Water and Wastewater Companies for Climate Mitigation

WaCCliM

The Roadmap to Low Carbon Urban Water Utilities

Annexes

The Water and Wastewater Companies for Climate Mitigation (WaCCliM) project, is a joint initiative between the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and the International Water Association (IWA). This project is part of the International Climate Initiative (IKI). The German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) supports this initiative on the basis of a decision adopted by the German Bundestag.

On behalf of:

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

of the Federal Republic of Germany

Implemented by:

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

IWA the international water association

Annex IV:

Overview of Opportunities & Solutions to lower the GHG footprint of Urban Water Utilities

This annex introduces the opportunities section of the Climate Smart Water platform [ClimateSmartWater.org] which has been developed under the WaCCliM project. This platform offers utilities free access to resources that may support them through this roadmap, on their journey towards a low carbon, low energy future.

The below sections presents an overview of potential solutions to lower GHG emissions while optimizing the water and energy efficiency across various stages of the Urban Water Cycle, as highlighted in section 3.1 of this book. This section also highlights the interconnectedness between different stages of the urban water cycle, by identify how one stage is impacted and also impacts other stages of the water cycle. Under each stage of the water cycle, several areas of improvements are identified, that may lead to a reduction in GHG emissions. Under each area of improvement specific solutions are described along with the points to consider while implementing and their benefits.

The information in this annex captures the solutions inventory as shown on the knowledge platform as of December 2018. It is recommended to go to the online portal to explore resources associated to these solutions and potential new solutions that might have been added since.

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1. Water Abstraction

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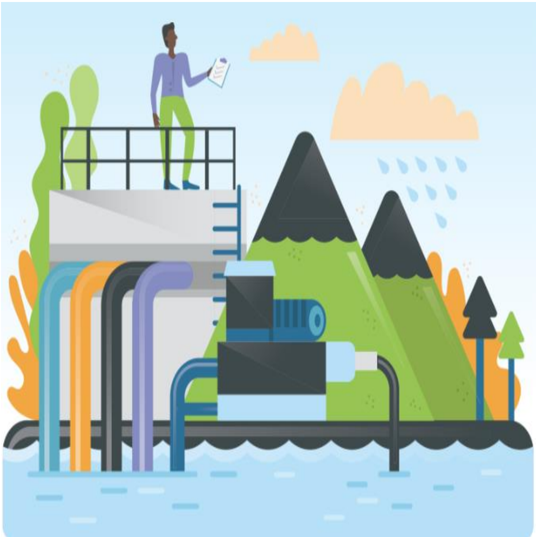
Drinking Water Treatment The distance and elevation of the drinking water treatment facilities will dictate how much energy is needed to pump the water from the source to the treatment.

Drinking Water Distribution Water loss in the distribution systems increases the volume of water abstracted and its associated energy requirements.

End users The volume of water abstraction is driven by the demand of end users and how efficient they are in their water use.



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Drinking Water Treatment The quality of the water abstracted defines the treatment required; hence the energy required.

End users End users could be inclined to reduce their water usage if they knew the water came from a limited source (water scarcity

Depending on the type, distance, and elevation of a city's water source(s), GHG emissions from the drinking water abstraction stage are typically generated by energy consumption for the pumping of water from the source to the treatment facility. In most cases, the GHG emissions are indirect emissions from importing grid electricity to run pumps; however, there can also be direct GHG emissions (methane, nitrous oxide, and carbon dioxide) from fuel consumption/combustion for powering the pump engines or equipment via emergency generators. If the source is surface water and above the elevation of the city, it is possible that the water can be transported to treatment using gravity instead of pumps, in which case there would be no additional GHG emissions. In order to optimize the water abstraction stage, some of the potential solutions that can be implemented are highlighted below.

1.1 Pump efficiency / optimization

Pumping efficiency and optimization can be tackled mainly by improving the electro-mechanical efficiency of individual pumps, and by either optimizing how an individual pump or pumping station is operated, or optimizing how multiple pumping stations pumping into the same system in parallel are automatically operated. In general, the solutions below can be applied at either level. Ultimately the idea is to maximize efficiency and reduce the energy consumption of the pumping station(s) in terms of kWh per m^3 pumped and in terms of standardized energy consumption, which accounts for elevation and is in units of $kWh/m^3/100$ m.

1.1.1 Evaluation of the pump impeller degradation

Description

An optimal control of the state of the mobile parts inside the pump as impeller can prevent some breakdown in the pumps, and also a good maintenance of these parts keep the pumping efficiency in high levels.

Points to Consider

Can help maintain best efficiency points and optimal pump performance which can help minimize energy consumption and costs

1.1.2 Replacement of Pumps

Description

Replacement of old pumps and motors helps to increase the overall efficiency of the pumping systems. New high efficiency electrical motors and pumps are available for any type of application: from chemical pumps to big water centrifugal pumps.

Points to Consider

Can potentially represent high capital costs, financing, payback period; cost-benefit based upon capital costs, increased energy efficiency, and energy savings, master planning, potential future changes to the system that can affect pumping requirements and performance.

Benefits

Increase the overall efficiency of the pumping systems. Reduce energy consumption and costs, reduce GHG emissions.

1.1.3 Automatic pump controller

Description

Automatic Pump Controllers make it possible to operate a rainwater system without a large pressure tank, pressure switch, and float switch. In the simplest design, the bottom inlet connects to the pump, the top outlet connects to the plumbing system, and the pump is plugged into the controller which is in turn plugged into to an electrical receptacle. When a faucet is opened, the controller senses the drop in line pressure and instantly turns on the pump to re-pressurize the line. If no water is available, the controller shuts down the pump to prevent dry-run damage.

Benefits

Simplest design, save money and energy avoiding the necessity of more complex infrastructure

1.1.4 Control pumping rate

Description

Based upon the system head conditions, pumps may be able to pump at higher rates than needed when operating at 100% motor speed. This flow rate can be controlled by one of two ways, throttling the pump with a valve if the pump is a constant speed pump, or changing the motor speed with a variable speed drive. The former is only energy efficient if the higher flow operating point of the pump without throttling is to the right of the best efficiency point on the pump performance curve, and the throttling results in reducing the flow to a point closer to the best efficiency point on the pump curve. Otherwise, throttling the pump can result in using more energy than at the higher flow, as well as wasting energy because you end up using more energy than is needed. When the demand on the system fluctuates significantly, the pumping rate can be controlled automatically by varying the speed of the motor with a variable frequency drive (VFD), such that the pump output matches only what is needed to meet demands or the intended pumping conditions. The pump's flow rate then increases or decreases based upon the affinity laws and the controlled speed of the motor. This way lower pumping rates can be achieved, which may result in lower efficiency than those at full motor speed; however, the energy consumption is still lower because the energy requirements to pump lower flows at lower heads are lower.

