



**Fraunhofer**  
SYSWASSER

FRAUNHOFER WATER SYSTEMS ALLIANCE

**RESEARCH FOR  
FUTURE WATER USAGE**





# WATER – A PRECIOUS RESOURCE

Water covers three quarters of the Earth's surface although only about one percent is available to us as fresh water. But a reliable and sufficient supply of safe water is one of the basic needs of all mankind. In spite of this, 780 million people worldwide still have no access to clean, entirely hygienic water. 1.1 billion lack proper sanitary facilities and the homes of 2.5 billion are not yet connected to a functioning wastewater disposal unit.<sup>1</sup>

Even if we only consider the last 50 years, the amount of water consumed on a global scale has tripled to the present-day figure of almost 4000 km<sup>3</sup> per year. Most of this, 70 percent worldwide and up to 90 percent in some developing countries, is used for irrigation. Although urban development is steadily on the increase, the amount of water needed for industrial purposes accounts for only 20 percent of the whole and private households use up a mere 10 percent. Groundwater covers approx. 20 percent of the global water demand and this percentage is increasing rapidly, although often accompanied by drastic reductions in groundwater levels.<sup>2</sup>

Dramatic increases in water demands can be expected for the near future as the world's population continues to increase. More food and energy will be required and the effects of climate changes, migration trends and urbanization levels will influence water demand more than ever before.

In spite of these evident facts, water is not treated as a precious resource and is often wasted in a multitude of ways. Even in developed countries, up to 25 percent of valuable drinking water is lost regularly, due solely to leaks in pipelines. This figure sometimes crosses the 50 percent mark in emerging and developing countries. Moreover, water infrastructure systems in industrialized countries are based on technologies which are more than 100 years old. They are inflexible and designed to use water only once. Indeed, wasting water is often an inherent part of old water infrastructure systems as this is the only way they can function trouble-free. Because conventional water infrastructure systems do not take aspects of sustainability into consideration, they are, by today's standards, largely unsuitable as models for emerging and developing countries, not only due to the high costs involved.

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<sup>1</sup> The Millennium Development Goals Report 2008, United Nations, New York, 2008

<sup>2</sup> Water in a Changing World, The United Nations World Water Development Report 3, United Nations, New York, 2009



## MOTIVATION, MISSION, GOALS AND RANGE OF SERVICES

Innovative technologies and holistic technical systems solutions are the best methods to meet the challenges facing the 21<sup>st</sup> century. This is why eleven Fraunhofer Institutes formed the Fraunhofer Water Systems Alliance in 2007 and pooled their skills to research and develop innovative water process technologies. The Alliance focuses mainly on transferring sustainable systems solutions for water recovery, infrastructure and wastewater purification to practice-oriented applications without neglecting the social, economic and ecological consequences involved. At the same time, water – as a resource – is systematically cross-linked to the fields of energy, waste management and agriculture where it is also highly relevant. In this way, the Alliance and its participating Institutes would like to play an active role in meeting one of the United Nations' Millennium Development Goals viz. to half the percentage of the world's population which has no reliable access to safe drinking water and appropriate sanitary facilities.

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### Range of services

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The innovations developed by the Fraunhofer Water Systems Alliance now cover the entire water cycle. They start with catchment areas, continue on to water distribution systems and end with methods for wastewater treatment. Socio-economic studies, status analyses, demand forecasts and financing concepts also belong to the Alliance's portfolio of services. Thanks to the wide range of expertise available in the

participating institutes and the researchers' interdisciplinary approach, the Fraunhofer Water Systems Alliance can develop innovative technical solutions, complex water management systems solutions and innovative urban water infrastructure concepts for nearly all topics connected with water management.

In accordance with the Fraunhofer Gesellschaft's overall mission, the services offered by the Fraunhofer Water Systems Alliance focus mainly on the research and development of innovative technologies followed by their application in pilot plants. The Alliance's range of services includes developing new, innovative and highly efficient process technologies (together with the accompanying measurement, steering and control technologies) for treating water and wastewater as well as the development of technologies for operating, monitoring and renovating water distribution networks and sewage networks.

The Alliance's portfolio of services includes implementing and integrating progressive technological components into holistic and sustainable master plans, building entire water infrastructure systems and adapting these to specific local and regional conditions.

Innovative water technologies and water infrastructure systems are tested in demonstration or pilot plants and validated in practical applications.

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# WATER UTILIZATION

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## Drinking water

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Water forms the basis of all life on earth and is the foremost primary basic foodstuff for all kinds of civilization. This is why very high standards are set for the quality of drinking water. It must not damage people's health so that strict regulations must be adhered to as regards chemical components and microbial composition. It must be free of germs and chemical substances which can cause illness. It should also be colourless, clear, cool, odorless and good to taste.

The main purpose of water infrastructure systems is to treat raw water and distribute good quality water to municipal and industrial areas. 95 percent of Germany's drinking water comes from central water suppliers and 70 percent is recovered from surface water or bank filtration. The water is treated before consumption mainly to remove particles, iron and manganese but also to make it soft and free of germs. Industrialized nations often waste good drinking water. In Germany, approx. 120 liters of water are consumed per person and day. Public water infrastructure systems distribute nothing but drinking water although only about 2 liters of actual drinking water quality is really needed per person and day. Drinking water or water of a similar quality is used for cooking, making drinks, personal hygiene, cleaning dishes and washing clothes. However, large quantities are also used for tasks which could be carried out with water of a lesser quality viz. flushing toilets, cleaning buildings or watering gardens.

