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Engineered Reliability

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MAGAZINE FOR HYDROPOWER TECHNOLOGY

HyPower

#26 | Spring 2015

WHY HYDROPOWER BRINGS MORE THAN JUST CLEAN ENERGY

EMPOWERING

GLOBAL EXPERTISE

VALUABLE INFRASTRUCTURE FOR RURAL NORTHERN INDIA

FULL-LINE SUPPLIER

SMALL HYDRO MAKES A BIG IMPACT IN CENTRAL AND SOUTH AMERICA

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HYDRO: POWERFUL AND BENEFICIAL

Rapid population growth, a push for economic and social development, and climate change are driving the search for reliable sources of renewable energy. Yet one of the best solutions has been around for far more than 100 years – dependable and proven, efficient and affordable: hydropower.

Since a few resourceful engineers and inventors, whose names remain eminent in the industry, first pushed forward hydropower technology in the mid-19th century, hydroelectric power has become a global success story. Today, it offers clean, stable and affordable electricity in all parts of the globe. Although it's one of the most established sources of energy, it's also one of the most innovative, constantly developing new technologies to better serve a growing world.

Hydropower is truly multi-functional: dams are used for flood protection, while greater control over water depths enables improved river navigation. Surrounding areas profit from improved irrigation systems and secure drinking water supply, while pumped storage reservoirs provide a means of storing power and lending stability to the grid – vital, as we see an increased use of volatile renewables like wind and solar.

Perhaps the greatest benefits hydropower can bring, though, are of the social and economic kind. The sheer presence of reliable electricity can make a huge difference to many people's lives in remote and underdeveloped regions, but there are also a number of secondary benefits: roads, hospitals, schools and new job opportunities. Education, health and the chance for social, professional and personal development are key for a better future, and hydropower can help facilitate the preconditions for this.

All these positive contributions can sometimes be overlooked, which is why we outline them in detail in this new issue of HyPower – a reminder of what a powerful and beneficial resource hydropower can be.
Enjoy the read!

Yours sincerely,

Ute Böhringer-Mai
Head of Communications

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A visual guide to the world's potential and installed hydropower capacity by continent

LIKE SWISS CLOCKWORK

WALES Voith Hydro has been helping to inject new life into RWE Innogy UK's largest hydropower station, Dolgarrog, in Wales. After generating energy for over 100 years, it has been undergoing major refurbishment: as well as comprehensive pipeline renewal, unit 4 has been successfully modernized by Voith's small hydro specialist Kössler, with the new runner operating like "Swiss clockwork," says Kössler CEO Josef Lampl. Due to the installation conditions on site, the runner was CFD-designed at Voith's Global R&D Center. Installation at the narrow powerhouse still proved a challenge, and to make the equipment a perfect fit, the assembly process was first modeled in 3-D. After successful commissioning, the 10 MW runner is now supporting the plant in covering high-peak energy demand for the national grid. //

RECORD-BREAKER

BRAZIL The largest runner ever produced by Voith Hydro in Latin America was shipped to the Belo Monte project in January. A 12-axle trailer left the Voith manufacturing shop in Manaus, Brazil, with the 320-ton, 8.5x5-meter runner to load it onto a barge for the 890-kilometer downstream journey towards the Belo Monte hydropower plant. Voith's new Manaus location is strategically located between several hydropower projects, planned or in progress. "This proximity enables greater flexibility and speed. Our customers benefit from it, from purchase to maintenance of equipment," explains Marcos Blumer, President & CEO of Voith Hydro Latin America. The Belo Monte hydropower plant on the Xingu River is expected to be commissioned in 2019 and will have an installed capacity of 11,233 MW. Voith is delivering four Francis turbines, four generators, electrical and mechanical auxiliaries, as well as providing the complete automation systems and the engineering for the project. //

CELEBRATING PAST AND FUTURE

CANADA Voith Hydro Mississauga in Ontario celebrated its 25th anniversary this April with a special two-day symposium, which featured expert training, a tour of its facilities and various topics related to the future of the Canadian hydro industry. The Mississauga site has established itself as a center of excellence for coil production modernization and service, and works with many different customers and all Voith Hydro locations worldwide. It combines both a high-tech facility, which was completely modernized in 2009, and an international team of highly experienced and specialized staff. //

