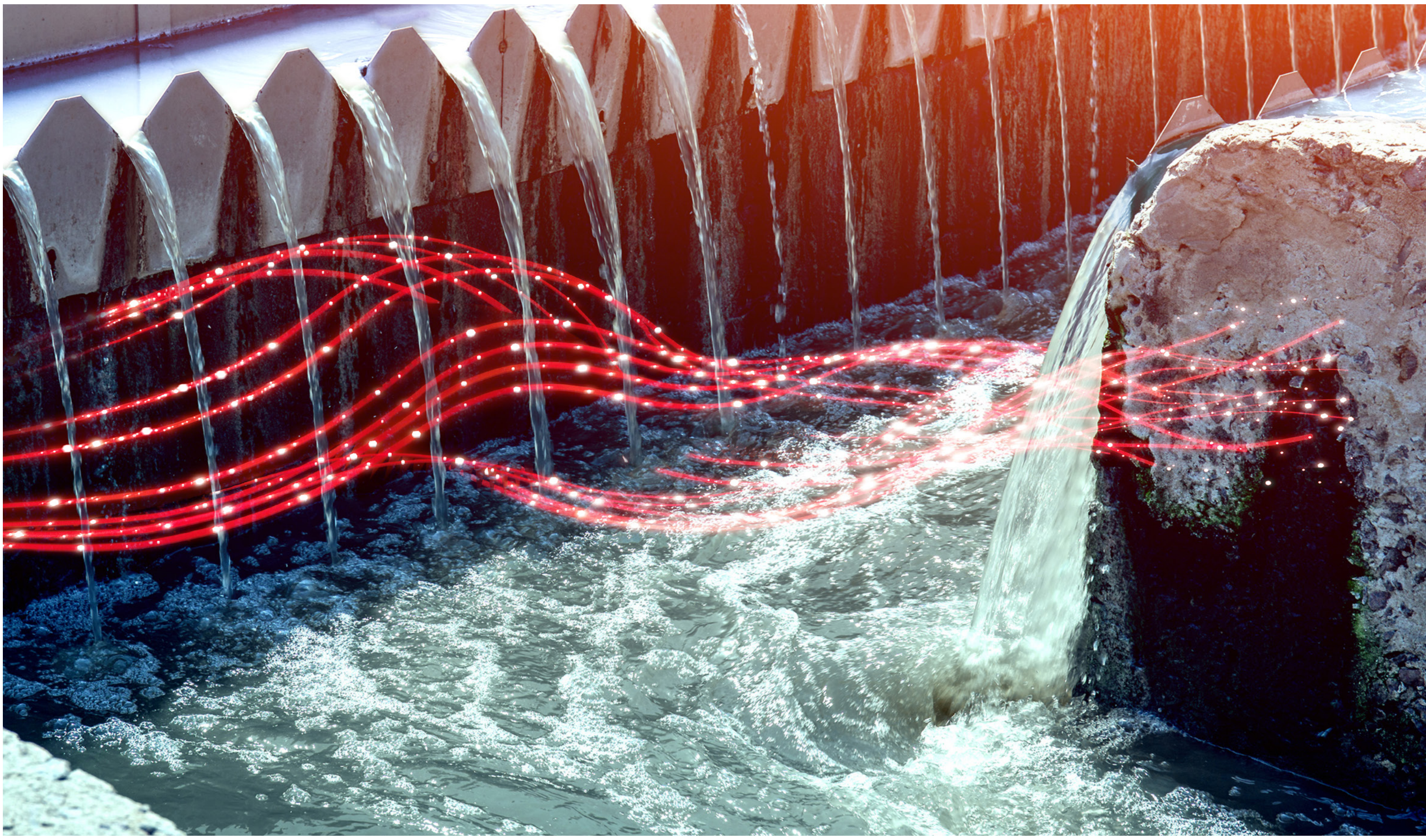
WHITE PAPER

Overcoming energy efficiency challenges in the water and wastewater industry



Growing water demand requires better energy efficiency

Water demand is continuing to increase as the global population grows. Clean water is required by people for drinking, cooking and washing, and by industrial facilities for cooling and other processes. Moreover, agriculture is also a major consumer of water, with irrigation using about 70% of the world's fresh water.[1] This White Paper takes a look at ways to reduce energy use and improve efficiency across the water industry.

