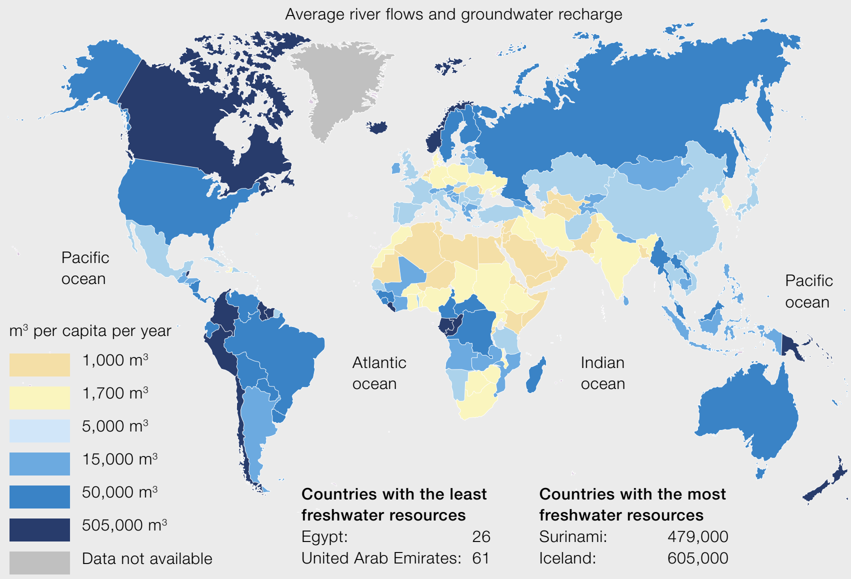
Water of life

Sustainability and energy efficiency in the water industry

DAVID PRIDGEON, WERNER JANIK, MARKUS GAUDER, SENTHILMURUGAN SUBBIAH, NAVEEN BHUTANI – Water shortages pose an immediate threat in terms of health issues and economic development. The threat is developing at an alarming rate due to growing demand. According to the United Nations [1], there are already 700 million people distributed across 43 countries facing a water shortage. Projections show dramatic changes over the next 15 years such that almost two thirds of the world's population are expected to live in water stressed countries by 2025 → 1 → 2 [2]. This equates to a 50 percent consumption increase by 2025 in developing countries and 18 per cent in developed countries, according to the UN's GEO-4 report. Traditionally the passive collection of rain water from rivers and reservoirs and the use of artesian wells have met the water demand in populated areas but the effects of population growth, greater urbanization and climate change are increasing the need for artificial desalination and advanced wastewater treatments. As energy plays a key role in production, transfer, distribution and treatment of water and wastewater, it is necessary to optimize its usage to increase the level of sustainability and to minimize specific costs.

1 Illustration of levels of freshwater in 2000



Source: World Resources 2000–2001, People and Ecosystems.
The Fraying Web of Life, World Resources Institute (WRI), Washington DC, 2000.

To secure future water supplies a tremendous investment in water infrastructure is required, either by rehabilitating deteriorating systems and plants or by extending the infrastructure by building new facilities. Depending on the region, these investments will occur in various water and wastewater applications. They include, for example, pumping stations for water transfer schemes, desalination, municipal and industrial water treatment, re-use and recycling, water distribution, municipal and industrial wastewater treatment and irrigation schemes for agriculture.

Such investments should not focus purely on the hardware of the infrastructure but should also encompass its operation and maintenance. A common factor in all the water and wastewater applications referred to above is that they are all very energy intensive processes → 3. Overall, tighter water quality standards, water stress and scarcity are drivers for more energy intensive technologies for tertiary or advanced wastewater treatment. In addition, in a growing number of countries, there are direct or indirect government incentives to reduce energy consumption.

This article looks at the energy efficiency aspects of the water supply, whereas the accompanying article "Managing water use responsibly" on pages 17–23 of this edition of *ABB Review* looks at the aspect of saving water itself. As these articles show, the topics are closely interrelated and the optimization of water networks must consider both aspects rather than one at the expense of the other.