BALANCING THE GRID

LUXEMBOURG Voith Hydro Heidenheim will refurbish four motor-generators at Vianden pumped storage plant, Luxembourg. The modernization work aims at continuing safe and stable operation of the highly flexible machines. With their ability to power up in short time and to quickly switch between operation modes, pumped storage plants like Vianden, besides storing energy, can balance load variations and thus strongly contribute to grid integration of renewables. The modernization also includes a new construction for the rotor poles that facilitates inspection and replacement of the poles. //

WORLD OF WATER

From food to sanitation, water is essential for much more than just drinking, but the planet's most important resource remains a rare commodity for millions across the globe.

USA: 380 liters

Europe: 190 liters

Africa: 19 liters

2 Contrasting consumption

- Residents of Sub-Saharan Africa use only 7-19 liters of water a day
- Europeans use around 190 liters a day on average
- American residents use about 380 liters of water a day

97%

1 Salt water dominates

About 97% of all water on Earth is salt water, leaving only 3% as freshwater. Approximately two-thirds of this freshwater is locked in glaciers and ice caps, making them unusable.

3 Journey for water

People in Africa and Asia have to walk an average of 3.7 miles to collect water. The United Nations estimates that Sub-Saharan Africa alone loses 40 billion hours a year collecting water; the same as an entire year's labor in all of France.

4 Missing the basics

783,000,000

people of the world's total population of around 7.3 billion do not have access to clean water and almost 2.5 billion do not have access to adequate sanitation.

95% water

5 Share of water

Tomato: 95%
Humans: 53-75%
Firewood: 50%
Recycled plastic cup: 50%

6 liters

6 Flushed away

The average toilet uses six liters of clean water in a single flush.

7 More than you thought?

Everything we eat and drink needs water to grow and be produced:

1 apple	70 liters
150g beefsteak	2,025 liters
1 slice of bread	40 liters
1 hamburger	2,400 liters
1 cup of coffee	140 liters

Sources: 1 US National Oceanic and Atmospheric Administration 2 6 US Environmental Protection Agency 3 United Nations Development Programme: *Resources Guide on Gender and Climate Change* (2009) 4 UN-Water 5 German Federal Agency for Civic Education: *Fluter* magazine 7 UN-Water; Water Footprint Network

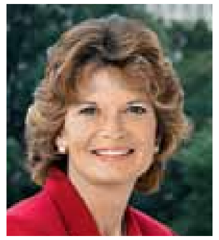
ENERGY AND MUCH MORE

Not just a reliable source of renewable power, **hydropower brings multiple socio-economic benefits** to many parts of the world.

Symptomatic of our growing demand for electricity, in just a few decades, the city of Abu Dhabi has mushroomed from a small port into a global financial metropolis that is expanding each year.

The population of the world is forecast to grow from 7.3 billion to 8 billion in the next nine years. That means a huge growth in demand for electricity just when mankind is struggling to reduce greenhouse gas emissions. The problem is that in most countries of the world – whether already industrialized or emerging – economic development is intrinsically linked with high levels of carbon emission due to overdependence on fossil fuel. The "dream solution" is a source of electricity which is infinite, has near-zero fuel costs and emissions, and which is also reliable and flexible. That is not as elusive as it sounds.

Thirty years ago the World Commission on Environment and Development pointed out that hydroelectric power stations that are developed and operated in a manner that is economically viable, environmentally sensible and socially responsible ▷



“The Department of Energy estimates we have the potential to produce 300 GW of additional hydroelectric energy in America.”

US Senator Lisa Murkowski, Chairwoman of the Energy and Natural Resources Committee

Hydropower’s global growth potential

According to researchers at the Leibniz Institute of Freshwater Ecology and Inland Fisheries in Berlin, hydropower development is primarily concentrated in developing countries and the emerging economies of Southeast Asia, South America and Africa. The Balkans, Anatolia and the Caucasus are additional centers of future dam construction.