The water and wastewater industry requires significant amounts of energy to produce and provide clean water, and to process the subsequent wastewater. It is estimated that between 3.5% to 4% of the world's electrical energy is consumed by the water and wastewater segments.[2] However, it has been calculated that energy consumption in the water sector could be reduced by 15% by 2040 if the right energy efficiency and energy recovery measures were adopted.[3]

Water and wastewater utilities use 4% of the world's energy, which is almost as much as the entire energy demand of Australia.[2]

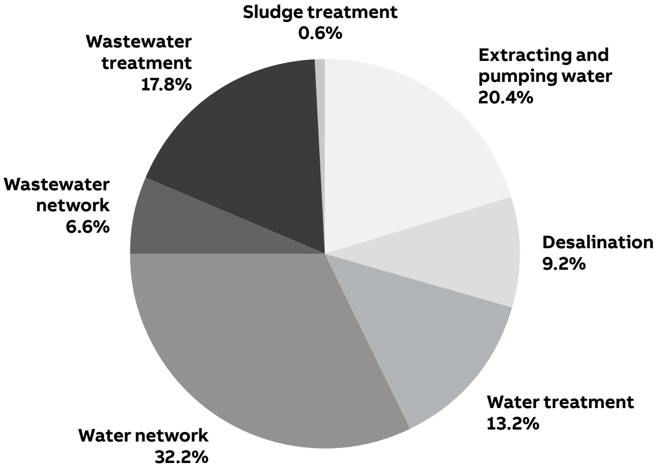
Utilities in the water and wastewater industry are increasingly looking for ways to improve their energy efficiency. This trend is driven by several things including new sustainability legislation. In the EU, for example, the European Green Deal sets out targets and policies that require businesses to reduce emissions and minimize their energy use, as well as to eliminate water pollution. Pressure on water tariff prices are also a big factor. It is estimated that in most cases water tariffs do not cover the cost of production and operation due to high energy costs and high

On average, energy accounts for 45% of the cost of water production.[4]

maintenance costs. The high energy consumption and costs are in large part to mechanical water flow control methods and oversized pumps and motors.

Different processes throughout the water and wastewater cycle consume different amounts of energy, however the prevalence of these processes varies by region. For example, the amount of wastewater processing varies around the world. As a result, globally, water distribution networks still consume by far the most energy even though wastewater processing uses more energy per cubic meter of throughput.[5]

Global water utility energy consumption by process[5]



A brief overview of energy use in the industry

Below is an overview of the processes that consume the most energy at each stage of water and wastewater handling.

Clean water
Water treatment facilities pump and process water to make it drinkable. It is estimated that pumping consumes around 80 to 85% of the energy used during water treatment, with centrifugal pumps being the most commonly used type of water application.[6] The amount of energy needed for treatment varies by location and water source, and on the level of contamination in the water.

The energy required to extract water, transport it to treatment facilities and to subsequently distribute the treated water to customers also varies significantly by location. Water sources and reservoirs can be many miles from the end customers. In some cases, like the South-North Water Transfer Project in China and the State Water Project in California, USA, water is transported well over 1000 km. Globally, most consumers are located in towns and cities and, as a result, around 70% of the electricity used for water supply and treatment is used to supply people in urban areas.[7]

Irrigation
Irrigated agriculture consumes most of the world's fresh water, and it accounts for roughly 70% of total global freshwater withdrawals.[8] In irrigation, the majority of the energy is consumed by the pumps used to pump ground or surface water. Both electric and diesel pumps are used around the world for irrigation applications.