It would be relatively easy for each household to save water by installing appropriate faucets and toilets. Vacuum and pressure systems are excellent alternatives to conventional gravity sewers. For example, flushing toilets could be replaced by vacuum toilets, already commonly in use on airplanes, ships and trains and even in some Scandinavian households.

Decentralized or semi-decentralized wastewater purification systems also help save the costs which are currently incurred by maintenance work on central sewage systems.

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## Process water

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It is simply not necessary to use water of drinking quality for all purposes in private households and industrial plants. In the industrial sector in particular, untreated raw water, rainwater or treated greywater or wastewater would be sufficient to fulfill many purposes. What kind of pre-treatment is needed depends on to the subsequent use of the treated water. For example, if recycled water is to be used for cleaning or cooling, the quality need not be as high as it must for – say – washing clothes. However, water used for agricultural purposes and for bathing must be absolutely hygienic with no traces of contamination which could damage health by accumulating in human organisms. On the other hand, if the treated water is to be used to irrigate fields, it is not necessary to remove nitrogen and phosphor entirely because their presence saves farmers costs for precisely these mineral fertilizers.

Generally speaking however, if water is to be re-used it is necessary to remove all solids and fats beforehand with appropriate technologies. Organic carbon (COD, BOD) must always be extracted from organically polluted wastewater. The best way to do this is to treat it biologically and strongly polluted wastewater is best treated anaerobically. Depending on the subsequent use of the water, it is sometimes necessary to remove the remaining COD as well e.g. in an aerobic biological process.

Innovative, adapted technologies for recovering, storing and re-using wastewater residual heat are also becoming more and more popular especially as the costs for energy are continuing to rise.



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## Irrigation

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Contrary to most of the rest of the inhabited world, irrigation does not yet play an important role in Germany's agriculture. However, this picture will definitely change in the near future as the quantities of water needed for agriculture will increase steadily on a global basis in our attempts to feed the world's ever-increasing population. The conversion of semi-arid areas into fields, higher water consumption for higher yields per hectare and the cultivation of so-called energy plants will aggravate this problem even further so that the need for irrigation technologies for agriculture in Germany will continue to grow. Climate changes in Middle Europe, characterized by heavier rainfall and longer periods of drought, will make irrigation a subject which cannot be ignored.

Many regions are faced with the dilemma of deciding whether scarce water resources should be used as drinking water or for agricultural purposes. To solve this problem, the Alliances' experts are working on water-saving irrigation technologies and developing concepts for re-using water to irrigate fields.

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## Rainwater

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The annual average of Germany's rainfall is enough to replenish its ground and surface water thus covering the country's water requirements. The only direct uses of rainwater at present are for storage in reservoirs as water supplies or for use as a means of transport in mixed channel systems. But rainwater can become a problem, especially in connection with torrential rains or flood control. Storage technologies for specific purposes are still a thing of the future although some countries do have so-called "rainwater retention basins" to store rainwater for discharge into surface waters as wastewater.

Rainwater is already being used in private households for many purposes where drinking water quality is not required e.g. watering gardens or flushing toilets. Indeed, rainwater has substantial advantages for many uses as it is only slightly contaminated and does not contain carbonates or other minerals which is the case for ground and surface water. It therefore makes good sense to catch and re-use rainwater even in regions with sufficient water supplies. Rainwater works just as well as drinking water e.g. for airconditioning buildings, for use in automated firefighting systems with high-pressure fumigation and for operating washing machines.

Rainwater can be retained and mixed with drinking water for softening using adapted reservoir technologies with relevant filtration and treatment technologies. It is also easy to turn rainwater into drinking water and this is already a favorite method for obtaining water in many regions. Drinking water contains natural components which not only make it safe for consumption but are also important for human nutrition e.g. calcium, magnesium, sodium, potassium, hydrocarbonate, sulfate and chloride. These have to be added to rainwater as salts before it can be used as drinking water. The same holds true for water generated from atmospheric humidity.

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# WATER TREATMENT

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The Fraunhofer Water Systems Alliance has several different technologies at various stages of development at its disposal for treating water and purifying industrial wastewater, either for re-use in the production process (wastewater recycling) or for direct discharge. These technologies were developed in separate Fraunhofer institutes but are used by the entire Alliance as technology modules for developing both optimized systems solutions and individual solutions. Together with its valuable past experience on water infrastructures, systems control, measurement technologies, automation and resource management, these new technologies enable the Alliance to develop skillful master plans and put these into action. For this purpose, the Alliance uses conventional methods as well as innovative future-oriented technology modules, some of which are described below.

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## Membrane separation technologies

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The services offered by the Fraunhofer Water Systems Alliance cover the entire spectrum of membrane technologies from micro and nanofiltration right through to reverse osmosis.

### Microsieves

Microsieves are highly permeable and highly selective. Due to their metallic properties, e.g. high mechanical strength, large filter areas can be built into the smallest spaces. The advantages of these parameters are currently being developed further in various systems and the microsieves are being tested in diverse practical applications.

### Ceramic membranes

Ceramic membranes are also characterized by high selectivity. Various different ceramic materials can be used to form separating layers with pore sizes ranging from several  $\mu\text{m}$  down to 0.9 nm depending on the intended application. The Alliance uses technically relevant membranes with separation surfaces of up to 0.25 m<sup>2</sup> per element in multi-channel pipes (7–19 channels) up to 1.2 m in length. These can be integrated in compact modules with filter surfaces of up to 25 m<sup>2</sup>.