Points to Consider

Pump performance curves and best efficiency point in relation to controlled flow rate , motor types for installing VFDs - only certain motors can be used as variable speed, costs of VFDs and new motors if necessary can be high, financing, cost-benefit based upon capital costs, increased energy efficiency, and energy savings

Benefits

Less energy consumption, lower energy costs, reduced GHG emissions and better control of pumping

1.1.5 Variable speed drives for pump speed control and adjustment of pumping head and flow

Description

Variable speed drives (frequency inverters) to control pumps/ electrical motors speed, allow adjusting the pumping flow and head to the demand treatment and/ or consumption. It makes it possible to adjust the flow depending on the demand hour/ day/ month/ season. Reducing pump/ electric motor speed to operate the pump at its maximum efficiency point results in reducing energy consumption per m^3 pumped.

Points to Consider

An automation system is needed for operation. Cost is typically justified for motor powers above 10-15 KW.

Benefits

Lower energy costs, higher operational flexibility.

1.2 Renewable energy / energy recovery in water abstraction

1.2.1 Use of solar and wind energy

Description

Use of solar panel and wind turbines to power pumps and other equipment.

Points to Consider

Technology details, sun direction / angle of panels, wind speeds and patterns, installation costs and financing models (i.e. loans, ESCO, power purchase agreements, etc.).

Benefits

Can significantly reduce grid energy consumption and related GHG emissions

1.2.2 Use of modern water wheels to produce electrical energy

Description

Modern water wheels can produce energy even at low water flow rates. Water abstraction devices exist where a water wheel provides the energy to a pump so that water can be pumped with no electrical energy demand.

Points to Consider

Common head differences for overshot water wheels are 2.9 - 6.0 m and flows of 0.1 - 1.2 m^3/s, undershot water wheels have head differences of 1.2 to 2.3 m and flow rates up to 3 m^3/s.

Benefits

Renewable energy, especially adequate for isolated areas with a poor access to electrical network

1.3 Rehabilitation of groundwater wells

The efficiency of groundwater wells decreases over time due to mechanical, chemical and biological processes at the well and the adjacent aquifer that lead to formation of incrustations, clogging, corrosion and biofouling among others. This can affect the water levels in the well; hence, the pumping head required for abstraction, and the pumping energy / GHG emissions. Rehabilitating wells so that the capacity of the wells and the original water levels can be restored can help reduce pumping energy consumption. Other benefits include:

- Lower energy costs to abstract same amounts of water

- Increases the pump life, by reducing potential pump damaging cavitation conditions
- Recover lost water quality (aesthetics) and reduce treatment costs

The rehabilitation of existing wells is generally more feasible than reconstruction or abandonment and construction of new wells at other locations. Below are a few methods for well rehabilitation, and their points to consider.

1.3.1 Brushing of well interior

Description
Mechanical cleaning of the well inside by brushing is one of the simplest methods. Often this method is also simply referred to as well cleaning.

Points to Consider
The effectivity of this mechanical rehabilitation is limited to the inside of the well. Other colmatation zones, i.e. the well gravel bed or the adjacent aquifer are not reached. Therefore, the positive effect on well efficiency is only short lived.

Benefits
Lower energy costs to abstract same amounts of water
Increases the pump life, by reducing the pumping head required.

1.3.2 Chemical water well rehabilitation

Description
Chemical rehabilitation of wells includes the introduction of chemical agents into the well and generally also extensive short circuit-pumping. The chemicals may take effect at the well itself and the adjacent gravel bed.

Points to Consider
Chemical agents introduced into the well can pollute the aquifer and may be a risk for safe drinking water. Chemicals may attack the well material itself especially if the protective layers of the materials are damaged. Large amounts of water are needed to be abstracted in order to fully remove the introduced chemicals. The time the well is out of service can be long. However, depending on the severity of biofouling and clogging, chemical treatment may be required.

Benefits
Lower energy costs to abstract same amounts of water
Increases the life of the well and Increases the pump life, by reducing the pumping head required.
Recover lost water quality (aesthetics).

1.3.3 Hydraulic water well rehabilitation

Description
Hydraulic methods include short-circuit-pumping, jetting among others. This take effect at the well itself and can take effect also in the adjacent gravel bed.

Points to Consider
Hydraulic methods may cause suffusions and subsiding and thereby reduce the well efficiency due to a decrease the permeability.

Benefits
The rehabilitation of existing wells is generally more feasible than reconstruction or abandonment and construction of new wells at other locations. One of the biggest benefits is lower energy costs, increases the life of the well and increases the pump life. Well rehabilitation can restore lost water quality and improve water aesthetics.

Impulse water well rehabilitation

Description

The efficiency of groundwater wells decreases over time due to mechanical, chemical and biological processes at the well and the adjacent aquifer that lead to formation of incrustations, clogging, corrosion and biofouling among others. The rehabilitation of existing wells is generally more feasible than reconstruction or abandonment and construction of new wells at other locations.

Points to Consider

Impulse methods may cause damage to the well if the intensity is too high. They may also lead to suffision and subsiding and thereby reduce the well efficiency due to a decrease the permeability.

Benefits

Lower energy costs to abstract same amounts of water
Increases the life of the well Increases the pump life, by reducing the pumping head required.
Recover lost water quality (aesthetics).

2 Drinking Water Treatment

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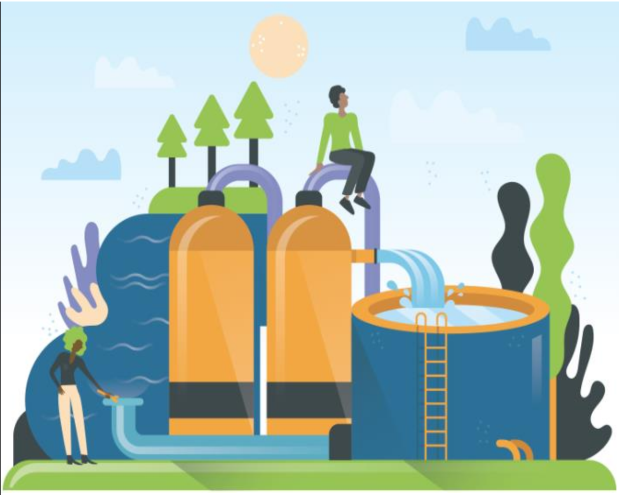
Water Abstraction The quality of the water abstracted defines the treatment required; hence the energy required.

