WATER 4.0

German Water Partnership

Solutions you can trust.

Contents

WATER 4.0 – An important element for the German water industry

The importance of digitization in our society has been increasing for some time; in the meantime, people have also begun to talk about a new basic trend that can change value creation chains and evolve into a new industrial revolution.

This has given rise to the discussion of terms such as "big data", "Internet of Things" and "cyber-physical systems", with the emergence of groups such as the Industrial Internet Consortium and Platform Industry 4.0 revealing the dynamic energy present in this environment. It is therefore imperative for the German water industry to participate actively in these innovation processes, to play a leading role and to maintain and/or further develop its competitiveness.

German Water Partnership (GWP) has made a significant contribution by establishing the working group WATER 4.0 and creating this brochure. The brochure provides the framework for defining the concept of WATER 4.0 and documents the importance of digitization for different user groups. This shows that there is not merely one solution but rather that – depending on the user groups – different forms of digitization can be important. This is also seen in a wide range of examples where GWP members are interpreting digitization on different levels of the value chain and also in complex integrated systems.

There are many different opportunities for the German water industry to participate in this new industrial revolution and we are pleased that German Water Partnership is actively contributing to this process with this brochure.

GWP Working Group Water 4.0

1. WATER 4.0 – Made in Germany

The water industry is constantly looking for possible ways of adapting itself to changed boundary conditions and to find effective and efficient solutions for global challenges. Climate change and urbanization – to name just two of the important driving forces around the globe – are constantly increasing the demand for scarce water resources.

Over the course of digitization, procedures, tools and other resources are increasingly becoming available and are ringing in a new era in water management. Comparable with other industries, the water industry is also in a position to further strengthen its future competitiveness through the use of automation in smart grids. Through the increased integration of IT, sensors and model applications, opportunities are created to better understand water management systems in terms of their complexity and degree of networking and to illustrate them in production, early warning and decision-making processes. The integration of planning and operating processes with the aid of intelligent hardware and software and of the independent exchange of information – from the user to individual components all the way to the supplier/disposer – is becoming more and more of a must for resource productivity and efficiency. For real-time-controlled processes, the Internet of Things and Services also plays an important role, because thus data for water-relevant processes and water qualities is becoming increasingly constant and available/usable, whenever and wherever required. In addition, it is also possible to perform additional networking with other data (e.g. weather) to create forecasts, which can be input into the operations management of water-relevant plants.

On the basis of a comparable advance in development in industrial production, namely INDUSTRY 4.0, [1; 2], the GWP has decided to call this change brought on by digital technology WATER 4.0 (see box).

GWP's understanding of WATER 4.0

WATER 4.0 puts digitization and automation at the center of a strategy for resource-efficient, flexible and competitive water management. In doing this, WATER 4.0 incorporates the same main features and terms of the industrial revolution INDUSTRY 4.0, such as "networking of machines, processes, storage systems and resources", "smart grids", "Internet of Things and Services", and brings them together in a systemic, water management context.

In the implementation of WATER 4.0, Cyber Physical Systems (CPS) are drivers of the optimal networking of virtual and real water systems, with planning, construction and operation being largely done by software.

This allows the intelligent networking of water users (agriculture, industry, and households) and components in a sustainable water infrastructure with the environment and the water circuit and follows a holistic approach along the value-added chain. Furthermore, WATER 4.0 allows a high degree of transparency for water users, thus covering current needs, and provides opportunities for sustainable, creative activity areas in water management.

Figure 1 shows a comparison of important developments in industry and in water management. With regard to the classification of developmental advances in water management, however, there are different possible interpretations and chronological spans. An important feature of the current fourth development stage in both sectors is the merging of real and virtual worlds into so-called Cyber-Physical Systems (CPS). This stage describes the linking of sensors, computer models, and a real-time controller with real water systems, with heavy participation of intelligent networks up to the intranet/Internet.

Cross-sectional technologies allow a holistic consideration of water, regardless of whether it is falling as precipitation, being pumped through a network for supplying drinking water, being transported to a wastewater treatment plant

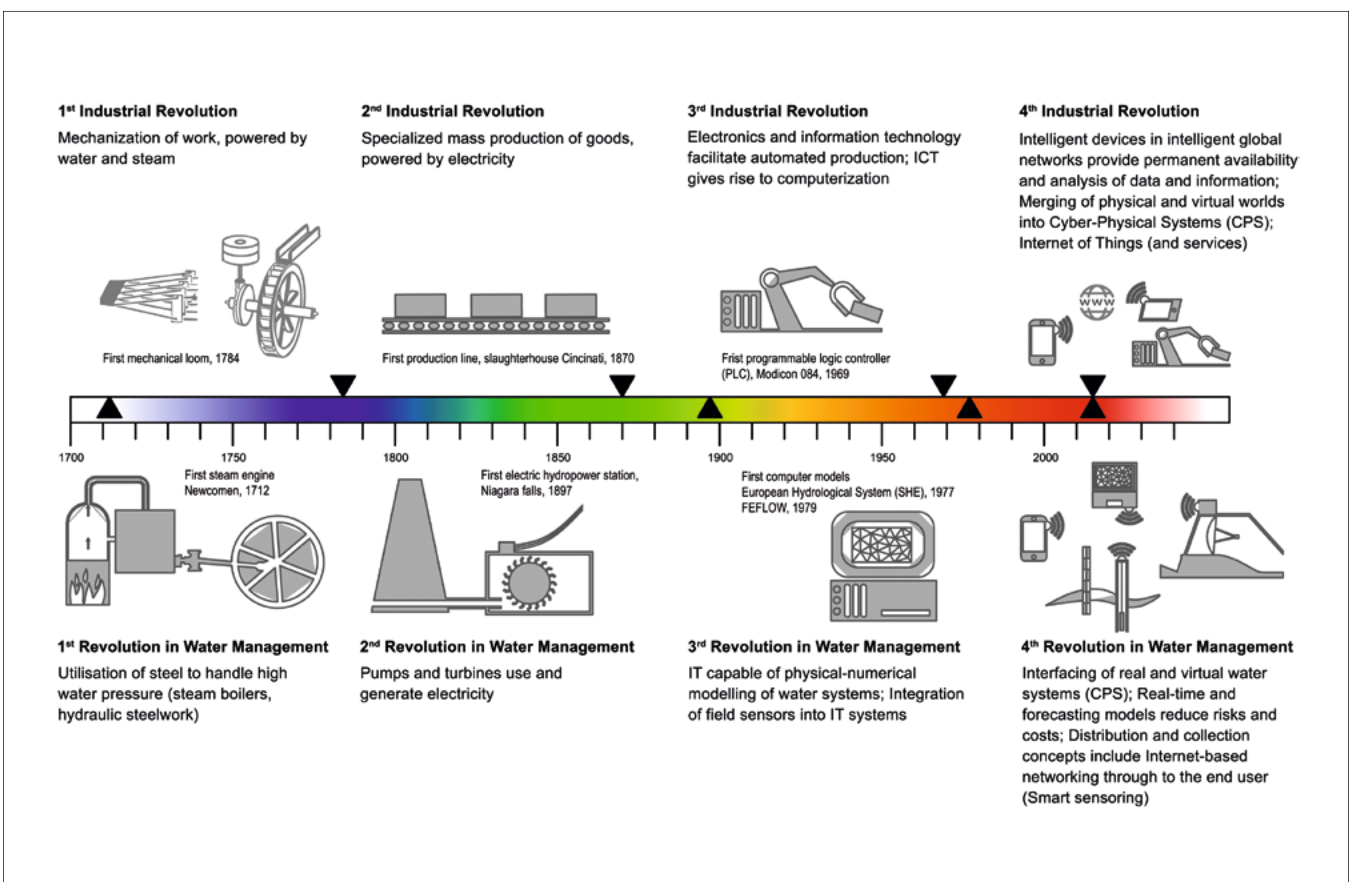

Figure 1: Comparison of the four industrial development stages based on acatec [1] with those of water management according to DHI [3]