The rotating movements of ceramic disk membranes in rotating disk filters prevent the formation of interfering surface layers with less energy requirements than other methods.

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## Ultrasonics

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### Sewage sludge disintegration

The Alliance has been successful in its attempts to improve the efficiency of anaerobic sewage sludge treatment by using ultrasound to disintegrate parts of the sludge.

#### Ultrasonic treatment

- speeds up the decomposition of organic substances,
- increases biogas production,
- improves the dewatering of residual sludges,
- reduces the need for additives.

All these advantages lead to significant reductions in operating costs. Current studies are under way to deal with problematic topics such as floating and bulking sludge, foam formation during digestion and the supply of internal carbon sources for denitrification.

### Cleaning membranes with ultrasonic sound

A combination of back-flushing and exposure to ultrasonic sound with high frequencies has proved to be especially suitable for cleaning membranes in water treatment plants. This method obtains excellent cleaning results with low energy consumption.



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### Electrophysical precipitation

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Electrophysical precipitation dissolves ions and hydroxides in water out of a sacrificial anode made of iron or aluminium. The ions form hydroxides which facilitate the separation of extremely small solid particles, often found in stable emulsions and suspensions, by means of adsorption, precipitation or flocculation. At the same time, water is cleaved on the surface of the electrodes into highly-reactive radicals which create numerous secondary reactions with water components leading to a decrease in chemical oxygen demand (COD). These oxidative processes can also be used for disinfecting.

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### Evaporation technologies

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Thermal processes are used to desalinate and concentrate seawater, brackish water and industrial process water. In this field, the Fraunhofer Water Systems Alliance is concentrating on optimizing processes which make use of available heat from industrial sources or which can be operated on energy from renewable sources such as e.g. low temperature solar systems.

#### Thermal solar membrane distillation

The Alliance is developing autonomous desalination systems which run entirely on solar energy. The energy for the desalination process is provided by thermal solar collectors and auxiliary units, such as recirculation pumps and valves, run on photovoltaic power. Besides exploiting solar energy, the Alliance is also working on utilizing wasteheat from industrial processes or from the cogeneration of power and heat.

### Solar desalination of seawater with a gravitation-supported vacuum evaporation plant

The process of gravitation-supported vacuum evaporation uses heat efficiently at low temperatures and is a simple and robust alternative to conventional methods. The vacuum is created and maintained by gravitation which is why vacuum or jet pumps are not required. The energy requirements are low so that standard solar thermal collectors are sufficient for providing the necessary thermal energy and a small photovoltaic module for running pumps and process control.

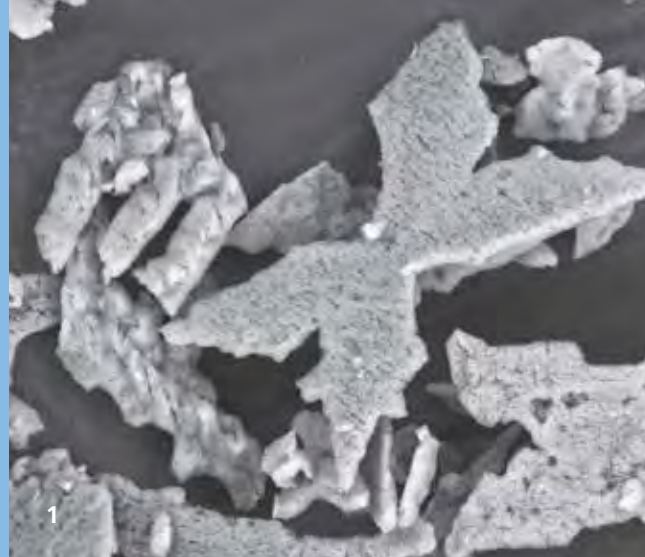
#### Generating drinking water from humidity

An alternative way to produce drinking water which does not require access to surface or groundwater is to generate water from humidity. This is a technology which can be operated solely on regenerative energy sources. To begin with, atmospheric humidity is absorbed from a highly concentrated salt solution. The bound water is then distilled from the circulating salt solution. The distilling plant is designed as a gravitation-supported vacuum evaporator to make it run at the lowest possible evaporation temperatures.

The process is easy to set up, cost-efficient and independent of all kinds of infrastructure so that it is highly suitable for decentralized water generation.

1 *The rotating disk filter is a dynamic filter with a pile of ceramic membrane disks. Source: Fraunhofer IGB.*

2 *Electrophysical precipitation of impurities. Source: Fraunhofer IGB.*



### Oxidation of pollutants and germs

The Fraunhofer Water Systems Alliance has developed various oxidation processes for sterilizing water and removing persistent or toxic pollutants as well as trace contamination (also called micropollutants) safely and effectively e.g. from the process waters of chemical and pharmaceutical industries.

#### Electrochemical oxidation

The process of electrochemical oxidation with diamond-coated electrodes is based on the generation of strong oxidizing agents directly in water. Water electrolysis is suppressed which leads to the production of e.g. ozone, peroxide and hydroxyl radicals with almost 100 percent current efficiency on the diamond-coated electrodes. These eliminate pollutants and germs efficiently so that it is not necessary to add further chemicals. The sterilizing process is easy to steer by regulating the low voltage or current density.

