within the grid system,
- reduced vulnerability,

which are outlined in the following.

Water savings and energy self-sufficiency

As already mentioned, greywater from showers and washing machines is treated to be reused as service water for toilet flushing. This saves energy in wastewater treatment and reduces the daily water needs to around 30 percent.

The integration of sludge and waste treatment leads to an increase in the overall system efficiency and a decrease in the amount of residues to be disposed. At the same time, the sludge is stabilized and a solution for the currently severely deficient treatment situation of wastewater sludge (cp. openPR 2008 and bfai 2008) is given. The biogas gained from the integrated anaerobic treatment of sludge and waste is (under biogas-optimized treatment conditions) sufficient to provide the STC's electric energy demand for wastewater, sludge, and waste treatment and may even produce a surplus for additional purposes. An energy self-sufficient operation of the integrated semicentralized supply and treatment systems is therefore possible (cp. Bieker et al. 2009).

In addition, the treatment of sewage sludge and waste considerably reduces the emission of greenhouse gases (GHG) arising from sanitary landfills. Anaerobic pre-treatment reduces the biodegradable fraction by about 60 percent. Throughout the energetic use of biogas, the emitted carbon is being completely oxidized to carbon dioxide. Only 40 percent of the biodegradable fraction is landfilled afterwards. This remaining fraction of the waste has a very low gas formation potential (cp. Bockreis et al. 2003).

In contrast, landfilling of the untreated residuals leads to high methane emissions, even under optimal operational conditions of the landfill. Methane has a 23 times higher global warming potential (GWP) than carbon dioxide (cp. IPCC, 2001). Therefore, any scenario including the landfilling of raw waste will lead to a higher GWP. A quantification of the impact of pre-treatment on the GWP is only possible if the operational conditions of the landfilling process are known.

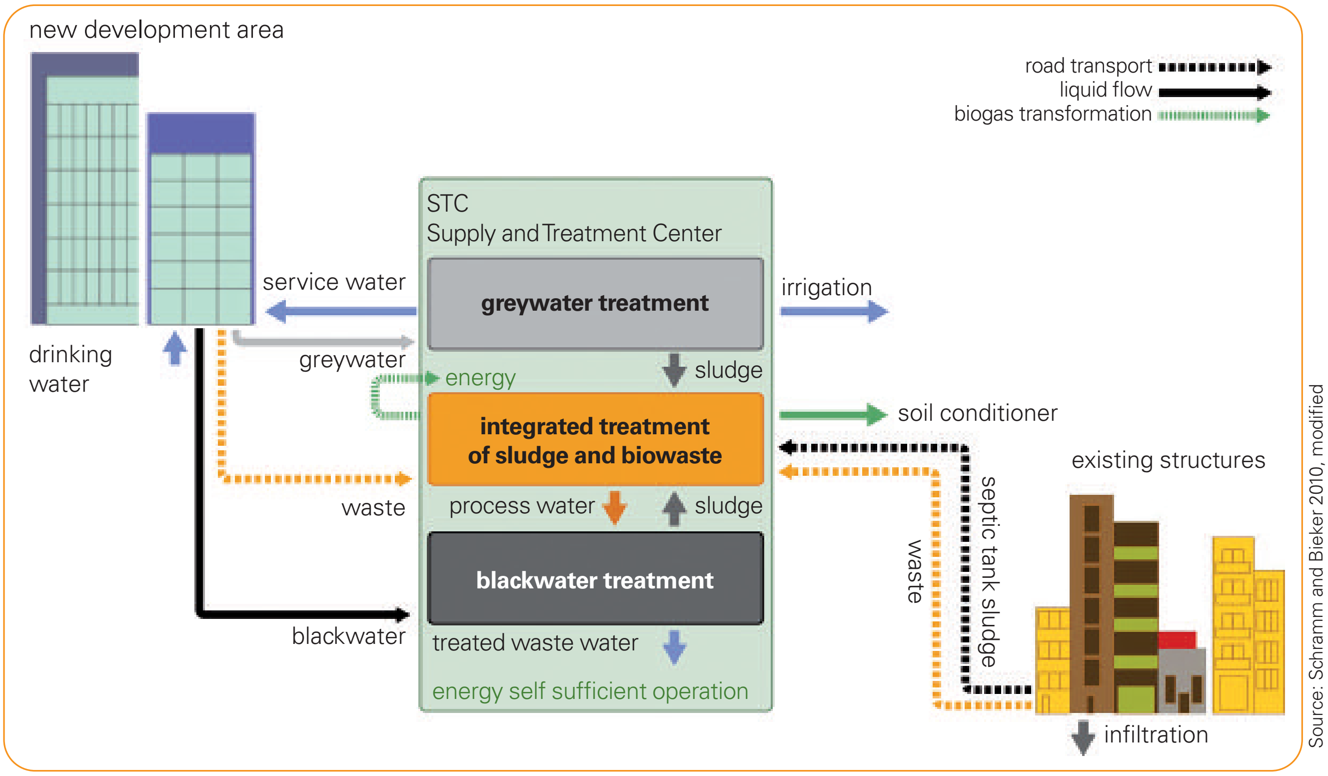
Capital commitment and planning certainty