Enormous energy savings can be achieved by controlling the discharge pressure and flow by varying their speed rather than using throttle valves.

Energy efficiency assessment

In order to achieve a higher level of energy efficiency, the complete application process needs to be taken into consideration to capture all opportunities for efficiency improvements and then to properly prioritize these opportunities. While for green field systems the optimization aspects may well be covered during the design phase, for plants and systems already in operation, the identification of improvement opportunities is a much more challenging exercise which requires a structured methodology for execution. Optimization of energy consumption can be achieved by following different reduction strategies including the optimization of the mechanical system, electrical system, the controls as well as implementing energy recovery or cogeneration measures.

An example of such an approach is the ABB concept of industrial energy efficiency (IEE). With this methodology, the focus is not only on individual items of equipment but on the overall system, considering the process and the site organization as well as the consumption of utilities. This concept of IEE employs a staged approach covering an opportunity identification phase, a master plan phase designed to assess and prioritize identified improvement opportunities and, in conclusion, the implementation phase. The execution is a joint effort by ABB and the client, involving experts from different disciplines.

Opportunity identification

During this phase the efficiency of existing utility systems is assessed and improvements that can be achieved from process control, equipment modification or alternative energy efficient technologies are identified. Available data such as around consumption or flow conditions as well as

Title picture
In many parts of he world, water is a scarce commodity. How can it's future supply be assured in the face of growing demand and climate change?

site assessments are considered as inputs for the analysis. Additionally, monitoring and targeting as well as the assessment of behaviors and practices relating to energy efficiency are part of the phase.

During opportunity identification, a critical analysis of process components in use is made. Asking, for instance:
- Is it required to run the process equipment at all?
- Can it be run for fewer hours, e.g., part time versus full time use?
- Can the process or equipment achieve the same results at a lower flow capacity?

Answers to such questions deliver a first indication of possible energy efficiency optimization potentials.

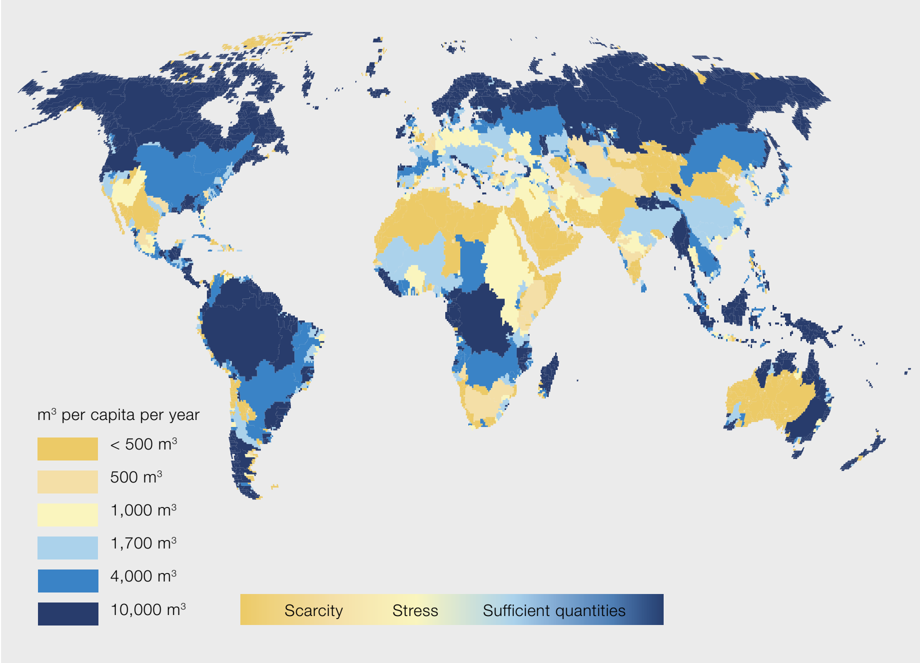
As an example, taking a closer look at the biological process of a wastewater treatment plant, the following general opportunities should be analyzed in more detail as according to experience, energy efficiency improvement potentials are connected with these:
- Optimizing sludge recirculation.
- Optimizing sequence of disc aerators.
- Reduction of sludge age.
- Implementing, or modification of, advanced controls.
- Changing the selected aerator type or optimization of aerators.