At least 3,700 major dams, each with a capacity of more than 1 MW, are either planned or currently under construction. These are predicted to increase global hydroelectricity capacity from the current level of around 1,000 GW by 70% to about 1,700 GW over the next 10 to 20 years. More than 40% of the hydropower capacity under construction or planned will be installed in low- and lower-middle-income countries.

Further potential lies in upgrading existing dams that have not yet been utilized for hydropower generation. In the US alone, less than 20% of dams are used to generate electricity from hydropower, with 80,000 dams awaiting electrification – a potential that has been estimated at 70 GW.

▷ represent the best concept of sustainable development. “That means, development that today addresses people’s needs without compromising the capacity of future generations for addressing their own needs,” the Commission said.

Today, more than 30 countries, from Brazil and Mozambique to Nepal and Norway, rely on hydropower for over 80% of their electricity. Even in fossil-fuel-rich countries, hydropower can play an important role. In the United States, for example, hydropower accounts for over half of all renewable electricity generation and 7% of total electricity generation. In fact, production of all renewables is growing rapidly, almost doubling between 1991 and 2011. But hydropower still represents the lion’s share of this and now accounts for about 16% of global electricity production.

UNIQUE QUALITIES

Hydropower is unique among renewable sources of energy. Like most others, it has the enormous advantage that its primary source of energy is not subject to daily fluctuations in international prices; it is free and steadily available. But unlike other renewables, hydropower is the only one that combines a high cost-benefit ratio and efficiency with flexibility and reliability. Solar and wind plants can cost as much to build as hydro plants, but produce less energy because they have lower plant factors. The energy conversion system efficiency for a well-operated hydroelectric power plant can be around 85-95%, compared with about 35% for wind energy, 15% for solar power and less than 50% for traditional thermal-electric plants. Recent studies show that when all project lifetime costs are taken into account, hydropower has the lowest electricity cost of any energy source. As Meike Van Ginneken, head of the World Bank’s Water Sector, notes, “Hydropower is the lowest-cost solution to providing electricity in many developing countries, with an average levelized cost of $0.03 to $0.05 per kWh, according to the Intergovernmental Panel on Climate Change. In addition, it is the largest and most readily scalable form of renewable power generation currently available. At such a low cost, hydropower can also compete economically with other large-scale energy generation technologies, such as gas- and coal-fired plants.”

ENERGY SECURITY

Hydropower also addresses a growing concern, especially in many developed countries, about energy security. Fossil fuel resources are not evenly distributed, and many nations are unduly dependent on imports. Volatility in international energy prices – and the need for foreign currency to pay for it – means that oil imports can create huge national economic challenges and worries for many countries.

This is a significant concern even for economies which already have well-developed hydropower resources. US Senator Lisa Murkowski, of Alaska, the new chairwoman of the Senate Committee on Energy and Natural Resources, believes her state offers a glimpse of the enormous potential of hydroelectric power: “It already generates 24% of our total electricity, and with 200 promising sites and 300 MW of projects being discussed at some level, it could generate enough power for the state to meet the goal of getting half of its power from renewable energy by 2025.”

Free, readily available and not subject to price fluctuations: water is an excellent source of reliable energy.

“Long life spans and zero-cost fuel provide clean, low-cost power for our homes and businesses.”

Linda Church Ciocci, Executive Director US National Hydropower Association

ULTIMATE FLEXIBILITY

Hydropower is also the ideal backstop for all grids. A unique feature of modern hydropower facilities is that they can go quickly from standstill to maximum output within a matter of minutes. This flexibility can help balance variations in generating capacity of other renewables and is a major reason why it should be embraced with enthusiasm, according to Atle Harby, Senior Research Scientist at SINTEF Energy Research and Director of Norway’s CEDREN research center.