Integrated semicentralized systems focus on compact near-by units, avoiding large distances between housing areas and treatment plants – with economic saving potentials and without any lack of comfort. In the past, odor, noise, and hygienic aspects have been sound reasons to locate waste and wastewater treatment modules far away from housing and other sensitive uses. Modern treatment technologies and methods enable close-by treatment with the opportunity to save large amounts of resources even without any changes in the habits of water use.

One essential consequence of the proximity between accruing and treatment location is the reduction of grid scale. 70 percent – 80 percent of the manufacturing costs of a wastewater treatment plant result from the sewer system (cp. Günthert & Reicherter 2001); any reduction in grid distances and diameters leads to saving potentials. Furthermore, the lifetime of grid systems are 50 years and more, a period that poses substantial economic risks when looking at the dynamic changes and unpredictable growth as to be found in Asian threshold countries these days. Another challenge is the subsequent implementation of wastewater and water supply systems: The larger the diameter, the more complicated, expensive and sophisticated new grid systems get.

Moreover, shorter distances induce lower investment needs for grid systems and operational costs for water transport and pumping. A disadvantage is the need of an altogether larger number of treatment facilities. Even in case there is a network of laboratory and workshop infrastructure, additional resources are undisputedly needed because of main treatment devices.

However, these additional needs in material and facilities come along with several advantages in overcoming the main challenge of the currently fast-growing urban regions: the celerity of urban growth and the rising resource demands. Planning and operation of semicentralized supply and treatment systems are much more reliable than of conventional centralized systems, as the integrated semicentralized system comprises smaller and better manageable frames in time and space. One line of argumentation regarding planning certainty leads development scenarios, such as: Realizing a centralized system for several 100,000 or even some million people is a planning risk. What happens, if the development scenarios fail because of unforeseeable circumstances such as the current worldwide economic turbulences? Huge amounts of capital are committed in the grid system – no matter of the step-by-step expansions of the treatment facilities. An economic disaster on the one hand – but a technical challenge, as well, as low flow velocities cause corrosion induced by anaerobic degradation. With semicentralized systems of some 10,000 properties, the planning scenarios offer a very different and dependable reliability, even in new development areas: Within two to four years the planned scales of integrated semicentralized supply and treatment systems can operate fully loaded (cp. Bieker, 2009). Systems of more than 50,000 modules require more extensive grid systems that need to be operated – depending on the growth rates of new development areas – up to 10 years and more to approach full capacity. This implicates technical challenges and economically insufficient revenues for one third to one half of the time of the relevant depreciation period. And even if these development scenarios fail, ►



▲ Fig. 3: Semicentralized supply and treatment concept – Case of Hanoi, Vietnam

the economic casualties would be incomparably lower than for centralized systems. This surplus in flexibility offers a huge advantage in spatial planning and spatial development in general. Further potentials may lie in the standardization of planning and construction processes of integrated semicentralized systems. Ascertained reductions in planning and implementation through off-the-peg solutions are conceivable, but are still under advanced investigation.