Drinking Water Distribution Water loss in the drinking water distribution system increases the volume of water treated, and therefore the energy requirements.

End users Excessive water usage by End Users increases the volume treated and therefore the energy requirements.



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Water Abstraction The distance and elevation of the drinking water treatment facilities will dictate how much energy is needed to pump the water from the source to the treatment

Drinking Water Distribution The distance and elevation of the drinking water treatment facilities will dictate how much energy is needed to convey the water to the end users at an adequate pressure.

The GHG emissions from the drinking water treatment stage depend on the type of treatment and electromechanical equipment used to operate the treatment facilities, such as: pumps, motors, blowers, mixers, flocculators, etc. In most cases, the GHG emissions in the drinking water treatment stage are indirect emissions from importing grid electricity to operate the electromechanical equipment; however, just as in the case as of the drinking water abstraction, there can be direct GHG emissions from fuel consumption/combustion for engines driving the pumps or powering equipment with emergency generators. Typically, during conventional filtration, which is the most common treatment type for surface water supplies, the majority of energy consumption is due to pumping and filter backwash operations. In sea water reverse osmosis, the majority of energy consumption is due to pumping through high pressure membranes. However, some systems, usually groundwater supplies, may need to disinfect only so the energy consumption during actual treatment is minimal. Key factors that impact the GHG emissions in the drinking water treatment stage include the following: In order to optimize the drinking water treatment stage, some of the potential solutions that can be implemented are highlighted below.

2.1 Drinking water treatment process optimization

2.1.1 Optimize filter backwashing sequence

Description

In conventional filtration, how the filter backwash sequence is initiated in conventional filtration can affect the frequency of backwashing. The more times that filters are backwashed, the more energy consumed during the process. Therefore, it is critical to optimise the backwashing sequence, such that filters are not excessively backwashed. The more optimal the sequence, the less GHG emissions generated from the treatment stage.

Benefits

Improved redundancy / flexibility, lower energy consumption / GHG emissions.

2.1.2 Optimize Membrane process

Description

In seawater reverse osmosis, the transmembrane pressure typically regulates the energy required for pumping seawater through the membrane in desalination. Owing to the nature of the process, the raw water salinity, and the required permeate salinity, the energy consumption for seawater reverse osmosis tends to be significantly higher than for conventional drinking water treatment. However, the configuration and control of the process, as well as the types of membrane used, can be optimised to minimise energy consumption and GHG emissions.

Benefits

Reduced energy consumption / GHG emissions.

2.1.3 Efficient UV lamps / operation

Description

Ultraviolet disinfection and how it is operated, controlled, and maintained can have an impact on the GHG emissions from energy consumption. In general, the higher the volume of water treated, and the higher the ultraviolet disinfection dose, the higher GHG emissions generated from the ultraviolet disinfection process. However, the dose (as impacted by water turbidity), control and maintenance can be optimised to minimise these emissions, while still meeting minimum disinfection requirements.

Points to Consider

Higher initial cost.

Benefits

Lower energy costs, lower maintenance costs as less lamps need to be maintained.

2.1.4 Improve Hydraulics of ozonation reactors

Description

Due to the relatively fast decay of ozone, even in pure water, optimizing the hydraulics of the ozonation reactor ensures an optimal exposure time of each water molecule to meet the adequate dose- time of exposure combination, which is key to achieving disinfection. Optimizing the hydraulics avoids having to overdose to achieve the required log removal of micro-organisms. A lower quantity of ozone needs to be generated for same disinfection efficiency.

Points to Consider

Hydraulics need to be modeled for optimal operation during the design phase.

Benefits
Lower energy, due to lower ozone quantity, lower equipment and maintenance costs due to lower ozone quantity required.

2.1.5 Optimize chlorine production

Description
Optimization of the equipment and production of the chlorine could lead a significant reduction in the energy consumption.

Benefits
Saving cost in disinfectants and higher disinfection efficiency

2.1.6 Replacement of green ozone generators

Description
Ozone disinfection has a high energy demand. The ozone generator represents approximately 90% of the total energy demand in the ozonation process, with the remaining 10% used for the ozone generator cooling and ozone destruction processes. Earlier models of the ozone generator had poor production efficiency; thermal loss during operation caused most of the electricity used to go to waste. Green Ozone Generator increases the electrical input capacity.

Benefits
Small-diameter discharge tubes, increased electrical input capacity, cost and resource savings. If thermal energy could be recovered, the benefits would be even greater.

2.1.7 Add or improve pre-treatment before membrane filtration

Description
It is essential to establish a good pre-treatment to avoid or minimize fouling, so productivity loss would be lower.

Benefits
Improve the life of membranes

2.2 Pump efficiency optimization

See Section 1.1

2.3 Other solutions

Other solutions that have been identified to support reducing the energy, water and carbon footprint of utilities will be provided on the ClimateSmartWater.org portal.

3 Drinking Water Distribution

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Drinking Water Treatment The distance and elevation of the drinking water treatment facilities will dictate how much energy is needed to convey the water to the end users at an adequate pressure.

End users The volume of water distributed, and therefore the energy required, is driven by the demand of end users and how efficient they are in their water use.

IMPACTS

Water Abstraction Water loss in the distribution systems increases the volume of water abstracted and its associated energy requirements.

Drinking Water Treatment Water loss in the drinking water distribution system increases the volume of water treated, and therefore the energy requirements.

Depending on the distance and elevation of the end users in relation to the treatment facilities, GHG emissions in the drinking water distribution stage will typically be related to energy consumption for the delivery of drinking water from the facilities to the end users. This stage usually requires pumping within the distribution system network to deliver water to end users at the minimum required pressure. The minimum required pressure varies per region, in highly urbanized areas with very tall buildings, the pressure is greater. In most cases, the GHG emissions are indirect emissions from using grid electricity to run pumps; however, just as in the case as of the previous drinking water abstraction and treatment stages, there can be direct GHG emissions from fuel consumption/combustion for engines or emergency generators driving the pumps. If the drinking water treatment takes place above the elevation of the city, it is possible that the water can be transported to the end users by gravity only, avoiding extra emissions. In order to optimize the drinking water distribution stage, some of the potential solutions that can be implemented are highlighted below.