The analysis and implementation of energy efficiency measures in a treatment process needs always to consider that there is an inherent risk that reducing energy consumption may adversely affect the operation of the biological process, eg, by reducing the amount of oxygen available for the digestion process. The selection of measures should therefore be carefully taken and consider the possible impacts on the process and its operation.

The master plan

During the phase of master plan development, the set of selected energy saving opportunities is developed into an implementation plan. For each of the opportunities, the key aspects for implementation are considered. The master plan development phase uses alignment and prioritization workshops with the customers to define elements such as the magnitude of energy savings and the investment range or constraints. The plan is developed based on the assessment of the opportunities in terms of:

2 Illustration of projected levels of freshwater in 2025



- The technical feasibility and data confidence of the energy saving opportunity.
- The business impact and development requirements of the energy saving opportunity.
- The timescale to implement the energy saving opportunity, including budget and site availability.
- The estimated time to achieve a complete return on investment.

As part of this phase, projects are separated into two tiers:
- Tier 1 describes those opportunities selected for immediate development towards implementation.
- Tier 2 gives opportunities that require further information prior to selection and development.

While for tier 1, opportunities project specifications are generated, for tier 2 opportunities a summary is created to enable the confirmation of the project.

The implementation phase

Implementation measures follow the outcomes of the master plan. For implementation measures, the implementation team set-up is driven by the nature of the projects themselves and the in-house capabilities of the client's organization.

Energy efficiency in different applications

Looking at pumping stations for instance, one of the potentials for major energy savings is associated with flow and pressure control. Control can be achieved using

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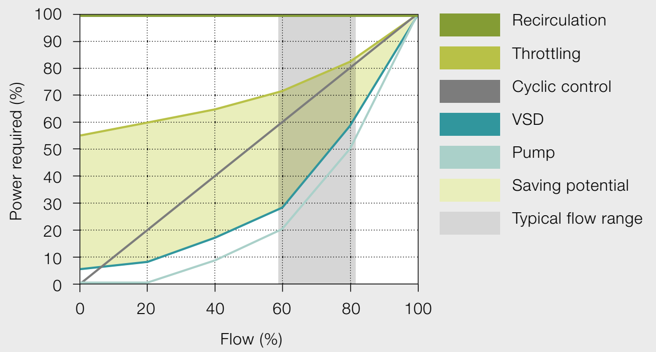
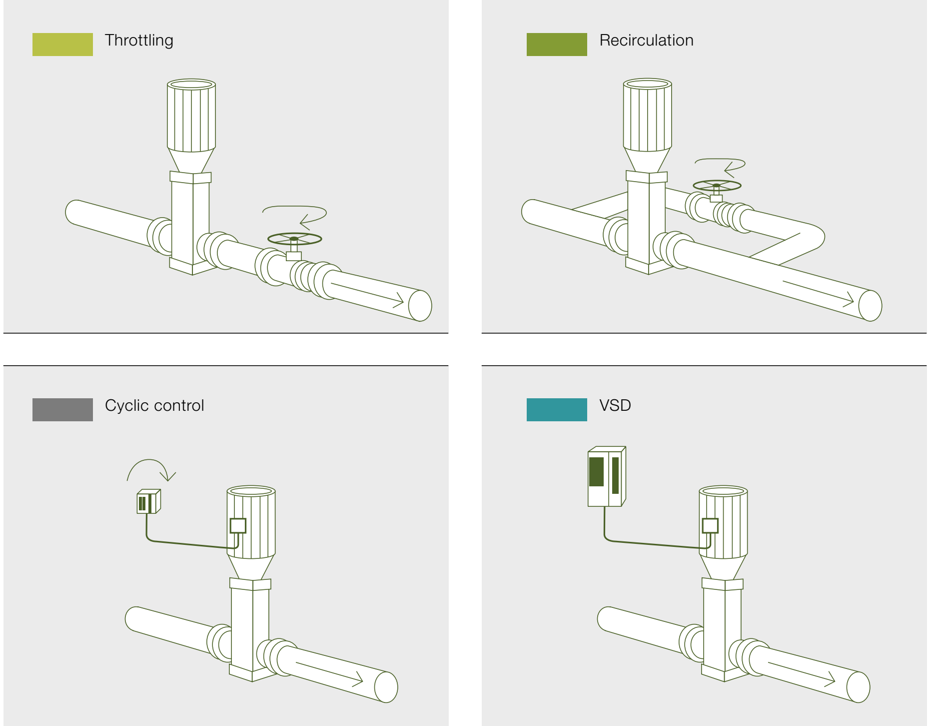
3 Comparison of energy consumption in various treatment processes