#### Ozonization

The Fraunhofer Water Systems Alliance has ozone generators which produce an oxygen-ozone composite with an ozone concentration which is two to three times above the maximum achieved with conventional electrochemical or gas discharge ozone generators. Less apparatus is involved and energy demands are significantly lower when compared with conventional ozone generators. Differing concentrations of pollutants pose no problem as an integrated TOC measuring/control system makes the system energy-efficient and ensures continuous operation.

### UV oxidation

In the influence of a microwave energy field, the gas filling a variably shaped glass case is turned into plasma which emits UV light in desired wavelengths depending on the choice of gas or gas mixture in the case. A laminar homogeneous emission of light reduces the formation of biofilms or surface layers. Maintenance is easy as the active electrotechnical components are located outside those parts of the apparatus which are in contact with the medium giving the apparatus a long operating life. The system is reliable and economic as it can sterilize even high volume streams of water due to a regular and normative radiation of high light power.

Modified and equipped with the proper gases to emit the required light spectra, the system can even be used to oxidize persistent organic compounds in oxidation processes for treating water.

- 1 *Magnesium ammonium phosphate (MAP) crystals recycled from nutrients. Source: Fraunhofer IGB*
- 2 *MAP from filtered wastewater after anaerobic biological treatment. Source: Fraunhofer IGB*
- 3 *Wastewater treatment plant in Schwerzen. High-load digestion is also profitable in smaller plants (10,000 PE). Source: Fraunhofer IGB*

TOC total organic carbon  
PE population equivalent





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## Biological treatment

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### Optimizing wastewater treatment plants

Over the years, the Fraunhofer Water Systems Alliance has gained vast experience in developing and optimizing purification processes in both municipal and industrial wastewater treatment plants. Systematic analysis and detailed measurements have helped optimize processes such as nitrification and denitrification for many wastewater treatment plants and have increased biogas yield thus improving the entire operation significantly. This method saves costs otherwise needed for reconstruction and building alterations.

### High-load digestion:

#### Less sewage sludge, more energy

In comparison with conventional digestion processes, high-load digestion excels through

- shorter residence times (5–7 days instead of 20),
- higher organic volume load (8–10 kg/m<sup>3</sup>×d instead of 1–2),
- improved degree of degradation (up to 70 percent of organic dry matter),
- less foam formation,
- increase in biogas yield,
- improved drainage of residual sludge,
- smaller amounts of sludge,
- cost savings for sludge disposal.

The high-load process can also be used to treat other organic substrates such as agricultural biowaste or organic municipal waste. A combination of high-load digestion with microfiltration using rotating disk filters leads to additional increases in turnover and achievable quantities of biogas. The filtrate is free of particles but rich in nutrients which can be recovered for use as fertilizers.

### Anaerobic biological purification of highly polluted wastewater

Anaerobic wastewater purification processes are especially suitable for treating wastewater which is highly polluted with organics – often to be found, for example, in the food and beverages industries, in slaughterhouses and at airports (de-icing agents).

Organic carbon compounds are turned into biogas in a bioreactor. Microorganisms are held back with microfilters to increase the production rate. The filtrated water is hygienic and safe so that it can be used to irrigate agricultural areas.

### Recycling nutrients

Besides organic load, wastewater also contains large amounts of nutrients such as nitrogen, phosphor, magnesium, potassium and sulfur. In conventional wastewater purification plants, it takes considerable efforts to eliminate these.

The Fraunhofer Water Systems Alliance is developing and optimizing various technologies to recover and recycle these nutrients:

- precipitation of magnesium ammonium phosphate (MAP, struvite) and potassium salts
- concentration of ammonium with an ion exchanger
- stripping ammoniac and precipitating ammonium salts in acid flue gas scrubbers.

The potential of these methods and products as profitable alternatives to conventional fertilizer production methods is extremely high.

### Energy-efficient and self-sufficient water treatment

One of the specialities of the structure and content of the Fraunhofer Water Systems Alliance's work is its focus on combining efficient energy systems with efficient water infrastructure systems.

The Alliance works mainly on using the physical and chemical energy found in water and on developing water infrastructure systems which are more energy-efficient or even provide their own energy.

Together with the production of biogas, phase change slurry and photovoltaic-run reverse osmosis are good examples for successful developments in these fields.

Components of measurement technologies which are self-sufficient as far as energy is concerned also play a major part in modern water management systems.

#### Phase change slurry

Part of the thermal energy found in wastewater is transferred into a long-term stable mechanical-thermal resilient emulsion with drops of paraffin in water in order to make use of the high energy densities which result from the paraffin's phase transition from solid to fluid (200 kJ/kg melting enthalpy). As the paraffin is blended into a suspension (phase change slurry, PCS), the material has the same advantages as fluid mediums e.g. pumpability and high heat performance. Various paraffins (with different chain lengths) can be used to find customized cooling mediums and/or appropriate cold storage applications for defined temperature ranges. The heat stored in the PCS can be released on demand through the heat pump and recycled into heating or warm water systems.

### Energy-efficient and energy self-sufficient photovoltaic systems

Energy-efficient and energy self-sufficient systems are especially suitable for arid and semi-arid regions where there is an abundance of solar radiation but a lack of desalination plants and water pump systems. For this reason, the Fraunhofer Water Systems Alliance has developed plants for desalinating seawater which work on the principal of reverse osmosis and are powered e.g. by photovoltaic modules (PV). The main focus is on systems where the PV generator is coupled directly to the desalination process. Efficient concepts for energy recovery will continue to play a major role in these developments.