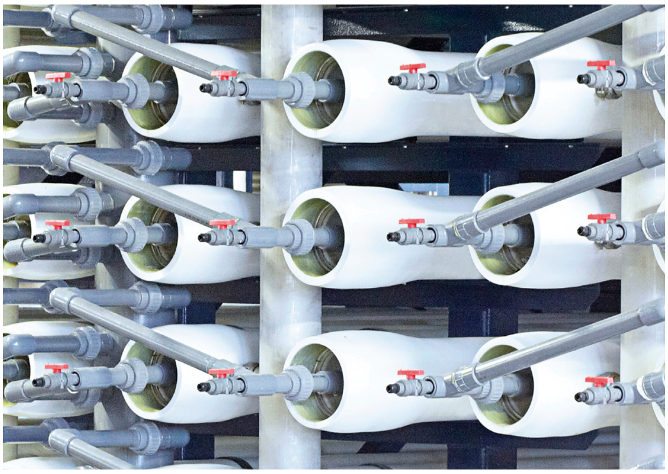
Wastewater
Wastewater treatment involves a number of energy intensive processes. In advanced wastewater treatment systems, which provide the most comprehensive water cleaning, the wastewater goes through three stages of treatment: Primary treatment to remove solids, Secondary treatment to remove dissolved organic matter and Tertiary treatment to remove nutrients like nitrogen and phosphorous as well as any remaining suspended solids.

Typically, about 50% of the energy used for wastewater treatment is consumed during secondary treatment.[9] One of the most energy intensive process in this stage is aeration during the biological processing. Pumps also consume a significant amount of energy, and these are used for wastewater collection and other processes throughout the plant. Together, aeration and wastewater pumping can account for more than 60% of the energy consumed by a wastewater plant.[10]

Sludge treatment
Due to its high solid content, pumping sludge uses a significant amount of energy, and processes like drying and thickening using centrifuges are the most energy intensive.

Desalination
Desalination is one of the most energy intensive areas of the water and wastewater industry. Although it produces less than 1% of the world's fresh water, it accounts for around 5% of the water sector's electricity use.[11]

Pumping processes use the most energy during desalination, for example, raising sea water to the level of the facility, high-pressure desalting with semi-permeable membranes and high-pressure pumping for reverse osmosis. The energy required to run high-pressure pumps accounts for approximately 25 to 40% of the overall cost of desalinated water.[12]



Opportunities for saving energy

There are several technologies available that can help water and wastewater plants improve their energy efficiency. The most notable of which are variable speed drives (VSD) and upgrading motors to more efficient models.

Because pumping systems are used throughout the water and wastewater process, they offer good opportunities for saving energy. It's estimated that upgrading to new pumping technology can lead to energy savings of 3 to 7%, and using VSDs with high-efficiency motors can result in about 25 to 30% energy savings.[13]

Optimizing pumping systems with VSDs and high-efficiency motors

Upgrading motors to more efficient models can improve the overall efficiency of water and wastewater applications. Currently, many motors have IE3, IE2 or even IE1 efficiency. For example, induction motors are available with up to IE4 efficiency and synchronous reluctance motors, like ABB's SynRM motors, are available with IE5 efficiency. Since each IE class delivers 20% lower losses, upgrading offers the potential for clear energy and cost savings.

VSDs and motors are applied to applications throughout the water and wastewater industry, including clean water production, desalination and wastewater and sludge treatment. VSDs and motors are also used in irrigation pumping systems to extract and transport water from wells and waterways, and to distribute it to crops via sprinklers and other systems. The energy savings enabled by VSD and motor packages can be significant.

$$\frac{Qn}{Qx} = \frac{Nn}{Nx}$$

$$\frac{Hn}{Hx} = \left(\frac{Nn}{Nx}\right)^2$$

$$\frac{Pn}{Px} = \left(\frac{Nn}{Nx}\right)^3$$

The affinity laws show:

Flow [Q] is proportional to speed [N]
Head [H] is proportional to speed [N] squared
Power is Flow * Head
A decrease of speed with 50% will give: 50% flow, 25% head and 12.5% power

The pump affinity laws for centrifugal loads such as fans and centrifugal pumps can be used to calculate the energy consumption and energy savings potential of related applications. For example, water and wastewater applications most commonly require flow control. If the flow is reduced by 20% using a VSD controlled motor, the power drawn by will be only 51% of its nominal power. Using mechanical flow control methods, with the motor running at full speed, the power consumption will be much higher.