“Wind power will vary a lot over the space of a week due to changing weather patterns. In some periods, weather patterns can tend to persist, affecting a lot of installations. Hydropower is the only renewable that has the ability to store energy for use when it is needed.” Linda Church Ciocci, Executive Director of the US National Hydropower Association, agrees wholeheartedly. “Hydropower is a vital part of our future as America demands energy that is not only cleaner, but more affordable. Long life spans, low operations and maintenance costs, and zero-cost fuel provide consumers with clean, low-cost power for our homes and businesses across the country. Not to mention the hundreds of thousands of jobs the industry has created already.”

THE POWER TO CHANGE LIVES

The benefits for developing economies can be enormous and far-reaching. Meike Van Ginneken says that for developing ▷

China's Three Gorges Dam brings vital flood protection and improved river navigation as well as clean energy.

▷ countries, hydropower contributes to reducing poverty and boosting shared prosperity. Also, water storage associated with some hydropower projects can make important contributions to water and food security and to climate resilience.

At Karcham Wangtoo in northern India, for example, the legacy of the hydropower plant completed in 2011 includes a new school, hospital and industrial training college for local villagers (see page 38 for more). After recent rehabilitation, the Cambambe plant in the southwest African country of Angola brings much-needed reliable electricity to the grid, while housing used during the construction has now been passed over to those living nearby. And royalties paid by the Itaipu project to local governments in Brazil and Paraguay have helped improve infrastructure considerably, with Foz do Iguaçu considered to have the best bus service and the best education system in all of Brazil's major cities.

In Costa Rica, hydropower development companies are required to provide community development funds to foster economic development in the project areas, while in Brazil companies are charged a fee for the water used to generate electricity, 45% of which goes to municipalities losing land to reservoir inundation and 45% to the state or provincial authorities. It is also important to recognize that hydropower is far from a "one-trick pony." Its infrastructure – especially reservoirs – is usually complementary to a range of economic and social objectives. Improved navigation, flood control, seasonal irrigation reserves, creating sustainable supplies of fresh water to prevent drought, fishing and recreational opportunities are all possible benefits that can contribute substantially to local social and economic development.

These and many other examples demonstrate ways in which the positive benefits of hydropower projects can be provided to entire communities, while at the same time offering meaningful mitigation to those that may have been most directly affected by their construction. //

"Hydropower is the lowest-cost solution to providing electricity in many developing countries."

Meike van Ginneken, Water Sector Leader, World Bank

HYDROPOWER IS ...

... renewable
By harnessing the power of running water without depleting it to produce electricity, hydropower is truly renewable.

... an enabler
Accumulation reservoirs offer incomparable operational flexibility as they can quickly respond to fluctuations in energy demand. This enables greater integration of more volatile renewables such as wind and solar power and brings stability to the grid.

... affordable
Highly efficient and with low operational and maintenance costs and an average lifetime of 50-100 years, a hydropower plant is a long-term investment that produces a high cost-benefit ratio. And unlike fuel or natural gas, river water is not subject to market fluctuations.

... reliable
Always available, hydropower can provide low-carbon base load power.

... good for economic and social development
As well as clean energy, hydropower projects also bring infrastructure such as roads and bridges to remote regions. Rivers can also be made more easily navigable, while improved educational and health facilities are a further plus.

... clean
The hydroelectric life cycle produces very small amounts of greenhouse gases. By offsetting emissions from fossil-fuel driven plants, it can help slow global warming. Hydropower plants also don't generate toxic by-products.

... versatile
Hydropower plants come in different forms and sizes. While large facilities feed into the public grid, small hydro plants can support individual businesses or residences; the energy is produced where it is needed.

... lifesaving
Dams can help protect areas vulnerable to flooding, while reservoirs act as a valuable means of storing water for drinking or irrigation.

... recreational
Reservoirs can be used for water sports, tourism and fishing, bringing both enjoyment and valuable further income to surrounding areas.

MORE THAN JUST CLEAN ENERGY

Dr. Münch is convinced that hydropower comes with many benefits and will progress positively, especially in developing regions.

From schools to roads and hospitals, **hydropower projects can bring many additional benefits to developing regions** all over the world, says Voith Hydro CEO Dr. Roland Münch.