through a network of channels, where it is purified and then reused for irrigation, if applicable, or used in an industrial process as a solvent or cleaning agent or for cooling and heating. They are not stand-alone technologies. Rather, they combine processes, measures, and technologies into an IT unit and include classic, tried-and-tested methods as well as new, innovative approaches. Both central and distributed solutions are possible for this. The only prerequisites are

- an exchange of data and information which is recorded online or entered and output offline (manually) and
- digital illustration of the system to be considered and the mutual influencing of a virtual and real system.

This results in a control loop which illustrates the natural water cycle and the anthropogenic influences, puts them together in a relation, continuously records and describes them, and thus helps to give a holistic view to make the best decisions.

It must be assumed that further autonomy of such systems will arise from the existing automation engineering solutions through cognitive model characteristics, which allow goal-oriented adaptation, modification, and partial self-organization. The further development of self-organizing cognitive systems is currently under research and development. The result is Cyber-Physical Water Systems (CPWS), which are suitable for integrated and long-term consideration and interaction of virtual and real environmental systems, while taking changing and changed processes into consideration.

In this respect, WATER 4.0 is not a concrete technology. No strict definition exists in terms of natural science. Rather, WATER 4.0 is the interaction of innovative, current and future networked technologies with water as the natural resource, product or industrial resource with the goal of sustainable management, usage and risk reduction, while taking the interests of all of the direct and indirect users and stakeholders into consideration. The networking of measurement and control systems with data analysis and modeling transforms data into information, which prepares, supports or makes decisions and implements measures and monitors their interventions in the water system (feedback). Likewise, the information compiled over time can lead to new knowledge as to how water can be better utilized in the various application areas.

Thus, WATER 4.0 is a holistic approach which lives on and evaluates digital data and inputs it into forecasts and which also falls back on data from other technical areas, thus allowing a holistic consideration and sustainable decisions. WATER 4.0 does not remain static "in the now". Rather, it follows technical developments and uses the new capabilities that are provided. The approach lives on the effect of the entire system and the comparison between virtual and real water systems and less on innovative individual elements.

With this brochure, the GWP would like to show which successful examples of the first-generation Cyber-Physical Water Systems already exist. The German water management provides a large number of products and cross-sectional technologies, which can be linked to CPWS. The use case or implementation scenario is often made easier, since a great amount of data from water management systems already exists.

2. Digitization in water management delivers value

Both the municipal and also the industrial water industry are facing enormous challenges: having been defined by decades of continuous growth in the population and the economy with a stable environment for building and expanding the water infrastructure, it is now experiencing major changes giving rise to new business models and stimulating competition in the market. A look at the digital revolution clearly shows the important changes the world has seen in recent years and the paradigm change we are facing today [7].

WATER 4.0 means change. Change is a basic principle of our world. Change opens up future opportunities, questions established viewpoints, inspires us to find new guiding principles and stimulates the German water sector and thus the members of German Water Partnership to make entrepreneurial decisions and create more value for their customers.

The offerings of the companies of the German water industry are highly diversified and customers and their expectations are equally diverse when it comes to the value gained from using digitized solutions (Figure 2). The customer base extends from planner and supplier, from complete plants for water supply and waste water disposal to municipal and industrial operators, all the way to consumers. Nevertheless, after an initial ad hoc survey involving 13 members, it is possible to derive the following initial assumptions [5,6], which

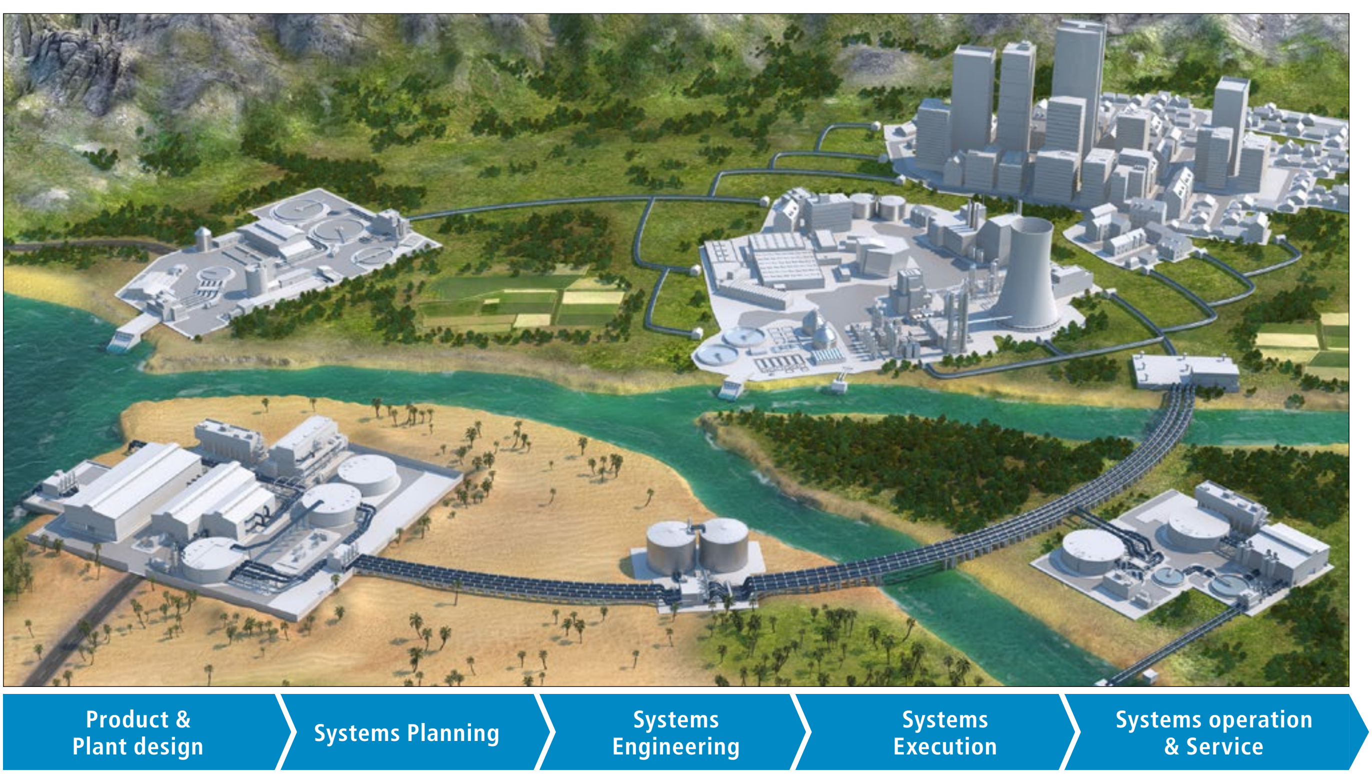

Figure 2: "Customers" in the water cycle (source: SIEMENS)

are based on the statements of a comprehensive customer survey conducted by Siemens [4] concerning "digitization in Germany", for both customers and the members of German Water Partnership:

› Product & design
› Systems Planning
› Systems
› Engineering
› Systems
› Execution

1. In the everyday business of most German companies in the water sector, digitization has become indispensable although a large percentage of companies are only in the early stages of implementation. Most members of GWP and their customers have recognized the potential of digitization and some of them at least have a high-level digital strategy. However, it has also been found that supply and disposal companies often approach this issue with caution.

2. Digitization is primarily regarded as a vehicle for the improvement of processes and efficiency. Large companies, SMEs, universities and operators have a similar view of this: digitization mainly signifies the management of data, the transition process from the analogue to the digital world and the networking of systems, devices or plants. As a result, the primary expectation is an improvement in quality, service and resource efficiency. Private and municipal enterprises frequently make use of digitization to develop new business models.

3. Further implementation of digitization is hampered mainly by a lack of standardization, a lack of cost-benefit analyses and data security worries. Many operators and manufacturers of solutions for water management miss the technical standards necessary for integrating and networking existing and new systems. In addition, a scarcity of cost-benefit analyses and feelings of insecurity resulting from discussions on data security are the main challenges to improving the implementation of digital technologies and processes. For many companies, the most important starting point for the further implementation of digitization is the involvement and training of their staff.

4. Digitization is usually organized centrally. The decisions to be made in the context of digitization are usually made by a central office. Therefore, the digital strategy often represents implementation of the "tone from the top". The challenge is to convince all the levels of the benefit of digital solutions (Figure 3).

Aspects of digitization

There are many aspects of digitization, and their importance – depending on the industry and point of view (manufacturer vs. customer) – is perceived differently. Both the visualization of and increase in process transparency in addition to the resource optimization (time, staff, investments) expected from the use of digital solutions are of overriding importance. For customers of the water industry, assistance systems for process simulation and decision support have proven to be prominent aspects of digitization [8]. The positive influence on the relationship with customers and suppliers expected from industry is generally confirmed by the water industry but is deemed less important (Figure 4).

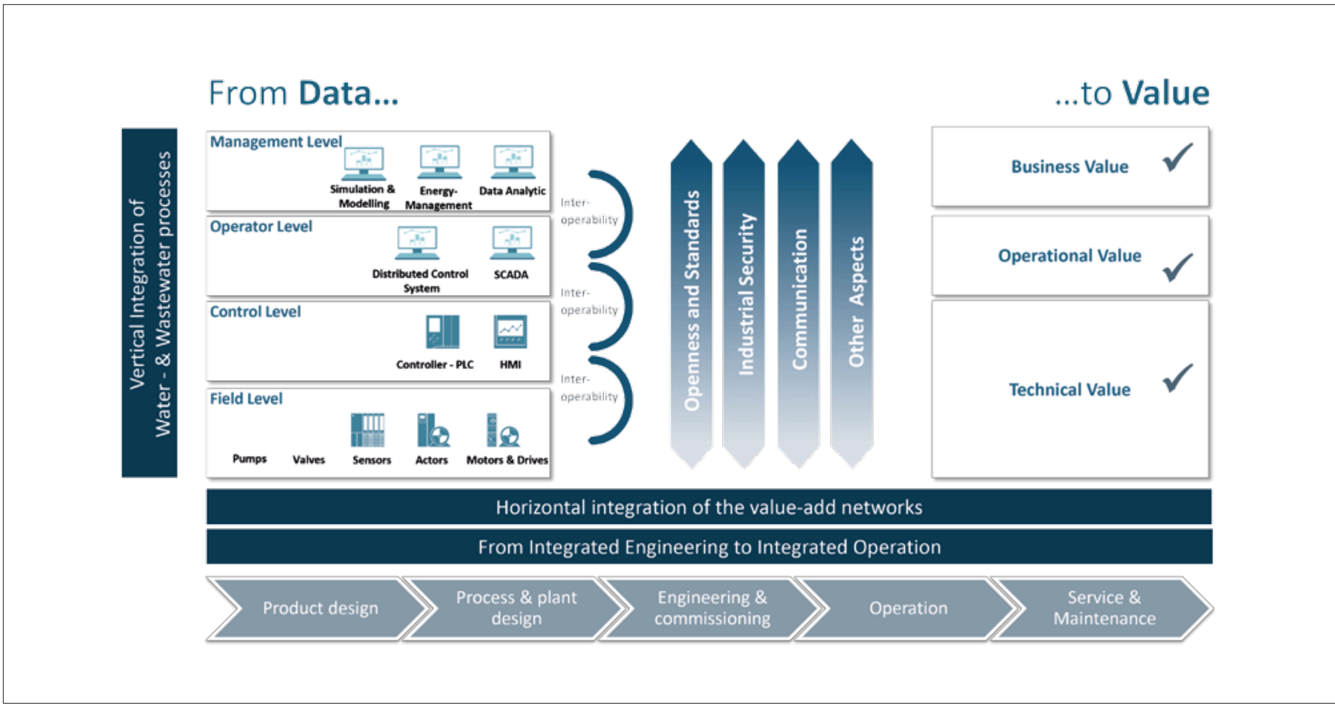

Figure 3: Digitization in water management creates value (source: German Water Partnership [5])