Using VSDs with high-efficiency motors can lower energy use in clean water, desalination and wastewater processes by about 25 to 30%.[14]

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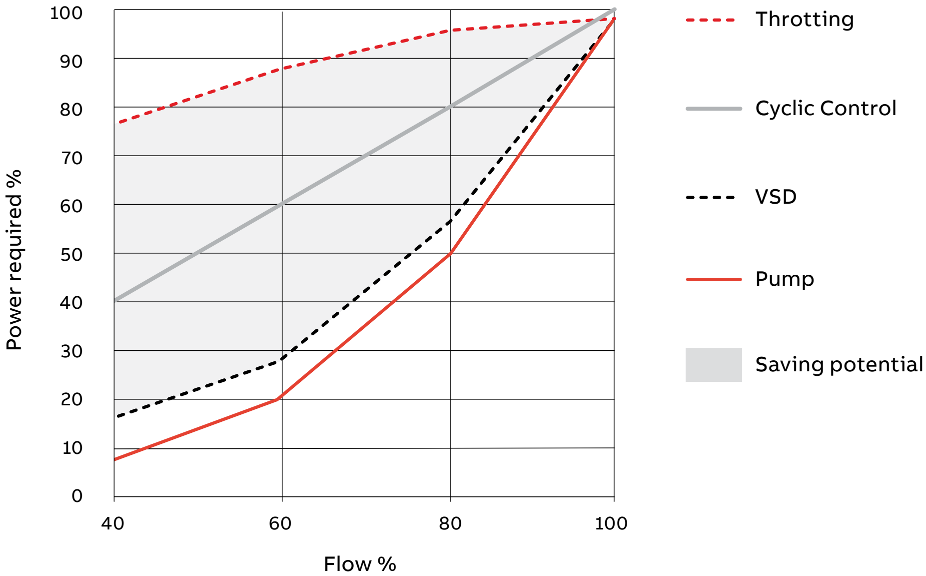
Water flow control by regulation of motor and pump speed.

Examples of the power consumption of various control methods.

Note that pumps have a minimum flow rate and they cannot go down to 0% flow.



VSDs can also be added to existing motors in a pumping system to improve energy efficiency, and in general, adding a VSD to an existing motor of a pump, fan or compressor, can reduce power consumption by 25%.[15]

Energy efficiency
Energy optimization using digital solutions is another way to reduce energy use. For example, it is estimated that optimizing the control of pumping systems in wastewater treatment plants could result in 10 to 20% energy savings.[16]

Energy optimization can be implemented in a continuous manner, for example, by installing sensors on motors and pumps, or even by optimizing the whole system architecture of a water and wastewater plant. Data from connected equipment, together with service expertise, can be used to remotely monitor and optimize pumping efficiency and performance. In addition, VSDs also provide convenient access to energy optimization functions, without the requirement for other equipment. For example, VSDs, like the ABB ACQ580 VSD for water and wastewater, include a built-in energy optimizer and built-in pump functionalities. This automatically ensures the maximum torque per ampere and reduces the energy drawn from the supply. VSDs can also include energy monitor functions to measure the savings in energy, CO_2 emissions and money.