As CEO you travel all over the world, in order to meet customers and inspect hydropower projects. What things have impressed you most?
For me as an engineer, the sheer size of our turbines and generators, their energy output and the power density are extremely impressive. The biggest turbines we build can produce power for more than a million people, while even small hydro equipment generates energy for up to 10,000 people. The size of the construction sites required for these projects, which sometimes involve several thousand employees, is also remarkable.

These projects often require a considerable amount of new infrastructure. Do local people benefit from this after construction has finished?
Yes, especially in areas that are not highly developed or very remote. New infrastructure might include transportation and road systems, as well as all the other things necessary for the workforce such as accommodation, canteens, schools, hospitals and wastewater treatment facilities. When visiting plants in operation, I have seen that these social facilities are very much appreciated and help to improve living standards among the local population. In this way, hydropower supports regional development, improves living standards and provides access to education.

And yet we keep seeing protests against large hydropower projects, because they are thought to damage established ways of life. Can you explain this?
Many people in developed countries say we should let people go on living in the conditions they are used to. This effectively means allowing them to live without access to education, medical care or modern infrastructure. I believe that children without schooling do not have a future. Education is the key to development. And we, in our highly developed world, do not have the right to decree that children in developing countries shall be deprived of a future. The World Bank has also recognized that hydropower is contributing to development and has increased its support in this sector.

Can you give us some concrete examples of local development through hydropower?
Karcham Wangtoo in India is a good example, and I had the opportunity of seeing these positive results myself. Children there are now going to school, and this opens up many opportunities for them. We also cooperate with customers in organizing local training schemes for commercial staff, for example in the Cambambe project in Angola. As a company we have had plenty of experience in carrying out projects and training personnel, and we pass it on through our projects all over the world.

Purely in structural terms, a hydropower plant can be seen as a multiple-use facility. What sorts of benefits are involved here?
One important aspect is flood protection. The flooding of the Yangtze has caused millions of deaths in the past, but with the construction of the Three Gorges Dam, this threat is under control. Other advantages include irrigation for local farming and a safe supply of drinking water. This helps people to get through periods of drought in Africa, for example. Improved navigation of rivers and artificial lakes can expand the local recreation opportunities.

What other advantages does hydropower offer to remote regions of developing countries?
Hydropower is an exceptionally stable and reliable form of energy production, ideally suited for decentralized power generation. In particular, it can replace the many diesel generators used in locations like India, Africa, Southeast Asia – and even in remote regions of Portugal – as a permanent source of supply or backup facility. Energy from diesel generators is costly, it is often difficult to procure the fuel, and above all it results in massive environmental pollution.

So in countries like this, hydropower is a better and more environmentally friendly alternative?
Yes, absolutely. Sometimes you can even physically feel it. I was recently sitting in a nice restaurant somewhere in Africa ▷

1 Dr. Münch is optimistic about hydropower's future and emphasizes Voith's broad portfolio.
2 The Jay Jyoti School is just one of the legacies of the Karcham Wangtoo project in India …
3 … which also include vital medical facilities for the surrounding villages.

▷ and it was hard to enjoy the good food. I got a constant taste of diesel soot on my tongue, not to mention the drone of the diesel generators in the background. But even in comparison with wind and solar energy, hydropower is preferable, as it delivers base load capability, meaning it is always available. And in the long term it is a highly economical resource, supplying energy at competitive prices and without any dependence on combustible fuels.

Are market developments heading more towards developing countries?
Yes, that is certainly the case. In recent years we have seen the market spread shifting significantly towards developing areas. Overall, the market situation in 2014 was a further improvement on previous years, driven in particular by projects in the developing world. Tarbela in Pakistan and Cambambe in Angola are examples. Indeed, Africa has huge hydropower potential, and there are also countries like Laos and Nepal, where we have had some interesting orders lately, in Nam Hinboun and Rasuwaghadi respectively. Of course, we must not forget China, which is still one of the biggest markets for new projects worldwide.