3.1 Distribution system scheme / operation

3.1.1 Establish or optimize pressure management areas (pressure zones)

Description

A pressure management area is a hydraulically discrete area which has the potential for reduction of excessive system pressures while still maintaining acceptable levels of service to the customers. For example, to supply water in a hilly terrain often high-water pressure heads are required at the pumping station. Without separate pressure zones, this can result in high pressures in low-lying areas, which increases probability of pipe failure.

Points to Consider

Smaller pressure zones may require multiple small reservoirs to break pressure surge due to extreme differences in elevation and to guarantee water availability in case of pumping malfunctions.

Benefits

Less energy consumption from less leaks in the systems and less pumping / treatment required, as well as lower pumping head requirements. Potential to recover energy between pressure zones.

3.1.2 Strategically manage water pressure

Description

Research has shown that the quantity of water lost through leakage is proportional to the operational pressure of the system. Therefore, reducing system pressure, particularly during periods of low demand, will have a significant impact on leakage.

Points to Consider

Service level is affected, especially in elevated areas or buildings.

Benefits

Less energy consumption from less leaks in the systems and less pumping / treatment required, as well as lower pumping head requirements.

3.1.3 Subdivide water distribution network in hilly terrain into separate pressure zones

Description

To supply water in a hilly terrain often high water pressure heads are applied at the pumping station. This requires however unnecessary energy and the high pressure heads in low-lying areas increase probability of pipe breakage. Hydraulic modelling of the network help to analyze constraints of the system and identify possible solutions.

Points to Consider

Smaller pressure zones may require multiple small reservoirs to break pressure surge due to extreme differences in elevation and to guarantee water availability in case of pumping malfunctions.

Benefits

Energy saving - Less water losses

3.1.4 Use a water distribution system modelling software

Description

Use a water distribution system modeling software to assess baseline and future operation, optimizing pump operation to reduce energy consumption, and identifying and reducing water losses.

Points to Consider

Smaller pressure zones may require multiple small reservoirs to break pressure surge due to extreme differences in elevation and to guarantee water availability in case of pumping malfunctions.

Benefits

Energy saving - Less water losses

3.2 Renewable energy / energy recovery in drinking water distribution

3.2.1 Use of solar and wind energy

See Section 1.2.1.

3.2.2 Install micro-turbines

Description

Micro turbines installed in water pipes allow converting the hydraulic potential energy loss resulting from the hydraulic design and the topography into electrical energy.

Points to Consider

The modalities of self-consumption of the electricity produced or the selling to the grid need to be well investigated. The installation cost is high; however, typically economical above certain flow rate.

Benefits

Produces renewable energy.

3.2.3 Establish pressure management areas (pressure zones)

Description

A pressure management area is a hydraulically discrete area which has the potential for reduction of excessive system pressures while still maintaining acceptable levels of service to the customers.

Benefits

Less energy consumption of water pumping. Potential to recover energy between pressure zones.

3.2.4 Heat recovery

Description

Urban water networks can contribute to the energy transition of cities by serving as an alternative source for heating and cooling

3.3 Pump efficiency / optimization

For details see section 1.1

3.4 Water loss reduction

3.4.1 Active leakage control

Description

Monitoring of water tank's water levels coupled with steptesting (closing of valves) enabling easier location of leaks. Since any small leak that goes undetected is a potential future large-scale burst, this action ensures, indirectly, a reduction of the amount of water lost. The monitoring can be facilitated by a supervisory control and data acquisition system (SCADA).

Points to Consider

Proper training of staff to work and use this tool is essential.

Benefits

Reduction of the amount of water lost.

3.4.2 Proactive Infrastructure Asset Management

Description

The timely rehabilitation/substitution replacement of pipes and service connections enables the reduction of minimizes the number of unplanned repairs and water loss in the water abstraction system; hence, its energy and GHG emissions. Proactive Infrastructure Asset Management aims at this.

Points to Consider

Management has to be proactive and not focus on short-term strategies that lead to lower levels of service in the future and higher costs for the user. In addition to risk of pipe failure, the cost-benefit of rehabilitating/replacing pipe versus anticipated savings in energy and reduction in GHG emissions from water loss reduction should be considered.

Benefits

Pipe rehabilitation/replacement reduces leakages resulting in energy and water savings, and GHG emissions reduction.

3.4.3 Subdivide water distribution network in hilly terrain into separate pressure zones

Description

To supply water in a hilly terrain often high water pressure heads are applied at the pumping station. This requires however unnecessary energy and the high pressure heads in low-lying areas increase probability of pipe breakage. Hydraulic modelling of the network help to analyze constraints of the system and identify possible solutions.

Points to Consider

Smaller pressure zones may require multiple small reservoirs to break pressure surge due to extreme differences in elevation and to guarantee water availability in case of pumping malfunctions.

Benefits

Energy saving, less water losses.

3.4.4 Use of a supervisory control and data acquisition system (SCADA)

Description

A SCADA enables the remote monitoring and control of the whole system, or parts of it, and processes information to generate alarms, reports, graphs or other outputs essential to operation and maintenance. By enabling the remote control of valves and pumps, the SCADA systems allows faster responses in emergency situations, such as fires or pipe bursts. Remote control, gathered with the system's monitoring, can also lead to a reduction of human resources and travelling needs, especially those related to the operation of electromechanical equipment.

Points to Consider

Proper training of staff to work and use this tool is essential

Benefits

- Faster responses in emergency situations, such as fires or pipe bursts.
- Reduction of human resources and traveling needs, especially those related to the operation of electromechanical equipment.

3.4.5 Water Audit

Description

Control and mitigation of drinking water losses in distribution systems conducting a water audit.

Benefits

Water Savings

Energy Savings

3.4.6 Water-loss reduction

Description

On this website you will find background information, know-how and best practices on the reduction of water loss from supply networks.

We also provide downloadable guidelines for the sustainable planning and implementation of water loss reduction projects and also offer several training modules.

http://www.waterlossreduction.com/index.php/en/

Benefits
Reduction water losses, guidelines, courses etc.

3.5 Other solutions

Other solutions that have been identified to support reducing the energy, water and carbon footprint of utilities are listed below but not yet been documented in detail. These solutions will be further documented on the ClimateSmartWater.org portal:

- Water loss reduction (Referencing work of IWA Water Loss Task Force)
- Use a water distribution system modelling software to assess baseline and future operation, optimizing pump operation to reduce energy consumption, identifying and reducing water losses, and optimizing pressure management and pressure zones.
- Pumps as turbines (PATs).