Recovering energy
In wastewater treatment plants, energy can also be recovered as heat or electricity generated using biogas from sludge. This energy can be used to reduce the overall energy requirements of the plant. Currently, the amount of electricity produced from sewage sludge accounts for about 4% of the electricity needs in the municipal wastewater sector, worldwide.[17] However, it is estimated that by making full use of energy recovery throughout the industry, recovered energy could provide over 55% of the sector's needs by 2040.[3]

CUSTOMER CASE

KLIS successfully starts the world’s largest multi-stage lift irrigation project

The Kaleshwaram Lift Irrigation System (KLIS) in India is the world’s largest multi-stage lift irrigation project. Annually, it lifts 5.5 billion m^3 of water to provide irrigation to parched areas of Telangana state. The KLIS relies a series of underground and surface water pumping stations in a system that stretches over 300 km. This raises water up from river or reservoir sources to be redistributed in channels and/or further reservoirs before pumping to the next stations. ABB supplied 37 motors of both 40 and 43 MW, and 15 load commutated inverter (LCI) drive units, as well as other electrical systems, to control and run the pumps and lift the enormous volume of water required efficiently. ABB’s LCI drive solution minimizes electrical stress and inrush current in the system, and ABB MV switchgear provides further protection, stability and management. Since the KLIS started up in 2019, Telangana farmers have already seen record crops of paddy and maize thanks to the improved irrigation.

CUSTOMER CASE

Saneago reduces energy consumption in clean water pumping

Saneago provides drinking water to more than 5.7 million people in the state of Goiás in Brazil. One of their biggest overheads is the cost of the energy required to pump water and, after an energy appraisal by a partner company, they identified several areas with clear potential for improvement. To address these, ABB provided 15 high-efficiency motors and 15 drives, as well as Smart Sensors and remote condition monitoring tools, for four inlet water pumping stations. The solution included ABB ACQ580 water-dedicated drives with intelligent multi-pump control functionality. These can control several pumps simultaneously to meet flow and pressure requirements according to the actual demand. Thanks to these ABB solutions, Saneago was able to reduce their energy consumption by 25%.

CUSTOMER CASE

KMEDP minimizes energy use in desalination

Desalination is expected to meet up to 30% of Singapore's water demand by 2060 and the new Keppel Mbrazarina East Desalination Plant (KMEDP) uses advanced ABB technology to help the country meet 7% of its daily water requirements. The plant is Singapore's first dual-mode facility, which means that it can treat either rainwater drawn from the nearby Marina Reservoir or seawater. Because desalination is an energy-intensive process, the plant relies on cutting-edge technologies from ABB to ensure maximum efficiency. These include automation and control systems as well as instrumentation and water analyzers. These systems control energy-efficient motors, variable speed drives and switchgear, also supplied by ABB. Combined with process optimization, this technology has the potential to reduce the plant's electricity consumption by up to 40%.

CUSTOMER CASE

SynRM motor and drive packages reduce sludge pumping energy consumption

The Bocholt sewage treatment plant in North Rhine-Westphalia, Germany, invested in four ABB SynRM motor and drive packages for reverse sludge pumping station II. Before this, the pumping station used six pumps. However, using SynRM motors and improving the impeller geometry in the pumps significantly improved both electrical and mechanical efficiency. This means that now only four pumps are needed. Furthermore, the new pumps also require less drive power and, because the motors are controlled by variable speed drives, the return sludge flow can be adapted according to the hydraulic load on the sewage treatment plant, which saves even more energy. Thanks to this and modernization work, the Bocholt sewage treatment plant has been able to reduce energy consumption by 40%.

Conclusion

As described in this white paper, numerous energy intensive processes are used throughout the water and wastewater industry. And, because pumping is involved at almost every stage, optimizing pumping systems is an attractive and effective way to improve energy efficiency and reduce operational costs. VSDs connected to motors provide an excellent way to improve pumping system efficiency because they are highly efficient, even at partial load, and they only use the amount of energy required by the application and no more. Together with energy optimization and energy recovery, improvements in VSD-motor packages give water and wastewater businesses realistic ways to save energy and save money.