What sorts of technology are important for these markets?
They can draw on the entire spectrum of our products, whether large hydro to meet the growing energy needs of these dynamically developing countries, or small hydro for a local and decentralized power supply. As allround providers, we offer the complete product range for hydropower plants of any size – turbines, generators and automation technology, along with the electrical and mechanical equipment needed. This allows us to meet the different requirements of our customers all over the world, including new products like our small hydro solution StreamDiver, which can upgrade existing dams in an economical and environmentally friendly way.

> "In comparison with wind and solar energy, hydropower is preferable, as it delivers base load capacity."
>
> **Dr. Roland Münch,** Voith Hydro CEO

What do you expect in terms of future market developments for new projects?
We anticipate a continuation of the current trends: China still holds enormous potential, and the Three Gorges Corporation, for example, is developing several new megaprojects; we see significant growth opportunities for hydropower in India and hope that the new government will encourage developments; Southeast Asia and the mountainous regions of Central Asia are other important growth markets. We have just opened a new office in Malaysia, in addition to our established branches in China, India and Japan, meaning we are well placed to capitalize on our opportunities in this region and be close to our customers.

So your view of the future is positive?
We can look forward to the future with optimism. Of course, we also have to face challenges in certain quarters. The energy shift in Germany, for example, has led to massive subsidies for the wind and solar sectors and a significant reduction of investments in hydropower, both in Germany and in neighboring countries. Cheap shale gas is reducing hydropower investments as well, especially in the United States. However, all in all, on a global scale, we can be confident that hydropower has many more good years to come. //

AWARD-WINNING

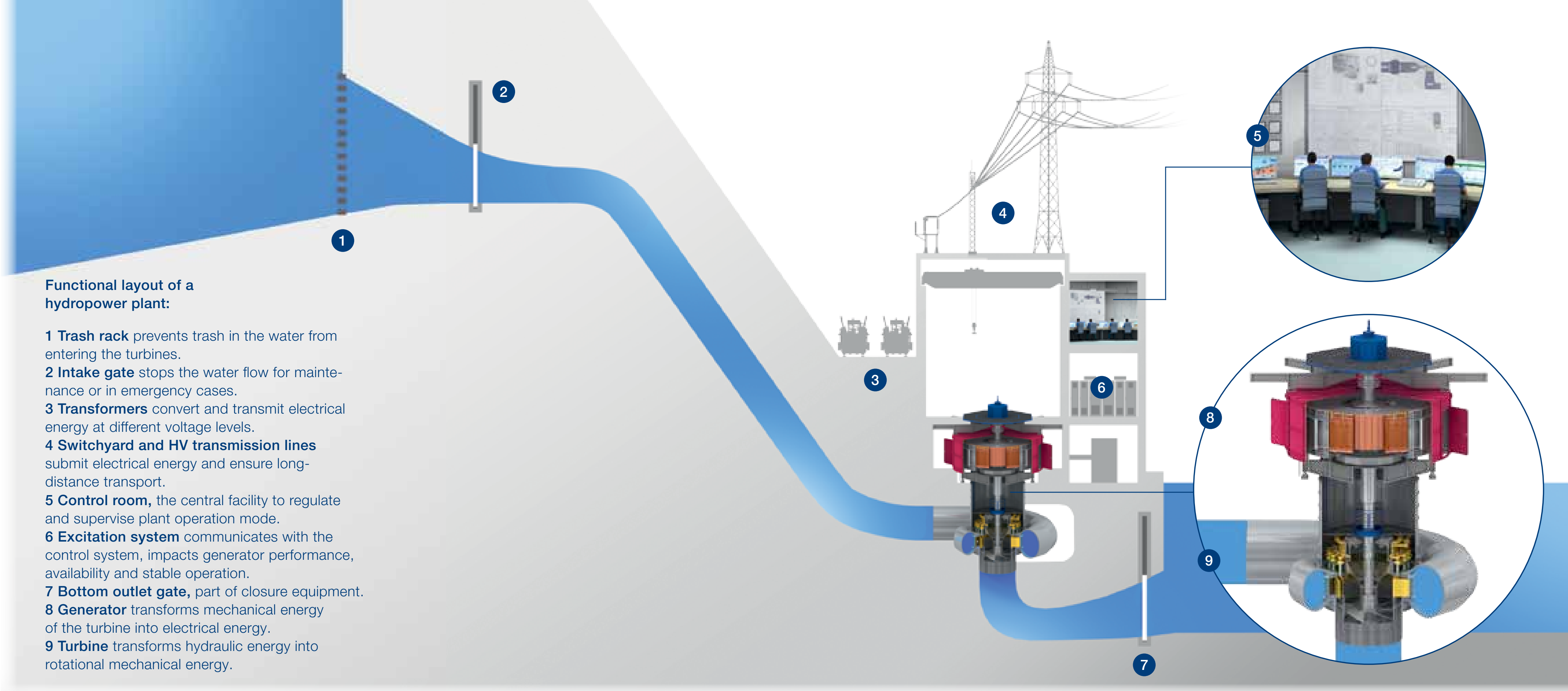
The aesthetics of technology: Voith wins the **PR Image of the Year** award.