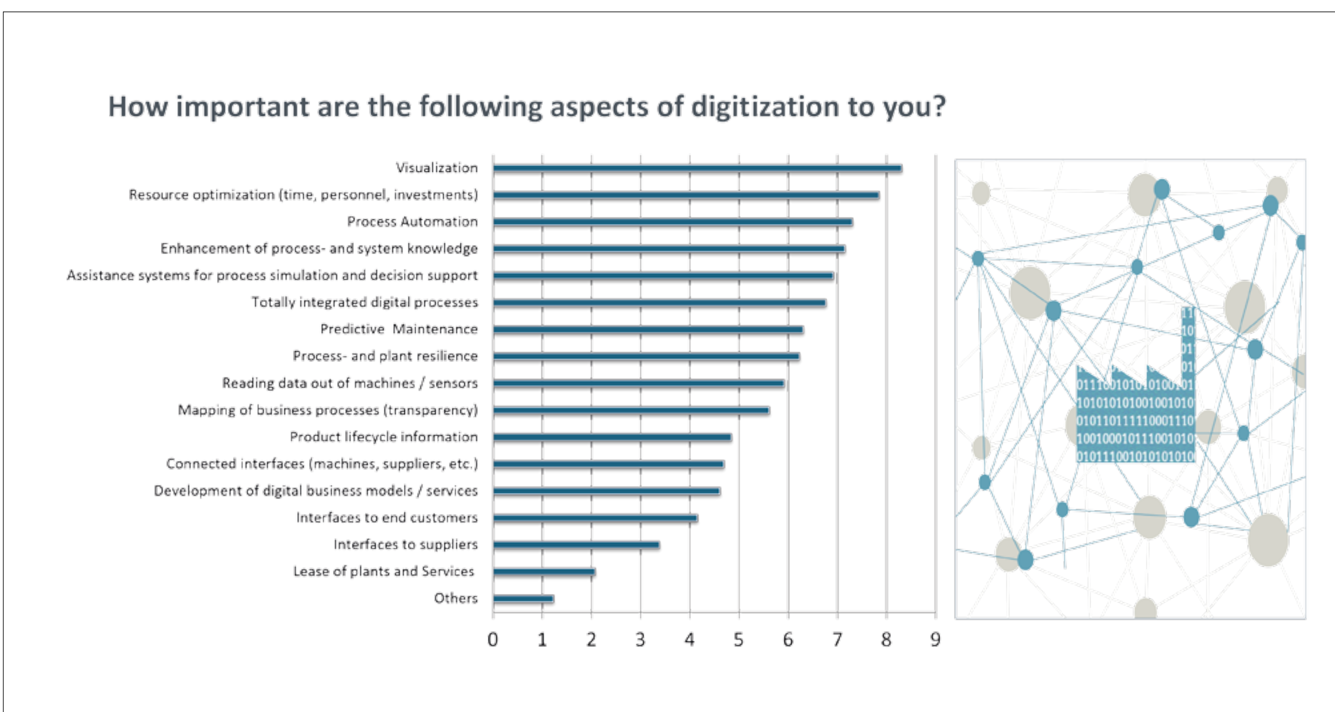

Figure 4: Aspects of digitization (source: German Water Partnership [5])

Potential, expectations and trends

Operational improvements in the areas of:

› Quality
› Service
› Resource efficiency

are very important to the key objective of digitization activities. Where these three areas are concerned, the water industry's expectations of the results to be gained from using digital solutions are probably deemed to be even higher than those of other industries [5]. By comparison, it appears that the water industry's customers do not expect synergy effects in daily collaboration or an open innovative corporate culture (Figure 5). For themselves and their customers, the GWP companies expect to gain potential for success as a result of new business models but very little as a result of better customer focus.

The trends that must be driven in order to implement digitization are recognized and assessed uniformly across all

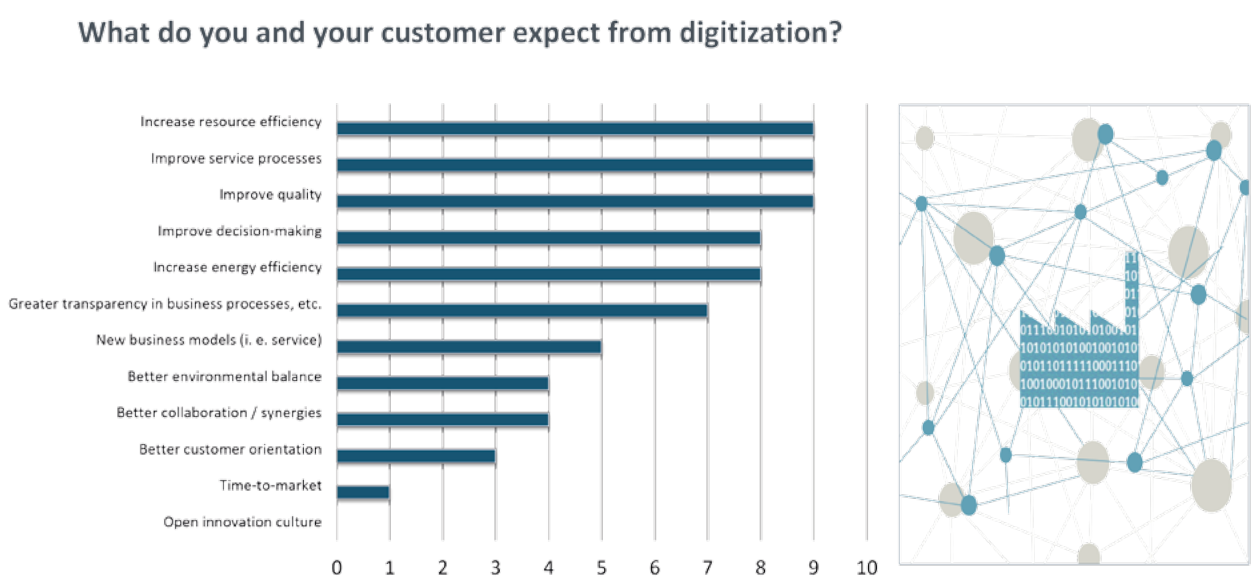

Figure 5: Expectations regarding digitization (source: German Water Partnership [5])

industries. Both industry in general and the water industry consider the "Internet of Things" and thus the networking of man, machine and cyber-physical water systems as most important for their customers. It is also assumed that customers of the water industry attach great importance to the development of analysis skills; for this they rely on Big Data or Smart Data Technology (Figure 6). Section 3 includes some impressive examples that have already been implemented using digital solutions of the German water industry.

Digitization and business strategies

Many market observers agree that digitization will only bring about essential innovations if appropriate efforts are not only made in uncoordinated field trials but also if a digital strategy is developed that is also included in the general business strategy [4]. According to the GWP members interviewed, more than 50% of the companies have at least partly developed an overall digital strategy in their organizations and those of their customers [6] and consider this implementation a key driver for digitization.

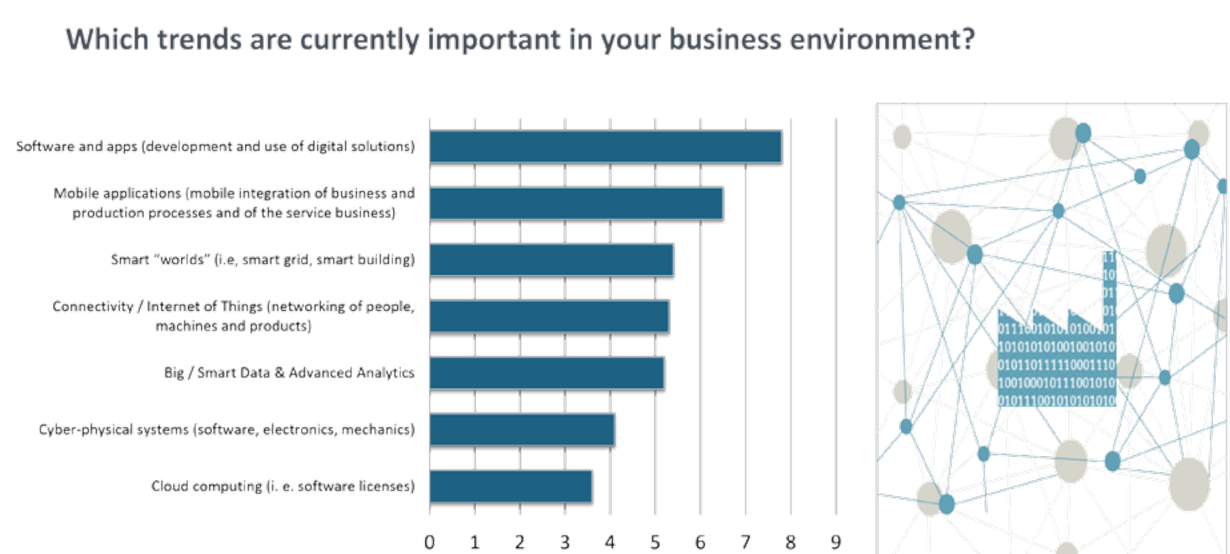

Figure 6: Trends of digitization (source: German Water Partnership [5])