Water infrastructure systems have a lot to contribute to intelligent load management because a number of their components permits energy to be stored and loads to be spread over time. This compensates for the energy fluctuations which affect networks due to increasing proportions of energy from regenerative sources and it also minimizes capacities required for storing electric energy. This results in optimized water and energy supply networks with a very high percentage of power generators running on regenerative energy.

<sup>1</sup> A look into the water house at Knittlingen.

Source: Fraunhofer IGB



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# WATER MANAGEMENT

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## Process measurement technology

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Measurement technology is an important field and a wide range of problems faces the operators of water supply and wastewater treatment plants in this connection. One major advantage of the Fraunhofer Water Systems Alliance is that its member Institutes specialize extensively in fields pertaining to measurement technology starting with biosensorics, on to microsystem technologies and nanotechnology, right up to the implementation of conventional physical and chemical measurement methods. In our experience, it is not possible to manage the processes of water plants in an optimum fashion without an efficient in situ diagnosis of the complex water-chemical and biological processes involved.

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## The automation of plants

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Plants for water supply and wastewater treatment are characterized by complex forms of interdependency. It is no longer possible to run a plant efficiently without using modern control technologies. The Fraunhofer Water Systems Alliance has solutions not only for already existing plants but also for those in the planning stage. Solutions range from pump control with optimum energy balance to decentralized automation for plants spread over several buildings. The Alliance's innovative applications can easily be linked up with existing process control systems.

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## Process simulation and optimization

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It is not easy to typify the complex control and regulation of water management processes, plants and treatment methods. Tasks to be solved range from the model-supported water management of transregional storage systems and widely spread water supply networks to controlling the growth of biocenosis in modern wastewater treatment plants. They include the extremely non-linear controlling of chemical titration methods and the robust inflow and outflow regulations for decentralized water supply and wastewater treatment plants. The Alliance is dedicated to finding the best solution for each specific task on hand and designs parameters to meet each customer's individual requirements. In a first step, all available technical data is monitored closely which forms the basis for optimizing systems and defining specific goals. The Alliance's aim is to find the most efficient and sustainable methods for managing not only water as a raw material but also the energy needed to supply this valuable resource. Intelligent IT solutions provide practical solutions for improving the supply of water to all users. These integrate all the information available on these highly complex systems in e.g. simulation models and help decision-makers find sound solutions for planning infrastructure, optimizing water supply and energy consumption, and managing extremes cases such as drought or flooding. Calculating scenarios helps experts to estimate the consequences of factors such as climate change, altered land use, economic aspects and population growth, and tests the efficiency of potential measures.