	Percentage of required energy expenditure for pump operation	Percentage of operational expenditure for energy
Pumping Station Applications	80	50 to 60
Water treatment	75	40 to 50
Wastewater treatment	main energy consumption due to aeration and solids handling	40 to 50
Desalination	Varies according to process employed	20 to 40

4 Comparative energy usage for flow control schemes



5 Different flow and pressure control solutions



either a mechanical or an electrical solution. In many cases, pumps are operated at partial loads and thus enormous energy savings can be achieved by controlling the discharge pressure and flow by varying their speed rather than using throttle valves for mechanical control ➔ 4 ➔ 5.

Pump affinity laws

1. Flow is proportional to pump speed
2. Pressure is proportional to the square of pump speed
3. Power is proportional to the cube of pump speed

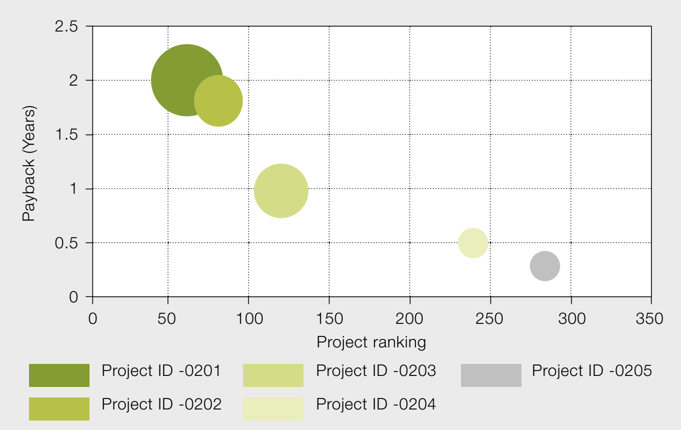
Such mechanical fixed speed solutions can be compared to adjusting the speed of a car by braking while keeping the foot on the gas, resulting in energy wastage and worn out equipment. The more elegant and energy efficient solution is to use variable frequency drives, allowing changes in production volume by adapting the motor speed. Such an approach can be compared to reducing the speed by taking the foot off the gas and switching to a lower gear.

For pumps with a relatively low static head the majority of the pump discharge head is required to overcome the friction loss in the pipe. By reducing the speed with a variable speed drive (VSD) to reduce the flow, the head is reduced as well. This will result in operating the pumps at its best efficiency point (BEP) over the operating speed range of the drive with the clear advantages of achieved energy savings, decreased of CO_2 emissions and minimized operating costs as well as a fast and precise process control. VSDs can also act as soft starters, reducing stress on the network, motors and pumps. During the start up process, VSDs progressively increase the motor speed and smoothly accelerate the load to its rated speed. A single variable speed drive can be used to start several pumps in sequence. The soft start feature eliminates high starting currents and voltage dips which can cause process trips, therefore maintenance costs are reduced and the lifetime of the system equipment extended. In case the demand for water is reduced, VSDs slowly reduce the speed of the pumps, avoiding water hammer and ensuring a minimum water velocity in the system.