The key external drivers for a digital strategy arising out of the corporate environment are existing standards and the requirements of customers and suppliers. For many companies, digitization must be anchored as a process in the organization of the water industry's customer which includes all phases from analysis to management and control (Figure 2). Approximately 50% of the GWP members interviewed consider the missing standards a great challenge, which also confirms the result of the survey conducted by Siemens [6].

At present, customer requirements and standards are not being considered in Germany, although they have been identified in the global market. A current study of the IDC (International Data Corporation) highlights the great importance of a digital strategy, particularly for SMEs if they are to operate successfully in the global market [9]. Accordingly, customers outside Europe already appear to be more digitally astute, putting into words requirements that are not (yet) requested by German operators of water and waste water plants.

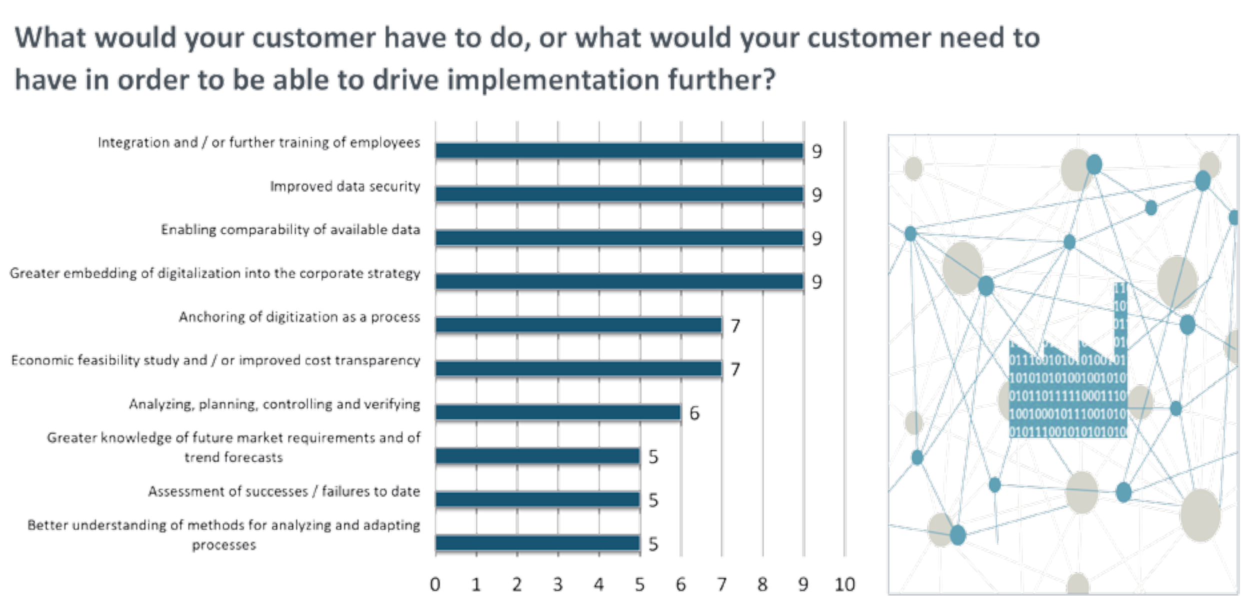

Figure 7: Drivers of digitization (source: German Water Partnership [5])

From data ... to values

Data are the raw material of our age—they are the starting point for interpretation and the input for decisions. WATER 4.0 creates and makes available data that are relevant to water management, and provides intelligent and goal-oriented data analysis. Assistance systems help to generate value-added knowledge from data. [Fig. 8]. This knowledge can help operators of water and wastewater systems to better understand the needs of their customers and their processes, to develop the right products and strategies, and to make themselves nothing short of future-proof. In Chapter 3, various examples are shown which contain all of the important aspects of digitization in water management and which have already been implemented with innovative solutions from German companies.

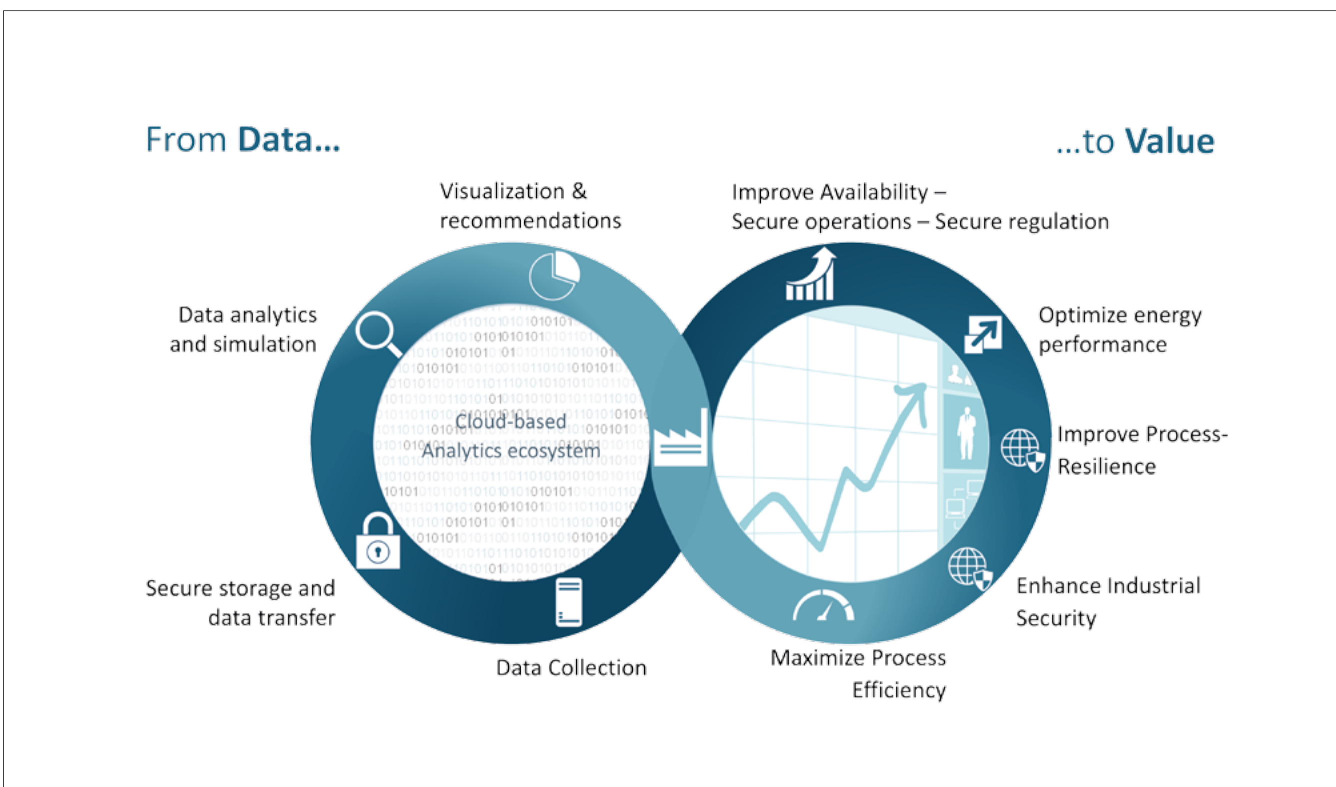

Figure 8: From data to values (source: SIEMENS)