<sup>1</sup> *Out-of-date wastewater infrastructure in Mongolia.*

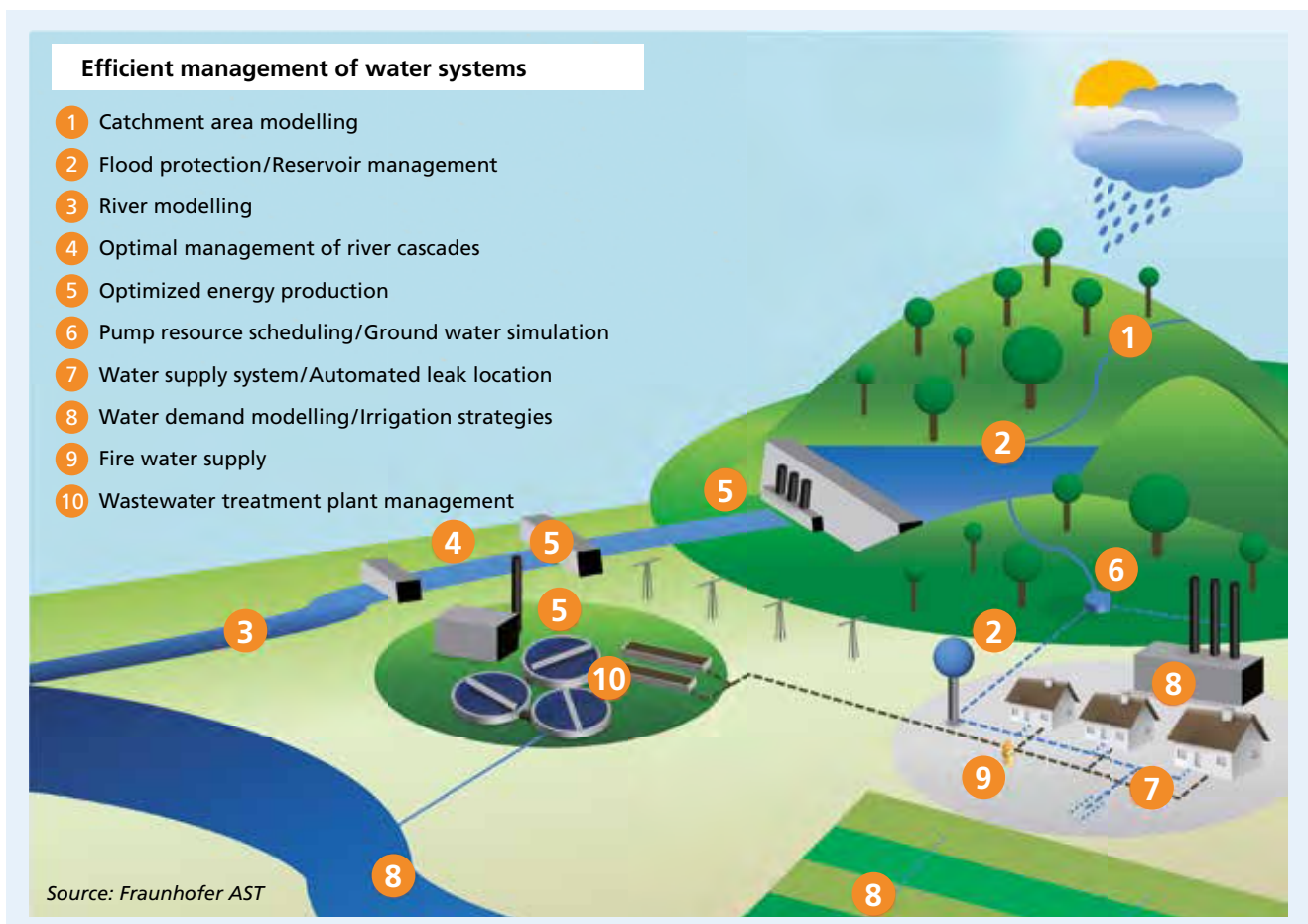
*Source: Fraunhofer AST*



Comprehensive basic know-how is essential, not only for managing water supply and wastewater treatment systems but also for planning new systems and extending canals, sewer systems, reservoirs, water treatment plants, supply networks and wastewater treatment plants. The Fraunhofer Water Systems Alliance offers its customers a comprehensive range of products for modeling all systems belonging to the water cycle beginning with catchment areas right through to wastewater treatment plants. These models can help investors to make the right decisions and are also designed to meet the requirements for automation.

This makes it possible to solve such complex problems as e.g.

- optimum water distribution and supply integrating all available sources of water (surface water, groundwater, treated wastewater),
- optimized multicriteria control of reservoirs (water supply, flood prevention) and
- finding and minimizing leakages in water networks.



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# WATER MANAGEMENT

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## SUSTAINABLE CONCEPT DESIGN AND PLANNING SERVICES

In order to design and plan future-oriented water infrastructure systems, the Fraunhofer Water Systems Alliance is developing integrated urban concepts, testing the sustainability and safety of infrastructure systems while examining whether they can be adapted to cope with changes in climate and population, carrying out market research and devising marketing strategies. Potential customers are not only public bodies such as municipal authorities, regional corporations and regional and provincial governments but also groups of investors involved in large construction schemes.

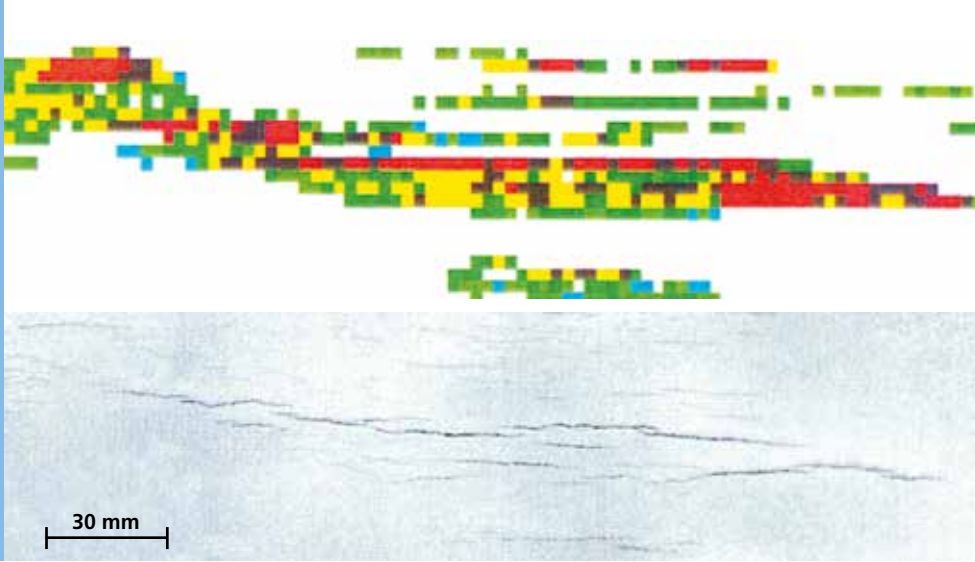
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### **Sustainable, regenerative water infrastructures**

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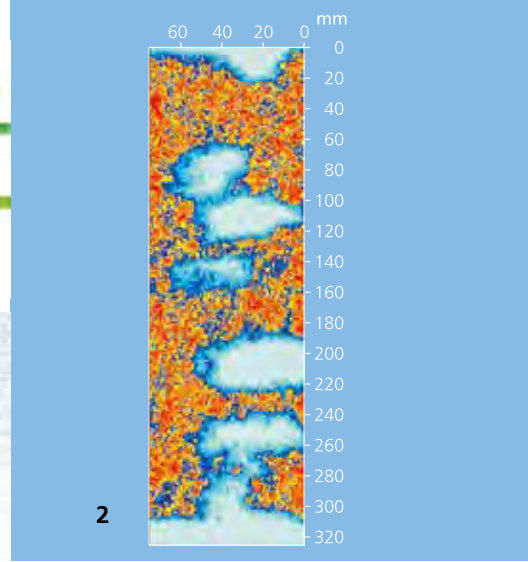
Nowadays, cities often make dynamic changes on top of the earth but neglect new developments down below. Conventional networks and units for water supply and wastewater disposal incur huge costs for maintenance, repair and renovation but are not at all flexible when it comes to dealing with changes in conditions due to climate change, demographic fluctuations and new environmental challenges. Most people agree that water supply and wastewater disposal are extremely important not only for each individual human being but also for each country's national economy. This is why it is important to find innovative sustainable alternatives for out-of-date systems. Small-scale systems with modular components can be adapted to work with modern technologies. These are often more flexible than conventional units operating on the same level and can easily be adapted to cope with changes in conditions. The Alliance is convinced that new concepts based on these systems are the best way to set up sustainable water supply and wastewater disposal systems.