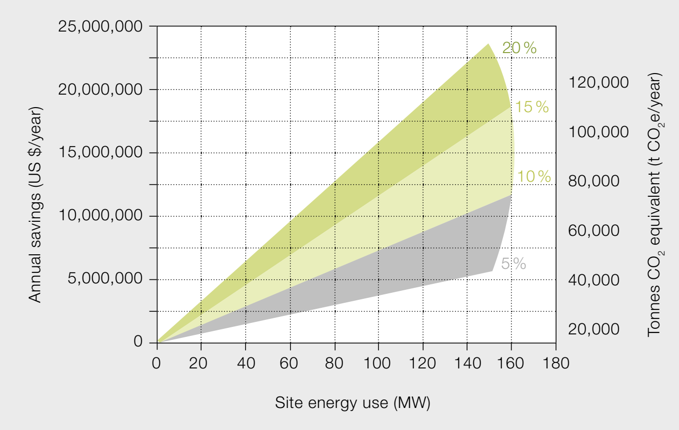
Taking a measured approach with PEMS

When it comes to energy efficiency and related improvement measures, a key challenge is always about the definition of a baseline in order to determine and evaluate the achieved improvements. In the case of pump systems, measuring the efficiency of a pump gives a more detailed insight and thus allows much better assessment and benchmarking of the equipment. The pump efficiency monitoring system (PEMS) is an ABB solution that allows the determination of the efficiency of a pump in real time and thus to get condition based information. PEMS applies thermodynamic principles for efficiency calculation and only requires as inputs pressure and temperature measurements on the suction and delivery side of the pump. If the electrical power

6 Typical example of evaluation of identified opportunities



7 Annual savings related to energy efficiency improvement and tonnes of CO_2 saved in relation to site energy use



is measured as well, the flow values can also be derived from this method. PEMS can not only be used for benchmarking activities but also provides reduced operational costs when operating the system with the highest efficiency. In addition, the plant availability can be increased by implementing optimized maintenance schedules. Taking a look at the broader picture is fundamental to developing a comprehensive strategy. The obvious potentials might not be the ones that deliver the highest benefits.

Economic aspects

As the methodology already implies, it is usually applied to existing plants. As a rule of thumb, for all plants to be considered for an energy assessment, the requirements such as follows should guide the selection process:

- Plants should have a remaining plant lifetime of at least 10 years. If the lifetime is too short there will not be enough time left to sufficiently enjoy the savings.
- The unit energy cost of plant operations should be above medium level compared to the global average. Energy costs which are too low may lead to the conclusion that the saved energy does not have sufficient value to be economically attractive.

However it is clear that among all of the opportunities identified, only those which have an attractive return on investment will be shortlisted. The payback graph shows a typical example of such an evaluation ➔ 6. The opportunity ranking gives information as to how quickly and simply an opportunity can be installed (high value means simple and quick installation), the bubble sizes are proportional to the value of savings per year, and most importantly it gives information on expected return on investment. The projects in focus have a payback period of less than three years.

Typically the amount of potential opportunities which are economically attractive and which are shortlisted for implementation will provide on average 5 to 10 percent of improvement in energy efficiency in total. Those savings do not only provide cost reduction in terms of energy saved or production increases, they also provide savings in CO_2 emissions ➔ 7. Savings in CO_2 emissions can be calculated as equivalent to energy consumption, where applicable carbon credit trading might support investment for energy savings. Results in the area of the grey segment in ➔ 7 can always be expected and would also lead to significant plant performance improvements in terms of energy savings.

Mechanical fixed speed solutions can be compared to adjusting the speed of a car by braking while keeping the foot on the gas.

ABB is increasingly looking at improving the energy efficiency of water applications including desalination processes and is thus stepping into the service business for energy efficiency assessments in general and carbon footprint assessments specifically. This allows to tap underlying opportunities through improved sustainability and better compliance at marketplace in the water industry. Using ABB's extensive R&D experience an extensive set of different solutions is available to improve energy efficiency in water and wastewater applications and thus to deliver advanced solutions.

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[1] www.un.org/waterforlifedecade/scarcity.html
[2] World Resources 2000-2001, People and Ecosystems: The fraying web of life, World Resources Institute (WRI), Washington DC, 2000.