3. Water management delivers value, examples

The previous sections have fully explained the term WATER 4.0 and described how it is embedded in industrial development processes. It has also been shown how increasing levels of digitization within water management can deliver value at different points. More convincing than mere words, however, are specific examples which document how GWP members are already implementing elements of WATER 4.0 and offering them in the market. This section describes different facets of WATER 4.0 on the basis of five examples which show digitization in action. There are plans to provide more examples of this kind in an occasional series on the GWP website.

The five examples:

3.1 Real-Time Control Vienna – design and implementation of sewer network control for the City of Vienna

3.2 Web-based real-time monitoring – water drainage in the tunnel construction project of German Railways (DB) Stuttgart-Ulm

3.3 Operational Real-Time Control and Warning System for Urban Areas and Receiving Waters

3.4 Waste water control with Totally Integrated Automation

3.5 iPERL – Digital measurement of water consumption: the example of ENTEGA Darmstadt

3.1 Real-Time Control Vienna – design and implementation of sewer network control for the City of Vienna

As part of an expansion plan for water pollution control, increased requirements were imposed on the City of Vienna's sewer network which had developed historically. To achieve the required objectives, large sewers with storage capacity and overflow were built into the watercourses adjacent to the Danube, the Danube Canal, Wienfluss and Liesing to minimize combined sewer overflows, and an integrated sewer control system, including on-line rainfall forecast and real-time simulation, was designed and implemented for optimum management of the storage capacity and overflow sewers. The management of detention reservoirs holding approximately 628,000 m³ in the City of Vienna's sewer system (length of the sewer system about 2,200 km, catchment area about 220 km²) serves two main objectives:

- Minimize discharges of rain water from the sewer system into the watercourses and
- Optimize the interaction between sewer system – sewage treatment plant – discharge into watercourses.

To achieve this, it is necessary to manage the rainfall drainage processes, with their temporal and spatial differences, in the five catchment areas of the main collectors (see Figure 9) using an integrated control system (RTC) (Figure 10). To this effect, three models were implemented:

1. Temporal and spatial short-term forecast model for rainfall distribution based on radar data
2. Hydrodynamic real-time simulation model for the simulation of rainfall drainage including real-time calibration of the models based on measured values
3. Optimization model for the control devices within the global system (fuzzy control)

Measured data received continuously from the system are used together with the forecast drainage/water levels of the real-time simulation model to operate the existing and planned control devices such that the defined target values are not exceeded. The software used is the hydrodynamic simulation model itwh.HYSTEM-EXTRAN along with itwh.CONTROL. The integrated control system implemented has been able to reduce the volume of combined sewer overflows by more than 50%. For future expansion of the network, a combined sewer and storm water flow rate of 18m³/s was determined for the main sewer. This will result in a balanced pollution load within the overall system.

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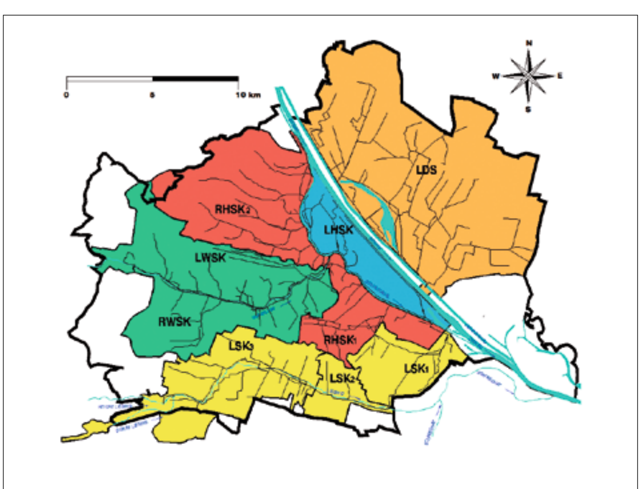

Figure 9: The Vienna sewer system - catchment areas and main sewer

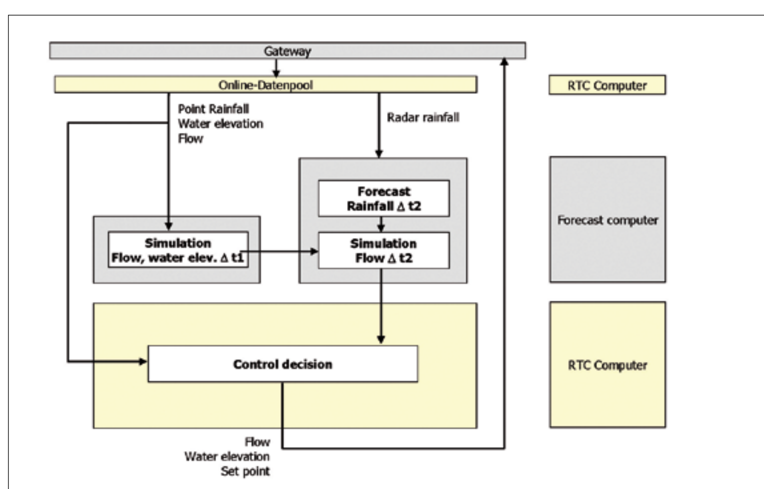

Figure 10: Dataflow for the integrated control system

3.2 Web-based real-time monitoring – water drainage in the tunnel construction project of German Railways (DB) Stuttgart-Ulm

Construction of the Alb descent tunnel is part of the German Railways (DB) Stuttgart-Ulm project in connection with the "Stuttgart 21" project. The route of the Alb descent tunnel leads through the Swabian Alb und thus through an area with highly complex and structurally difficult geological and hydrogeological soil conditions.