PR-Bild Award 2014
Die besten Fotos des Jahres

"Exceptionally beautiful; pure aesthetics," was the jury's verdict on this photo of a Voith Francis runner. The picture was named PR Image of the Year, chosen from more than 1,700 images submitted by companies across Germany, Switzerland and Austria. The runner will be installed at the Bratsk hydropower plant in Siberia in order to increase output and efficiency. With an annual production of around 30,000 gigawatt hours, Bratsk is one of the world's most powerful hydroelectric plants.

COMPREHENSIVE EXPERTISE

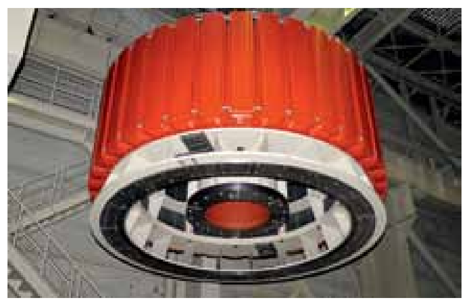
From a range of generators and turbines to tailor-made automation systems, **Voith's product portfolio covers the full life cycle** of large and small hydropower plants.



Functional layout of a hydropower plant:

1 Trash rack prevents trash in the water from entering the turbines.
2 Intake gate stops the water flow for maintenance or in emergency cases.
3 Transformers convert and transmit electrical energy at different voltage levels.
4 Switchyard and HV transmission lines submit electrical energy and ensure long-distance transport.
5 Control room, the central facility to regulate and supervise plant operation mode.
6 Excitation system communicates with the control system, impacts generator performance, availability and stable operation.
7 Bottom outlet gate, part of closure equipment.
8 Generator transforms mechanical energy of the turbine into electrical energy.
9 Turbine transforms hydraulic energy into rotational mechanical energy.

Conventional generator
Air- or water-cooled, they can be installed horizontally or vertically. Voith produces both low- and high-speed machines.
> Output: up to 1,100 MVA; Voltage: up to 25 kV



Bulb generator
Low-speed machines for bulb turbines. Usually installed horizontally, and air-cooled, smaller machines can be cooled by water via bulb shell.
> Output: up to 100 MVA; Voltage: up to 13.8 kV

Motor-generator
Usually high-speed machines, air- or water-cooled, operable with reversible pump-turbines or in ternary sets.
> Output: approx. 530 MVA; Voltage: up to 23 kV

Asynchronous generator
Air-cooled, usually vertically installed, and also used as motor-generators. Suitable for variable-speed pumped-storage, though rarely installed.
> Output: up to 500 MVA; Voltage: up to 22 kV

Francis turbine
For wide head ranges and large flow volumes. Spiral version can also be used vertically.
> Power: up to 1,000 MW; Head: up to 800 m; Runner size: up to 11 m

Kaplan turbine
Low-pressure applications with high water volume. Horizontal and vertical use.
> Power: up to 350 MW; Head: up to 90 m; Runner size: up to 12 m

Automation systems
The power plant's brain. Voith develops tailor-made solutions to ensure complete service and seamless availability...