4 Wastewater Collection

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Wastewater Treatment The distance and elevation of the wastewater treatment facilities dictates whether wastewater needs to be pumped (as opposed to gravity flow).

Wastewater Discharge When there is no wastewater treatment, the distance and elevation of the final discharge point dictates whether wastewater needs to be pumped

End users The less water entering the collection system from end users, the less pumping energy is required (in pumped systems). However, reduced flows in the collection system network can lead to greater detention times, which can possibly result in greater methane emissions from the collection system.

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Wastewater Treatment**:** The wastewater treatment energy depends on the volume and concentration of the water collected. Collection systems with high infiltration and rain water collection lead to less efficient treatment. Collection systems with long detention times allowing for anaerobic organic matter decay, may lead to the use of chemicals in the treatment to ensure nitrogen removal.

End users The type of collection system affects the amount of water used in the homes (dry or flush toilets, greywater separated from blackwater).

The GHG emissions related to the wastewater collection stage can include (but are not limited to): indirect CO_2 emissions from grid electricity consumption for wastewater pumping with electric motors, and/or direct GHG emissions from fuel consumption for engine driven or powered pumps. The energy consumption for pumping is dependent on the amount of wastewater pumped, as well as the distance and elevation of the end users in relation to the wastewater treatment plant. Inflow/infiltration in the sewer system not only impacts the downstream wastewater treatment, but if there is pumping in the sewer system, the energy consumption will be higher due to the additional volumes that are pumped, thereby also increasing GHG emissions. Methane (CH_4) is produced via methanogenesis when there are anaerobic conditions in sewers (Guisasola et al., 2008), and emitted downstream wherever there might be stripping of methane from the liquid to the air. Generally long detention times in the sewers leads to a greater risk of methane production and emissions (Foley et al., 2010). Methane emissions have a significantly higher global warming potential than CO_2, so it should become a high priority when possible to minimize detention times in the collection system, whether those systems are gravity or pressure, to reduce methane emissions. Although some studies have reported N_2O emissions to be significant from sewers (Short et al., 2014), the conditions leading to N_2O emissions in sewers are still not very well understood. In order to optimize the wastewater collection stage, some of the potential solutions that can be implemented are highlighted below.

4.1 Pump efficiency / optimization

For details see Section 1.1

4.2 Renewable energy / energy recovery in wastewater collection

4.2.1 Use of solar and wind energy

See Section 1.2.1.

4.2.2 Heat recovery from wastewater

Description

Temperature of water in sewers often varies between 15 and 25 degrees C. It represents a major pathway of heat loss from modern buildings. Through the installation of heat exchangers in large sewers or at the treatment plant, a small portion of this thermal energy can be recovered and used by heat pumps for local heating of buildings.

Points to Consider

By reducing the wastewater temperature, the treatment process may be affected (slower degradation). The minimum design temperature of the treatment plant should be considered when designing the heat exchanger.

Benefits

Can significantly reduce grid energy consumption and related GHG emissions

4.3 Other solutions

Other solutions that have been identified to support reducing the energy, water and carbon footprint of utilities are listed below but not yet been documented in detail. These solutions will be further documented on the ClimateSmartWater.org portal:

- Use a sewer modelling software to assess baseline and future operation, optimizing pump operation to reduce energy consumption, and identifying and reducing infiltration / inflow.
- Chemical addition in sewers to reduce hydrogen sulfide and methane emissions
- Avoid anaerobic conditions in sewers
- Green infrastructure
- Reducing Combined Sewer Overflow (CSO)
- Reduction of inflow / Infiltration

5 Wastewater Treatment

IMPACTED BY

Wastewater Collection The distance and elevation of the wastewater treatment facilities dictates whether wastewater needs to be pumped (as opposed to gravity flow).

Reuse Water Treatment Impacted because of the amount of wastewater to be recycled will depend on the amount of wastewater generated. The recycled water treatment system design and energy consumption is generally influenced by the amount and quality of source water available from wastewater treatment plant effluents.

IMPACTS

Wastewater Collection The wastewater treatment energy depends on the volume and concentration of the water collected. Collection systems with high infiltration and rain water collection lead to less efficient treatment. Collection systems with long detention times allowing for anaerobic organic matter decay, may lead to the use of chemicals in the treatment to ensure nitrogen removal.

End users Wastewater treatment energy depends on the volume and concentration of the water collected, as well as the total organic and nitrogen load. The energy recovery potential is proportional to the organic load.

In many cases, indirect CO_2 emissions from grid electricity consumption to power electromechanical equipment, such as: pumps, blowers, mixers, and screens, needed for various wastewater treatment unit operations, make up the majority of a wastewater treatment plant's (WWTP) GHG emissions. Typically, the aeration process is the most energy intensive. Therefore, opportunities to optimize the aeration system and control should be evaluated whenever possible, assuming that the air supply is controllable and dissolved oxygen can be measured in short time intervals throughout the day. In some cases, nitrous oxide, which is produced from biological nitrogen removal processes, impacts the WWTP's carbon footprint significantly due to its higher global warming potential (300 times that of CO_2). Therefore, reducing nitrous oxide emissions through process optimisation is a high priority whenever feasible. There is the potential for additional methane emissions from: the incomplete flaring of biogas during anaerobic digestion, poorly managed activated sludge systems, stripping of methane in reject water sent to aeration tanks, leaking biogas piping, and sludge storage. Direct emissions of CO_2, methane, and nitrous oxide from the fuel consumption/combustion for engine driven pumps and blowers can also occur. Methane and nitrous oxide are emitted from sludge disposal off-site, with emission volume depending on the sludge disposal method and the type of sludge (i.e. undigested and digested). From a regulatory standpoint, the discharge limits of the WWTP can also impact GHG emissions due to higher energy consumption required for nitrogen and phosphorus removal, as well as increased nitrous oxide emissions from the nitrification and denitrification process. In order to optimize the wastewater treatment stage, some of the potential solutions that can be implemented are highlighted below.

5.1 Biogas valorisation

The biogas produced in anaerobic processes has the potential to be used as renewable energy for heat and electricity, and after upgrading, as city gas supply. Below are various uses of biogas after if anaerobic digestion is employed.

5.1.1 Use biogas for co-generation on-site

Description
Use the biogas production to produce energy for powering various process-mechanical equipment.

Points to Consider
Specific equipment / installations are required. High capital and operational costs.

Benefits
Reduce energy consumption / GHG emissions.