Vulnerability

Finally, semicentralized scales are less vulnerable in terms of external influences. Even in case of a complete system failure as a result of natural disasters such as floods or earthquakes, the impact on civil life is not comparable in terms of affected properties.

One reason is that there is not only one large plant in one location, but several STCs are allocated in several locations. This way, the risk of a complete breakdown is reduced and failures caused by floodings etc. might only be local. In addition, due to their standardized modular structure, affected STCs can be repaired or newly constructed in comparatively short periods of time. Furthermore, it is easily conceivable to set up individual modules in a first step in order to gain initial supply and treatment capacities and to extend the system step by step until the complete STC is implemented. Particularly when considering the climate change and the associated increased cases of extreme weather conditions, the issue of vulnerability is assumed to become more and more important in infrastructure development worldwide.

Adaption to regional requirements

The flexibility of the modular design of the semicentralized supply and treatment system allows the adaption to different requirements. The case study of Hanoi, which had the task to develop a semicentralized supply and treatment system within significantly different infrastructural framework conditions, shows the flexible potential of the modular infrastructure approach.

In Hanoi, domestic wastewater **predominantly** flows into septic tanks that are installed under each building. The conception is to settle the inherent solids and discharge overflowing liquid into the public stormwater sewer, where existent, or otherwise to leave liquids drain into the underground. The difficulty is that there are no regulations for emptying the septic tanks in order to remove accumulating solids. As emptying involves costs for the owners, most of the citizens restrain from emptying their septic tanks as long as possible (mostly as long as the wastewater does not re-appear in the bathrooms). The resulting infiltration into the ground causes severe soil and groundwater contamination by ammonia, consequently leading to considerable problems in the production of drinking water. But even the tanks that get emptied are part of the problem. Private companies emptying the septic tanks often dump the sludge illegally into the open stormwater sewers. The official way is to transport the sludge out of the cities and sell it (untreated) as fertilizer in local agriculture or as fish feed in aquaculture enterprises.

The initial Semizentral approach was designed for new development areas within fast- growing urban regions in Asia. In this case, this focus was extended in order to improve the situation within the existing urban structure in the City of Hanoi. Therefore, the approach of a combination of upgrading existing supply and disposal infrastructures within the urban structure and implementing integrated supply and treatment systems within new urban expansion areas was developed. This extended semicentralized supply and treatment approach still offers the opportunity to integrate different supply and treatment flows **(Fig. 3)**.

In the new development area, wastewater streams are collected separately and the service water gained from treated greywater is used for toilet flushing – like in the initial Semizentral approach. In addition, the resulting sewage sludge is treated together with organic waste and sludge from the septic tanks of existing nearby city districts. This way, the situation of the existing structures, here the limited capacity of the septic tanks, gets improved and therefore the soil contamination is reduced. The combined utilization of the two infrastructure systems will benefit the whole city of Hanoi – by improving the situation of existing structures and implementing an integrated supply and treatment concept for new development areas.

Current research and outlook

The described flexibility of semicentralized supply and treatment systems facilitates their application within new development areas. But there's still research to do to enable and assure the realization of the mentioned theoretical potentials in the future. Therefore current research is done in the following fields:

- The challenge of water reuse in terms of acceptance (color and odor). Which treatment steps offer best possible results (color- and smell-free service water) in combination of low energy demands?
- The individual adaption of the construction kit (variation in modularity and scale) to specific circumstances and needs in order to find the best-fit solution in terms of economic, ecological and social (acceptance) reasons.
- The challenge of resource and energy efficiency. Which changes need to be done in technical design and operation in order to achieve highest energy recovery rates?

The top future challenge will be – in cooperation with different partners from industry – to start real-scale implementation and to actually construct a semicentralized supply and treatment system for 10,000 inhabitants and more. Only then one will be able to assess how well the research results can be integrated in actual daily operation processes and to determine the changes in operating procedures in comparison with conventional separate sectoral infrastructure systems. Negotiations are being conducted with German and Chinese partners.

Comment

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