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(2) IEA World Energy Outlook 2018, Page 122, https://iea.blob.core.windows.net/assets/77ecf96c-5f4b-4d0d-9d93-d81b938217cb/World_Energy_Outlook_2018.pdf

(3) Water-Energy Nexus, World Energy Outlook Special Report, 2016, page 6, https://iea.blob.core.windows.net/assets/e4a7e1a5-b6ed-4f36-911f-b0111e49aab9/WorldEnergyOutlook2016ExcerptWaterEnergyNexus.pdf

(4) Water-Energy Nexus, World Energy Outlook Special Report, 2016, page 30, https://iea.blob.core.windows.net/assets/e4a7e1a5-b6ed-4f36-911f-b0111e49aab9/WorldEnergyOutlook2016ExcerptWaterEnergyNexus.pdf

(5) GWI Water Data webinar

(6) Water-Energy Nexus, World Energy Outlook Special Report, 2016, page 33, https://iea.blob.core.windows.net/assets/e4a7e1a5-b6ed-4f36-911f-b0111e49aab9/WorldEnergyOutlook2016ExcerptWaterEnergyNexus.pdf

(7) ABB, Water treatment plants, Providing clean and safe drinking water, page 2, https://library.e.abb.com/public/37a912f8291c4647abee3e3e05078d52/Cleanwater_brochure_3AXD50000483624_REVB_EN.pdf

(8) Water-Energy Nexus, World Energy Outlook Special Report, 2016, page 11, https://iea.blob.core.windows.net/assets/e4a7e1a5-b6ed-4f36-911f-b0111e49aab9/WorldEnergyOutlook2016ExcerptWaterEnergyNexus.pdf

(9) Water-Energy Nexus, World Energy Outlook Special Report, 2016, page 35, https://iea.blob.core.windows.net/assets/e4a7e1a5-b6ed-4f36-911f-b0111e49aab9/WorldEnergyOutlook2016ExcerptWaterEnergyNexus.pdf

(10) ABB, Wastewater treatment plant, Building resilient, safe and sustainable facilities, page 2, https://search.abb.com/library/Download.aspx?DocumentID=3AXD50000421060&LanguageCode=en&DocumentPartId=&Action=Launch

(11) Water-Energy Nexus, World Energy Outlook Special Report, 2016, page 30-31, https://iea.blob.core.windows.net/assets/e4a7e1a5-b6ed-4f36-911f-b0111e49aab9/WorldEnergyOutlook2016ExcerptWaterEnergyNexus.pdf

(12) U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Chapter 7 Desalination, Powering the Blue Economy: Exploring Opportunities for Marine Renewable Energy in Maritime Markets, April 2019, page 90. https://www.energy.gov/sites/prod/files/2019/09/f66/73355-v2.pdf

(13) World Bank Energy Sector Management Assistance Program, Technical Report 001/12, Box 2.1, page 13. https://www.esmap.org/sites/default/files/esmap-files/FINAL_EECI-WWU_TR001-12_Resized.pdf

(14) For an example of the calculations involved, see “Program Insights: Variable frequency drives,” Consortium for Energy Efficiency, 2019, https://www.cee1. org/content/variable-frequency-drives.

(15) As specified by technical specification IEC TS 60034-30-2 (2016)

(16) Enhancing the Energy Efficiency of Wastewater Treatment Plants through Co-digestion and Fuel Cell Systems, Frontiers in environmental science, 30 October 2017, Page 2. Frontiers | Enhancing the Energy Efficiency of Wastewater Treatment Plants through Co-digestion and Fuel Cell Systems | Environmental Science (frontiersin.org)

(17) Water-Energy Nexus, World Energy Outlook Special Report, 2016, page 34, https://iea.blob.core.windows.net/assets/e4a7e1a5-b6ed-4f36-911f-b0111e49aab9/WorldEnergyOutlook2016ExcerptWaterEnergyNexus.pdf

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