5.1.2 Use biogas for heating purposes on-site

Description
The method of cogeneration of heat and power (CHP) is a key solution to improve energy efficiency and thus to reduce CO2 emissions at a WWTP. A CHP plant consists of an electrical generator combined with equipment for recovering and using the heat produced by that generator. The generator can be a prime mover such as a gas turbine or a reciprocating engine. Alternatively, it may consist of a steam turbine generating power from high pressure steam produced in a boiler. Normally depending on the efficiency factor 30-40% electricity and 60-70% heat can be generated out of 100% biogas.

The heat produced at the WWTP is normally used to heat up the digesters depending on the process (mesophilic or thermophilic treatment) to 37° or 50°C. Nowadays heat can also be used in new sludge treatment concepts such as sludge pre-treatment (e.g. hydrolysis) which needs temperatures between 40°C up to 160°C (depending on the process).

Points to Consider
Exact heat balances have to be carried out before decision making for heat use on site. Specific installations are required.

Benefits
Save energy and heat consumption; reducing CO2 footprint; saving operational costs; coming closer to energy-neutrality or evening more energy-positivity.

5.1.3 Use biogas to provide heating to neighbouring areas

Description
If the WWTP will have surplus heat and internal usage of heat is covered the possibility to supply the neighbouring areas with the heat produced during the treatment is possible.

Points to Consider
Specific infrastructure it's required; district heating systems should be required in the neighbourhood if not distances to potential customers should be not to long;

Benefits
Save energy, GHG emissions, and heat consumption; gaining additional revenues.

5.2 Renewable energy / energy recovery in wastewater treatment

5.2.1 Use of solar and wind energy

See Section 1.2.1.

5.2.2 Energy Self-sufficient Wastewater Treatment

Description
Municipal wastewater treatment in Europe currently requires a significant amount of energy to eliminate organic matter and nutrients such as nitrogen and phosphorus from the sewage prior to its

discharge to receiving waters. Under the assumption of an average electricity demand of 32 kWh per capita and year for large wastewater treatment plants (WWTP) as current benchmark1, the municipal wastewater sector within the European Union (EU) consumes at least 16,000 Gigawatthours (GWh) per year for its service, which is equivalent to the annual power generation of two large (1,000 Megawatt) power plants. By using the chemical energy content (as COD) as well as having the right combination of technologies to require also finally also the limiting values for discharging (which is the first goal of a wastewater treatment plant) your WWTP can become energy-neutral or even energy positive.

Points to Consider

The investment cost associated to energy neutrality or even energy positive plants may be high, but the energy savings often make this approach economically feasible. Energy neutral or positive plants may only be achieved under specific design configurations and using different combination of treatment processes which are always site specific and cannot be generalized.

Benefits

The facility becomes independent to power cost fluctuations

5.2.3 Heat recovery from wastewater

See Section 4.2.2.

5.3 Optimizing or reconfiguring wastewater treatment plants

There are several measures or strategies that can help to improve the efficiency and performance of individual unit processes and the overall efficiency of the wastewater treatment stage, as well as to help to reduce their energy consumption and the GHG emissions. In many cases energy consumption (mainly from aeration for biological process for the activated sludge process) makes up the majority of the WWTP GHG emissions; however, all unit processes should be considered to ensure maximum reduction in energy and GHG emissions. In some cases, nitrous oxide can make up the majority of the carbon footprint due to its high global warming potential (approximately 300 times that of CO_2). Therefore, the potential for nitrous oxide emissions and opportunities for reducing them through process optimization should be evaluated quantitatively or qualitatively whenever possible. Similarly, methane has a significantly higher global warming potential than CO_2 (30 times that of CO2); therefore, qualitatively understanding the potential for fugitive methane emissions around the WWTP is important for minimizing GHG emissions. Moving away from activated sludge and towards new wastewater treatment plant configurations and processes, such as short-cut nitrogen processes for the mainstream, can also present opportunities to minimize energy and GHG emissions.

5.3.1 Optimize aeration based on ammonia load

Description

The diurnal ammonia loads coming to the WWTP and how the aeration is controlled for ammonia removal (when it is required) can have a significant impact on both energy consumption and nitrous oxide emissions. Depending on the ammonia concentrations/loads, too much or too little dissolved oxygen can result in high nitrous oxide production and emissions. The control of dissolved oxygen in biological reactors is fundamental. Therefore, an appropriate dissolved oxygen concentration can lessen GHG emissions generated from the wastewater treatment stage.

Points to Consider

[1] DWA (2013): 25th Benchmarking of German wastewater treatment plants.

Should be checked with modelling. Control system capabilities should be reviewed.

Benefits
Reduced energy consumption / GHG emissions.

5.3.2 Supplemental carbon addition

Description
The chemical oxygen demand/nitrogen (COD/N) ratio in wastewater can influence the nitrous oxide emissions from heterotrophic denitrification. A low COD/N ratio resulting from carbon-limited wastewater can inhibit the reduction steps necessary to reducing nitrate to nitrogen gas during denitrification. When the COD/N ratio is low, nitrous oxide, which is an intermediate in this process, can accumulate and be emitted rather than being reduced to nitrogen gas. Adding or optimizing external carbon in this case can help both the nitrogen removal process and to minimize nitrous oxide emissions.

Points to Consider
Complete denitrification based on different doses should be checked with modelling. Different carbon sources can lead to higher or lower N_2O production.

Benefits
Reduced GHG emissions.

5.3.3 Reconfigure to aerobic granular sludge processes

Description
The development of aerobic granules has several advantages; these include good biomass retention, the ability to withstand shock and toxic loadings, and the presence of both aerobic and anoxic zones inside the granules which can simultaneously permit different treatment processes to occur.

Points to Consider
1. Formation of aerobic granules is complex and results from interacting physical, chemical and biological factors. 2. Granule density and granule size greatly influences the specific COD removal rate and the specific oxygen uptake rate (SOUR) because of the mass transfer. Depending on dissolved oxygen and nitrite concentrations, operating conditions can lead to nitrous oxide production.

Benefits
Reduced aeration requirements, faster settling of the sludge compared to conventional activated sludge

5.3.4 Membrane Bioreactor (MBR) in combination with reverse osmosis (RO) as a replacement for conventional activated sludge plants and advanced treatment for water re-use

Description
Membrane Bioreactors can be used to replace conventional activated sludge plants and produce better quality filtrate which can then be re-used. MBRs have a much smaller area footprint which is especially relevant in urban areas.

Points to Consider
Wastewater effluent has generally a high biofouling potential which can in turn reduce the efficiency of an MBR. Physical and chemical methods exist to reduce biofouling.