Sustainability assessments are carried out to help decision-makers decide whether an existing water management system can be made fit for the future and which management strategy is worth following. Sustainability analyses reveal which parts of a plant need to be modernized and recommend radical changes in concepts when this is the better solution for existing water infrastructure systems. They are also essential for deciding which solution is best for each specific situation and aim at describing all aspects of direct and indirect effects of water management systems. From an ecological point of view, it is important to consider the element input in waters as well as the efficient use and recycling of resources. For economic assessments, the comparatively long life of important components (e.g. distribution and sewage networks) is a major aspect. Comprehensive assessments should include e.g. whether changing conditions can be taken into consideration. Social and technical aspects (acceptance, convenience and security) are also highly relevant and should not be neglected.



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30 mm



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### Integrated urban structures (for water, energy and waste)

It is vital for both society and the economy that our water infrastructure systems are sustainable and efficient. However, dynamic change should not mean that out-of-date structures are extended in a chaotic manner as this could harm both the climate and the environment as well as the longterm cost-effective running of the systems. It is worthwhile to take a holistic look at various areas of urban infrastructure as these are often closely interlinked. Energy can be generated from wastewater and waste, and is itself needed to supply water and treat wastewater. Components of water supply and wastewater disposal should not be considered separately but together with transport routes in order to draw up an integrated master plan for more efficient infrastructure systems. On the other hand, the differentiated development of single components within an overall urban concept will provide further flexibility in the future and help make water supply and wastewater disposal systems safer and more sustainable.

### Security and safety aspects for water infrastructures

Security is of existential importance for modern industrial companies when it comes to securing water supplies and safeguarding water management infrastructures. The security services offered by the Fraunhofer Water Systems Alliance include hazard analyses and concepts for preventing, detecting and resisting acts of aggression as well as protective measures to keep the effects of natural catastrophes (such as floods, droughts and earthquakes) to a minimum and to deal efficiently with the after-effects. Because such topics are often politically charged, this research field is subject to special confidentiality criteria and requirements. The Fraunhofer Water Systems Alliance is pledged to observe these and ensures stringent compliance in its daily work.

The direct prevention methods developed and adapted by the Fraunhofer Water Systems Alliance are systems for testing and monitoring the condition of pipeline systems, reservoirs and buildings. To date, ultrasound, eddy current, thermography and microwave methods have been developed to detect cracks and corrosion in pipes and reservoirs. Methods and combinations of methods are adapted to test the different kinds of material in use such as metal, plastic and concrete, and to design specific sensors and test systems. Sensors can be moved across the test area from outside or be inserted into pigs for internal examinations. Electromagnetic ultrasonic sensors generate guided waves for a long range inspection of pipe segments buried under the earth. Only part of the pipe needs to be accessible for sensor application.

Buildings made of stone or concrete can be inspected and monitored at regular time intervals e.g. with microwave or NMR methods to characterize moisture. Thermographic and ultrasound methods detect cracks and inhomogeneity in structures, and electromagnetic technologies localize steel reinforcement and characterize its current condition. The Fraunhofer Water Systems Alliance also offers special test services by combining new developments with conventional systems already on the market.

The Alliance's totally non-destructive and almost non-destructive testing methods help operators to provide their customers with a reliable high-quality supply of that valuable dwindling resource: water.

1 Above: Ultrasound display; below: photo of inner crack. Source: Fraunhofer IZFP.

2 Inner corrosion localized by air-coupled ultrasound. Source: Fraunhofer IZFP.

### Remediation support for contaminated groundwater

Groundwater is the most important source of water in many regions of the world. However, it is often overused and contaminated due to water shortages and the non-sustainable industrial and agricultural structures prevailing in the region. Decision-support systems based on models can be a valuable tool for decision-makers aiming at using aquifers in a sustainable fashion. Long-term strategies for withdrawing water and renovating systems can be simulated and optimized. This is the best way to choose the appropriate remediation method which should be efficient, cost-effective and fulfill legal requirements. The Fraunhofer Water Systems Alliance has ample experience both at home and abroad in modeling complex ground and surface systems so that it can set up support systems for decision-makers to fit every specific requirement.