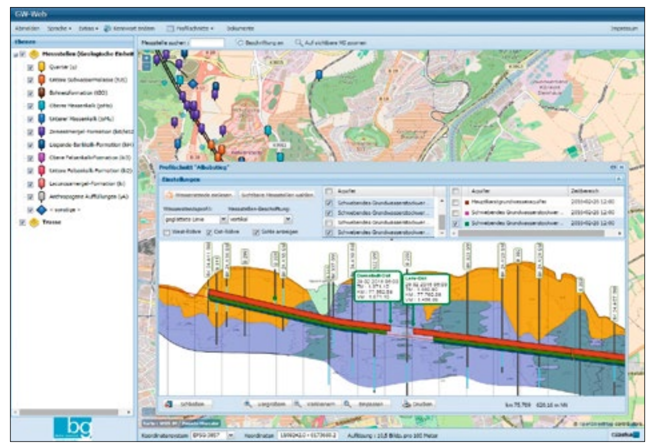

Figure 11: Web-based monitoring of tunnel construction

Highly complex field environment

This complex groundwater situation in the Swabian Alb requires close spatial and temporal monitoring of the groundwater hydraulics, the water quality and the drilling progress. For this purpose, a web-based real-time monitoring, information and early warning system was implemented in 2012.

A collective solution

Some 60 groundwater monitoring wells along the tunnel route form the heart of this system. They are equipped with modern data collectors and GSM/GPS modems of the type "SEBA SlimLogCom" for continuously monitoring the water level. The remote data transmission systems were optimized using special antennas for the sometimes difficult installation and reception conditions. State-of-the-art sensor technology directly monitors the hydraulics and hydro-chemistry as well as the changes thereto in the various aquifers. Information regarding groundwater level, water quality and sensor data is supplied continuously and is recorded and managed automatically in the groundwater monitoring system GW-Base and GW-Web supplied by ribeka GmbH (Figure 11). In addition to GIS functionality with all the project information, an extensive range of professional scientific and statistical functionalities create a comprehensive monitoring and early warning system within a very demanding and highly sensitive geotechnical project environment. GW-Base/GW-Web is the only monitoring system of its kind, providing for the first time – along with measured data for hydrology and climate data – important online data about the geology in a complex hydrogeological environment.

Automated monitoring

The continuously measured groundwater data is integrated directly online into geological and technical profile sections in real-time, thus providing essential information for safe construction progress and water drainage in the tunnel excavation. The current status of the tunnel excavation (calotte, bench, invert) is illustrated in real-time in the profile; it is always up-to-date and can be viewed on the spot by the construction manager and the client. GW-Base and GW-Web provide comprehensive functions for control and for the preservation of evidence during large-scale lowering of groundwater with subsequent reinfiltration into the aquifers. Access rights tailored to the different user groups and comprehensive report management complete the system.

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3.3 Operational Real-Time Control and Warning System for Urban Areas and Receiving Waters

Initial situation

"Water Vision 2100" has been initiated in the Danish seaport of Aarhus with the aim to ensure clean water both for nature and drinking water now and in 2100, also taking account of the climate change. The vision covers the areas of groundwater, water supply, waste water disposal, storm surges, water resource management and land use. This covers the entire urban water cycle including the catchment area; consequently, the requirements on data management are very high. As part of implementing the vision and in order to support the opportunities for recreational use of the lake, river and harbor, the City of Aarhus in 2005 decided to improve the hygienic water quality in the receiving waters mainly achieved by reducing frequency of combined sewer overflow. During 2007-2013 the project requirements were met according to the WATER 4.0 approach with an integrated real-time control and warning system. The system has been put into automated operation in 2013 and comprises the following tasks: data acquisition, data processing, data validation, model design, optimal strategy development, sending of control instructions and control of the infrastructure elements, triggering operational alarms, and alerting the public (figure 12).

Focus

The most important objectives of the project concern the alignment of the infrastructure with the high population growth, the creation of sufficient real-time controllable storage capacity to avoid combined waste water overflow along with water pollution, integration of the water into urban areas, development of the port area to a recreation area with high water quality (EU Directive 2006/7/EC, Bathing Water Directive), and adaptation to climate change. All of this was done taking into account the limited possibilities for structural measures due to cost and space reasons.

The system

The result of the initial analysis consisted of the localization of the hazard areas and other key points of the sewer system of Aarhus. Based on this analysis, a revision of the sewer, retention and control systems took place. A real-time system including integrated control and warning was built and put into operation. Three sewage treatment plants, nine underground wastewater storage tanks, all combined sewer overflows and rainwater overflows have been networked in real-time. In addition, a local weather radar has been installed, delivering the dynamic boundary conditions for the rain. The MIKE Powered by DHI Software solutions are used enabling a holistic system understanding and guaranteeing complex control.

The result of a WATER 4.0 approach

The EU Bathing Water Directive for river and harbor is met. Due to the holistic planning with the involvement of all stakeholders at an early stage, the infrastructure investment was reduced significantly. The involvement of the public supported the acceptance of the construction work. Combined sewer overflows could be reduced significantly; operational costs were reduced and are transparent.

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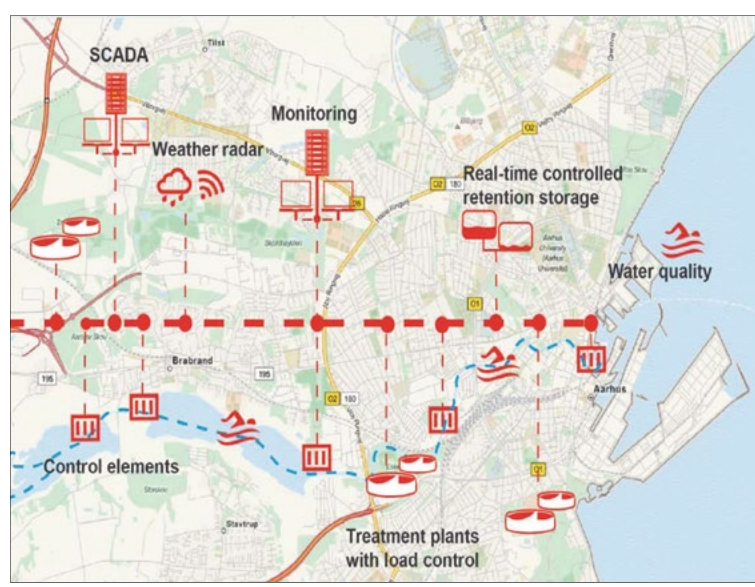

Figure 12: System architecture of the real-time system based on the example of Aarhus

3.4 Controlled waste water with Totally Integrated Automation

Time savings of up to 20% can be made when engineering waste water treatment plants. This requires integrated planning of the entire drive and control technology on the same system platform. This is the conclusion reached by a company that equipped a municipality in Bulgaria with a sewage plant.

Nowadays, huge emphasis is placed on advanced automation in sewage plants. Not only in Germany but also abroad: Dresden-based technology company Biogest International has an export rate of 80%. Its services range from the complete engineering of electrotechnology to commissioning and service. The company's latest project was to provide the entire automation and drive technology equipment for a sewage plant in Provadia. The project in Bulgaria was the first time that Biogest International had used only a single integrated engineering platform for everything from planning and programming to commissioning and maintenance of the entire drive and control technology. To do this, the technology company relies on Totally Integrated Automation (TIA) which is offered by Siemens as a perfectly coordinated complete solution.