5.3.5 Optimization of membrane physical and chemical cleaning

Description
Backwashing of membranes requires water and energy; its optimization is crucial to increase the overall efficiency of the treatment process. Membrane cleaning efficiency depends on many parameters such as hydrodynamic conditions, concentration and temperature of chemical cleaning solution, as well as sequence of cleaning. Biofouling increases gradually the resistance of membranes and can only be

partially remediated. It increases need for backwashing and reduces the lifetime of the membrane. Solutions and technologies for reducing membrane biofouling are therefore important.

Benefits
Increase the overall efficiency of the treatment process, reduced energy consumption / GHG emissions.

5.4 Pump efficiency / optimization

For details see Section 1.1

5.5Sludge handling and treatment in the wastewater treatment plant

5.5.1 Sludge Screw press

Description
Screw press can be more efficient than sludge centrifugation.

Points to Consider
Amounts that can be processed by a screw press are limited.

5.6 Energy Neutral Wastewater Treatment

Description
This section is an overview of facilities for wastewater treatment and sludge handling which have set a target to be energy neutral or positive.

Points to Consider
The investment cost associated to energy neutrality or energy positive plants may be high but the energy savings often make this approach economically feasible. Energy neutral or positive plants may only be achieved under specific design configurations.

Benefits
The facility becomes independent to power cost fluctuations.

5.7 Other solutions

Other solutions that have been identified to support reducing the energy, water and carbon footprint of utilities are listed below but not yet been documented in detail. These solutions will be further documented on the ClimateSmartWater.org portal:

- Use of wastewater treatment process modelling software to identify opportunities for optimizing process and reducing energy consumption and GHG emissions
- Nutrient recovery
- Install aerobic/anaerobic pre-treatment
- Optimize aeration process
- Optimize sidestream processes
- Thermal Hydrolysis
- Ultrasonic Treatment
- Sludge belt-filter press
- Covering of treatment facilities
- Biogas for vehicles

6 Wastewater Discharge

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Wastewater Treatment The distance and elevation difference between the wastewater treatment and discharge impacts the energy requirements or recovery potential. Furthermore, if there is no wastewater treatment, then the direct GHG emissions resulting from the direct discharge to receiving waters range between 30 and 45 kg/per year.

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Wastewater Collection When there is no wastewater treatment, the distance and elevation of the final discharge point dictates whether wastewater needs to be pumped.

In order to optimize the wastewater discharge stage, some of the potential solutions that can be implemented are highlighted below.

6.1 Energy recovery in wastewater discharge

See section 4.2.2

6.2 Pump efficiency / optimization

For details see section 1.1

7 Reuse Water Treatment

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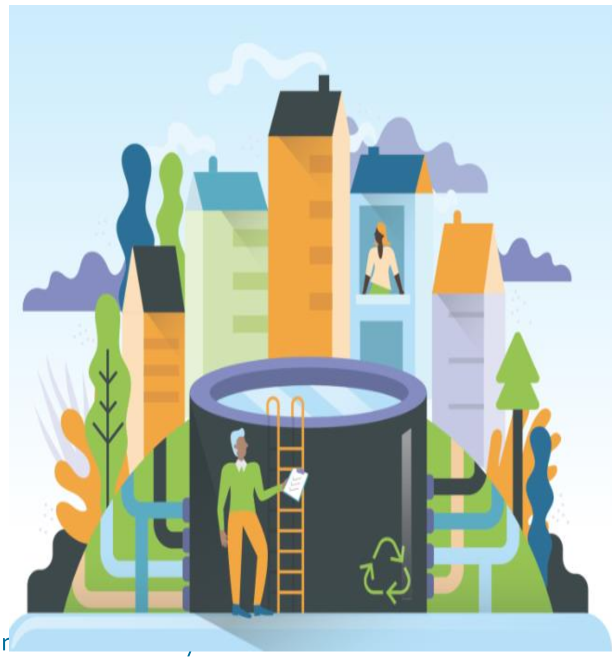
Wastewater Treatment Recycled water treatment can be impacted by wastewater treatment because the amount of wastewater to be recycled will depend on the amount of wastewater generated. The recycled water treatment system design and energy consumption is generally influenced by the amount and quality of source water available from wastewater treatment plant effluents.

End users Depending upon the recycled water demand (quantity and water quality) by the end users, the level of treatment required will be defined and, hence, the related energy and GHG emissions. The higher the water quality, the more energy intensive the treatment process becomes.



IMPACTS

Reuse Water Distribution The capacity and location of the reuse water treatment facility impacts the pumping requirements of the distribution system.

End users Reuse water for usages such as irrigation, cleaning, toilet flushing or even drinking, depends on the level of treatment of the reuse water.

The more reuse water that is demanded, the more wastewater effluent needing to be treated and/or delivered. The end users impact the GHG emissions of the Discharge/Reuse stage by how they use water. Therefore, the less reuse water demanded, the less GHG emissions generated from the discharge/reuse stage. However, there are generally more offsetting benefits if water is reused in terms of water security and/or reduced GHG emissions. In order to optimize the reuse water treatment stage, some of the potential solutions that can be implemented are highlighted below.

7.1 Pump efficiency / optimization

For details see Section 1.1

7.2 Reuse Water Treatment Process Optimization

7.2.1 Add or improve pre-treatment before membrane filtration

Description

It is essential to establish a good pre-treatment to avoid or minimize fouling, so productivity loss would be lower.

Benefits

Improve the life of membranes.

7.2.2 Optimization of membrane physical and chemical cleaning

Description

Backwashing of membranes requires water and energy; its optimization is crucial to increase the overall efficiency of the treatment process. Membrane cleaning efficiency depends on many parameters such as hydrodynamic conditions, concentration and temperature of chemical cleaning solution, as well as sequence of cleaning. Biofouling increases gradually the resistance of membranes and can only be partially remediated. It increases need for backwashing and reduces the lifetime of the membrane. Solutions and technologies for reducing membrane biofouling are therefore important.

Benefits

Increase the overall efficiency of the treatment process, reduced energy consumption / GHG emissions.

7.2.3 Assess water recycling options

Description

In case water can be re-used on site, the amount that needs to be collected and treated and hence the energy demand for treatment can be reduced.

Benefits

Save some water and energy.

7.2.4 Efficient UV lamps / operation

See Section 2.1.3.