### Flood protection

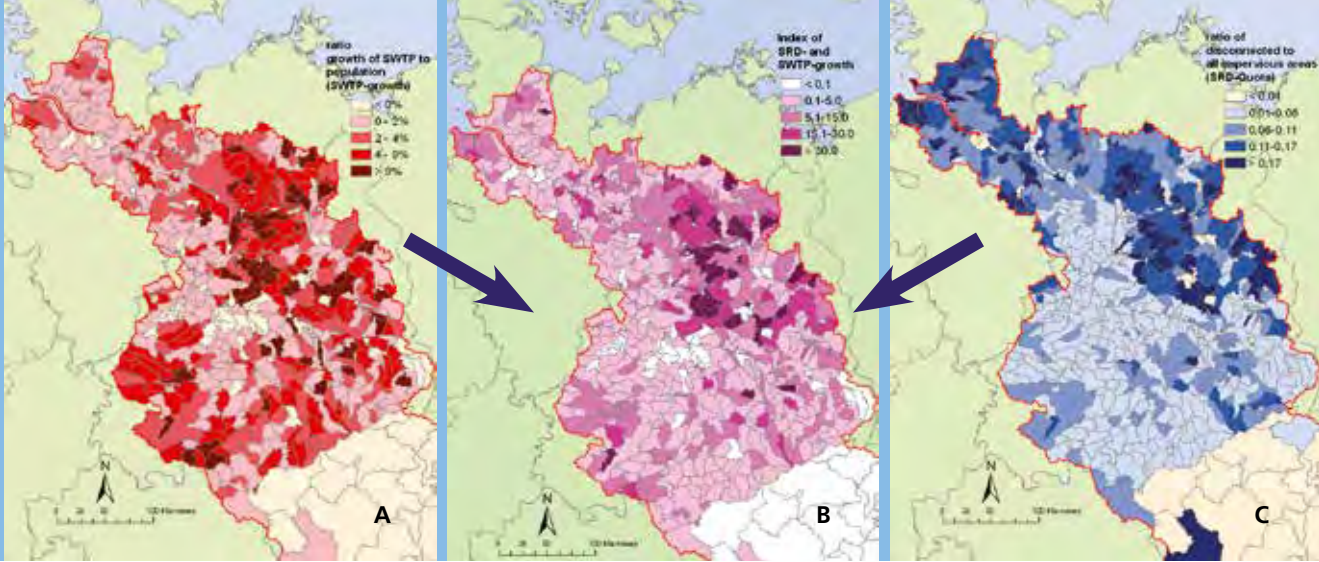
Flooding caused by heavy local rainfalls in urban areas often results in severe damages. For this reason, rules and regulations on national and European levels are currently being laid down for flood protection depending on the use and infrastructure of areas in an attempt to keep costs for damages to a minimum on a longterm basis. This means that the local authorities responsible for disposing of wastewater will have to test the effectiveness of their drainage systems and estimate failure rates and potential damages as exactly as possible.

### Analyzing water infrastructures and adapting these to climate and population changes

The operators of water infrastructure systems are often confronted with conditions which are by no means static. Changes in climate lead to unusual rainfalls and to changes in the distribution of precipitation. The amount of water required is changing because populations are dwindling and aging fast resulting in changes in behavior patterns for water use. For wastewater disposal, this causes changes not only in the amount of wastewater produced but also in its composition and loads. New environmental rules, e.g. for the use of rainwater or elimination of additional pollutants, also mean that new treatment technologies and approaches must be developed and applied.

Existing and future water infrastructure concepts will have to be tested and evaluated for their ability to cope with such changes in marginal conditions. This is the only way to find suitable concepts for the conditions prevailing in specific local regions as these can be extremely different.





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### Market analysis and marketing measures

New challenges are continuing to crop up and must be met to guarantee a reliable, efficient, high-quality water supply together with effective wastewater disposal for the good of the general public. When systems are being adapted and new concepts planned, it is not enough to concentrate exclusively on new technological components. Market analyses and marketing measures are excellent tools for the planning phase because they identify the advantages and disadvantages of single components and entire systems.

Interviews with experts and user surveys are good methods for detecting trends and testing the acceptance of new systems. The Fraunhofer Water Systems Alliance runs pilot projects and carries out market-oriented pilot studies to test and analyze the application of new technologies under realistic conditions. This is the best way to optimize detailed aspects of promising solutions and guarantees that these innovative technologies will run successfully on a longterm basis.

1 The focal points of implementing more decentralised wastewater management in the German Elbe river basin. The common tendency (B) results from the multiplicative connection of surface runoff disconnection (SRD) (A) and sanitary waste treatment plant (SWTP) growth (C). Source: Fraunhofer ISI



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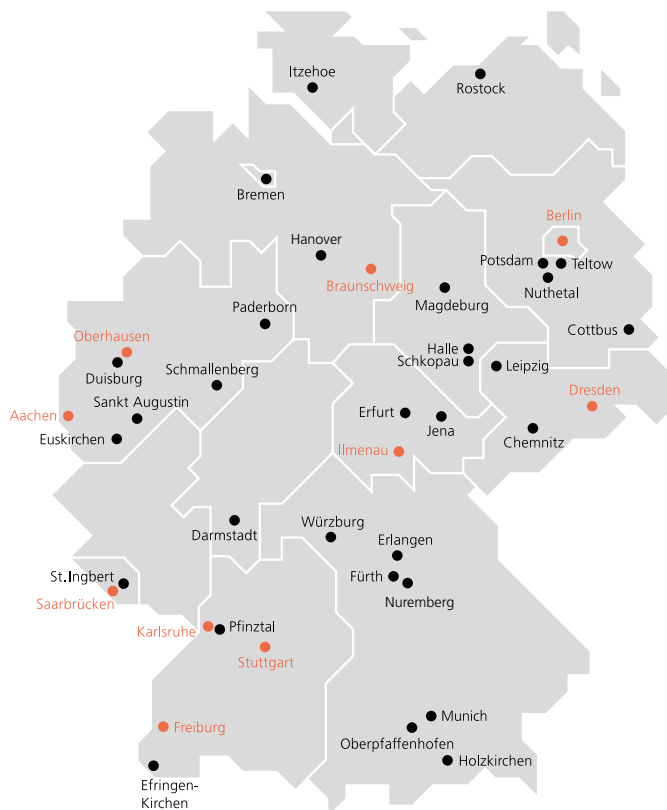
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