Dr. Richard Gruhler, Head of Automation at Biogest International, says, "For us it's a major advantage that in the course of TIA we can implement both the automation technology and also the entire drive technology of our plants using the Integrated Drive Systems approach – from a single source." With Integrated Drive Systems (IDS), Siemens brings together all the power train components that form an efficient and integrated solution: inverters, motors, clutches and gearboxes. Thus, the whole automation system is perfectly coordinated – from the integrated drive portfolio and integration in the automation level, through to integration in life cycle IT and service. This helps increase productivity, reliability and economy and also results in a shorter time-to-market and a shorter time-to-profit.

Figure 13: Optimized engineering in sewage plants – Biogest International GmbH equips a sewage treatment plant in Provadia, Bulgaria

Significant savings in engineering

The crucial advantage of this state-of-the-art drive technology characterized by TIA is the accelerated engineering, from planning to commissioning, that now also includes the entire powertrain. Gruhler explains the difference compared to the past, "Using the Engineering Framework TIA Portal by Siemens, we can now program, parameterize, visualize and analyze everything on one platform, from controller to motor". Gruhler thus quantifies the benefits provided by Integrated Engineering from Siemens, "This significantly reduces the programming and parameterization effort and our time saving on engineering of the whole system is at least 20%."

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3.5. iPERL – digital measurement of water consumption: the example of ENTEGA Darmstadt

Optimized distribution of drinking water, dealing sensitively with this valuable resource and customers' growing expectations which extend as far as smart metering solutions: these are the increasingly demanding challenges faced by water companies. With a total of 40,000 smart water meters, ENTEGA Darmstadt, a service provider for energy and infrastructure, is setting the course for a sustainable solution. "For safety reasons, our 300 shaft meters always have to be read manually by two competent people," explains Martin Grüger, in charge of measurement technology at ENTEGA. "This means high requirements in terms of staff and time and therefore high costs. To reduce the effort and expense, we were looking for modern, cost-effective alternatives. This is how we found iPERL."

Figure 14: Data supplier – iPERL measuring device represents a new dimension in water measurement

iPERL by Sensus (Figure 14) not only enabled ENTEGA to modernize the measuring concept but also allowed the organization to optimize downstream water distribution processes. The EAS-encrypted data communication already integrated in iPERL enables quick and easy remote reading of the consumption data. Water meters can be integrated in the readout and accounting system. The economic consequences are enormous: operating costs due to manual reading can be significantly reduced or even saved completely. Since iPERL was introduced, there is no longer any need for ENTEGA's 300 shafts to be read manually. And, thanks to remote reading, it is no longer necessary to make appointments with thousands of consumers. Grüger says, "This way, we can read 6,000 measuring devices per day instead of 200 water meters. In future, we plan to record the meter readings of our entire supply network within seven days, enabling us to supersede the rolling reading concept."

Service increases customer satisfaction
In addition to optimizing operating costs, iPERL also has a positive effect on service. Grüger says, "Housing associations prefer date-based reading rather than the previous rolling basis for meter reading. We can easily provide this service with iPERL."

Precise measurement technology using even the lowest flow rates
The metrological properties of iPERL are particularly important in Darmstadt. Sensus has equipped this metering device with residual magnetic field technology, enabling a precise reading from the nominal size Q3 4 and above with a starting value of as little as one litre per hour. Both the construction and the contact-free measuring technology also have a positive effect on pressure management, as Martin Grüger confirms, "At some points of our network, the pressure is low and we appreciate being able to minimize the pressure loss with iPERL. This also contributes to cost and energy efficiency."

Conclusion
Sensus ushers in a new generation of metering with iPERL. Following on from the water clock and the water meter, water suppliers can now use "smart" measuring instruments serving as powerful "data providers". The philosophy and the technical concept of iPERL replace conventional water metering with a communicative system that continuously records and communicates data on consumption and operating conditions, thus providing accurate and valuable information.

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4. WATER 4.0 – Outlook

Pursuit of the WATER 4.0 topic within GWP is intended to strengthen and support the German water industry in national and international competition as explained in the preceding sections. WATER 4.0 offers what is presently a unique opportunity to define a progressive and promising approach to addressing the water problems of the future and to pooling the innovations of the companies in the German water industry.

Ideally, unique selling propositions (USP) will be created within existing business opportunities and completely new areas of activity will also emerge. WATER 4.0 offers new prospects and opportunities for collaboration between GWP companies, for example, working in flexible cooperative relationships that can provide the customer with innovative services in virtual joint ventures as part of a cyber-physical water system (CPWS).

The connection of CPWS to Enterprise Resource Planning (ERP) landscapes is conceivable on a medium to long-term basis, and this may fundamentally improve value creation in the water industry, especially for operators. Improvements in the quality of operations/organization management can be expected. The connection of WATER 4.0 to Building Information Modelling (BIM) will also play a significant role. The Federal Government is currently promoting the "upgrading" of Germany's digital infrastructure. The software-based BIM work method for planning, building and operating buildings thrives on the active networking of all stakeholders; this will certainly be important for larger plants such as sewage plants and waterworks.

The conceptual world of WATER 4.0 is relevant both for central applications and also for decentralized, in situ, standalone or isolated solutions of any size; central and decentralized automation structures can be combined. Isolated facilities such as rainwater retention basins or small sewage plants can act as self-learning systems to identify their own incidents, warn of operational risks, request external support if needed or order supplies and spare parts. In addition, WATER 4.0 offers enormous potential for optimizing the management of water infrastructure systems for even more efficient use of resources (e.g. energy, water, staff) with simultaneous improvement in the security of supply and disposal (e.g. minimizing water pollution).

Initial surveys have shown that the key point in networking and automation of the water infrastructure is deemed to be the massive impact on education and training and the skills of all the staff involved in value creation (see also Section 2). In order to meet the new requirements, we need to ask questions: what skills are needed and how do we develop the knowledge of the parties involved? Current skilled and training occupations in the water industry will only partially meet the new requirements; the knowledge imparted is mainly factual and experience-based. In future, both experienced and new staff will need preparation to enable them to deal with the new situation, and education and training will need to focus on the new challenges ahead. New technical equipment and upgrading of the systems will need to be accompanied by education and training that is matched to the new requirements. The existing training occupations in environmental engineering, "Supply engineering specialist" and "Waste water engineering specialist", will need to be adapted; new job descriptions and job profiles will emerge. WATER 4.0 will require the establishment of a new job profile, namely "Aquatronics engineer". In addition to the huge importance of WATER 4.0 for the German and European water market, the transfer of knowledge to and potential business prospects in developing and emerging countries will become increasingly important for many GWP companies and will represent significant opportunities for development. In Africa and Asia especially, it will be possible to jump from WATER 2.0 or 2.1 straight to WATER 4.0; water bills in Uganda, for example, are already being paid via smartphone apps [10]. Especially in rapidly developing countries, it may become possible to network all the water infrastructure entities using modern transmission technologies.

Conclusion – focusing on the future

The route towards WATER 4.0 is an evolutionary process. Existing basic technologies and experience must be adapted to the special needs of the water industry – particularly in the international environment. At the same time, it is necessary to implement innovative solutions and to leverage market potential together at the same time. This will then enable Germany to use WATER 4.0 to improve its international competitiveness and create new, innovative, social infrastructures for work.

German Water Partnership

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