7.2.5 Improve Hydraulics of ozonation reactors

Description

Due to the relatively fast decay of ozone, even in pure water, optimizing the hydraulics of the ozonation reactor ensures an optimal exposure time of each water molecule to meet the adequate dose- time of exposure combination, which is key to achieving disinfection. Optimizing the hydraulics avoids having to overdose to achieve the required log removal of micro-organisms. A lower quantity of ozone needs to be generated for same disinfection efficiency.

Points to Consider

Hydraulics need to be modelled for optimal operation during the design phase.

Benefits
Lower energy, due to lower ozone quantity Lower equipment and maintenance costs due to lower ozone quantity required.

7.2.6 Nutrient recovery from effluent

Description
In case the effluent is reused in agriculture or aquaculture, the nutrient content in the effluent is beneficial. The treatment process selected may therefore minimize the nutrient elimination typically desired when the effluent is discharged to a river, a lake or used for groundwater recharge.

Points to Consider
The concentration in nutrients shall not exceed the uptake needs of the plants or fish. Dilution might be required.

Benefits
Savings in chemical fertilizers or feed. Potential of nitrate contamination on ground water supplies.

7.2.7 Optimization of membrane operation condition

Description
Membrane processes produce a concentration gradient of dissolved salts approaching the membrane surfaces. It increases need for backwashing and reduces the lifetime of the membrane. Various saturation indexes, such as the Stiff-Davis and Langelier, should be maintained below precipitating values in the brine (through pH control or deposit control agents) to prevent calcium carbonate fouling.

Benefits
More operation efficiency which in turn means energy saving.

7.2.8 Optimization of membrane physical and chemical cleaning

Description
Backwashing of membranes requires water and energy; its optimization is crucial to increase the overall efficiency of the treatment process. Membrane cleaning efficiency depends on many parameters such as hydrodynamic conditions, concentration and temperature of chemical cleaning solution, as well as sequence of cleaning. Biofouling increases gradually the resistance of membranes and can only be partially remediated. It increases need for backwashing and reduces the lifetime of the membrane. Solutions and technologies for reducing membrane biofouling are therefore important.

Benefits
Increase the overall efficiency of the treatment process.

7.2.9 Optimize chlorine production

Description
Optimization of the equipment and production of the chlorine could lead a significant reduction in the energy consumption.

Benefits
Saving cost in disinfectants and higher disinfection efficiency

7.2.10 Replacement of green ozone generators

Description
Ozone disinfection has a high energy demand. The ozone generator represents approximately 90% of the total energy demand in the ozonation process, with the remaining 10% used for the ozone generator cooling and ozone destruction processes. Earlier models of the ozone generator had poor

production efficiency; thermal loss during operation caused most of the electricity used to go to waste. Green Ozone Generator increases the electrical input capacity.

Benefits
1) Small-diameter discharge tubes 2) Increased electrical input capacity 3) Cost and resource savings

7.3 Renewable energy

7.3.1 Use of solar and wind energy

See Section 1.2.1.

7.4 Other solutions

Other solutions that have been identified to support reducing the energy, water and carbon footprint of utilities will be provided on the ClimateSmartWater.org portal.

8 Reuse Water Distribution

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Reuse Water Treatment The capacity and location of the reuse water treatment facility impacts the pumping requirements of the distribution system.

End users The reuse water demand by end users and their location compared to the treatment facility dictate the volumes to be distributed over which distance and the associated pumping or truck

IMPACTS

End users Access to reuse water dictates whether it is used and how much. The use of reuse water by end users offsets water consumption from the raw water source, which reduces the dependency on a potentially limited water resource and may, reduce pumping and treatment energy.

Similar to drinking water distribution, for reuse water distribution depending on the distance and elevation of the end users in relation to the treatment facilities, GHG emissions in the distribution stage will typically be related to energy. This stage usually requires pumping within the distribution system network to deliver water to end users at the minimum required pressure. In order to optimize the reuse water distribution stage, some of the potential solutions that can be implemented are highlighted below.

8.1 Distribution system scheme / operation

For details see section 3.1

8.2 Pump efficiency / optimization

For details see section 1.1

9. Global management solutions, guidelines or general information of interest for UWS

9.1 Proactive Infrastructure Asset Management

Description

The timely rehabilitation/substitution replacement of pipes and service connections enables the reduction of minimizes the number of unplanned repairs and water loss in the water abstraction system; hence, its energy and GHG emissions. A Proactive Infrastructure Asset Management aims at this.

Points to Consider

Management has to be proactive and not focus on short-term strategies that lead to lower levels of service in the future and higher costs for the user. In addition to risk of pipe failure, the cost-benefit of rehabilitating/replacing pipe versus anticipated savings in energy and reduction in GHG emissions from water loss reduction should be considered.

Benefits

Pipe rehabilitation/replacement reduces leakages resulting in energy and water savings, and GHG emissions reduction.

9.2 SCADA System to control pumping / treatment plant operation

Description

Use of supervisory, control, and data acquisition (SCADA) system for monitoring, supervision and controlling of pumping and treatment systems can help minimize energy consumption of GHG emissions. It includes measurements in real time of water levels, pressures, flows, energy consumption, water quality and other operational parameters. It also helps to adjust and control the pump station and treatment plant operation, contributing to reduction of water losses or infiltrations, reduce pumping during energy peak hours and adjust pumping volumes to the needs of the system. The SCADA systems provide utility managers with access to real-time operating data and can help offset the higher operating costs by minimizing unplanned downtime and improving maintenance plans. The SCADA system can also be used to optimize pumping in real-time through advanced pump optimization software and control, or through either a model-based or knowledge-based optimization that is implemented via a rule-based system programmed into the SCADA system. This type of optimization entails the use of algorithms to determine the best pumping/treatment scheme for a given situation. This can incorporate the peak energy times previously referenced, but also a prioritization of which pumps or pumping stations are used to maximize efficiency whenever possible. For example, if only a certain volume is demanded, then the SCADA system will first operate the most efficient pumps or pumping stations to meet the demand until greater capacity or more pumps are needed.

Points to Consider

The initial installation costs can be high, operational benefits other than energy efficiency are high, cost-benefit based upon listed benefits

Benefits

Lower energy consumption and costs, Greater operational reliability and flexibility, Facilitates assessing system performance and reporting, improved asset management, reduced GHG emissions, reduced risks associated to sub-optimal operation

Water and Wastewater Companies
for Climate Mitigation

WaCCliM

The Water and Wastewater Companies for Climate Mitigation (WaCCliM) project, is a joint initiative between the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and the International Water Association (IWA). This project is part of the International Climate Initiative (IKI). The German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) supports this initiative on the basis of a decision adopted by the German Bundestag.

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IWA the international water association