Pelton turbine
For high heads. Adaptable to achieve optimum efficiency, even with fluctuating water supply.
> Power: up to 500 MW; Head: up to 2,000 m; Runner size: up to 6.5 m

Bulb turbine
Can offer high full-load efficiency and flow capacity at relatively low construction costs.
> Power: up to 100 MW; Head: up to 30 m; Runner size: up to 10 m

...from a single source to support safe operation and early fault detection: turbine governors; generator excitation; control and protection systems; monitoring, analysis, diagnostics.

1 Foyers is located on the picturesque banks of Scotland's notorious Loch Ness.
2 Transporting the huge 100-ton valves was no easy task.

MORE RELIABLE THAN EVER

Modernization work at the **Foyers pumped storage plant in Scotland** has sped up reaction time and increased reliability.

"The story of the Foyers pumped storage project didn't start last century, but the century before," says John McDonald, Head of Hydro Generation at energy company SSE. At that time, explains McDonald, it was a dam for an aluminium smelter. The contemporary incarnation started in 1974 and significant recent work by Voith has enabled the plant a long-term and sustainable future well into the 21st century.

Until 2014, Foyers was still home to the two original valves that had been fitted when the plant was first commissioned, but periodic inspections had shown that they were no longer in the best condition and ought to be replaced. McDonald explains that the pumped storage plant and the valves were originally envisaged to "balance day and night energy needs, but as time went on, the usage altered." The plant needed an upgrade to valves to ensure they were reliable, efficient and could operate quickly at extremely short notice, so SSE asked for Voith's expertise in services for hydropower plants. With up to 10,000 mode changes a year – through generating or spinning, for example – the plant required the most up-to-date and efficient valves around. Carsten Fleck, Voith Hydro project manager, was heavily involved in the work on the southern bank of Loch Ness in Scotland. "This was a vital project for the customer and the guarantees of quality and the strict timeline had to be adhered to," he says. "Every day that the plant is down results in a loss of income."

SIZE MATTERS

The project presented a number of design and logistical challenges. Simply, the sheer size and weight of the valves meant that transporting them, removing the old valves and replacing with the new was an immense proposition. "We changed the overhead crane at the station," explains McDonald, "because if we hadn't, the size of the valves would have meant taking a lot of time and expense to dismantle them and then rebuild in situ." Voith experts had to additionally cut the existing flange and weld a new one onto the inlet valve in a very precise position – no mean feat, comments McDonald.

Fleck concurs, and adds that a lot of the work was done in very limited spacial conditions: 'To take out an old valve measuring around 3.5 meters in diameter and weighing around 100 tons, and replace it with one of similar dimensions and weight was a huge challenge, especially given the timeline pressure."

That it was done so successfully is a testament to the fine collaboration work between Voith and SSE, says Fleck. "We could rely on a very good relationship and cooperative work environment." The result of the project is a solution ▷

Putting the finishing touches to one of the two valves prior to delivery and installation.

that is “modern and technically reliable.” Work was completed in October 2014 and “though we are still in the period of testing,” explains McDonald, “what is critical has been the performance so far. Yes, it took three months or so and we lost a quarter of our revenue while the plant was down, but it was carried out on time and since then it’s been performing well.”

SHORTER RESPONSE TIME

The upshot is that the Foyers plant is back up and supplying critical energy. With its two modern valves, both of which help provide 150 MW of stable energy to the national grid, the plant can react quicker to the challenges of fluctuations in renewables. McDonald praises the valves’ ability to “perform with a shorter response time” and he is delighted that they are “more reliable than ever.”

With the service job now successfully complete, Carsten Fleck can also reflect on a rewarding working environment: a pumped storage plant amidst mountains and the famous Loch Ness. “Some people might see it as a little barren, but for me it was a great place to work and I’ll always be very fond of the Scottish landscape.” //

Pumped storage technology: Bringing many benefits

Pumped storage plants such as Foyers have proven to be the only technology capable of storing energy on an industrial scale, but they also come with several other advantages.

Energy storage
Grid stability
Peak-load energy supply
Integration of renewables
Network reserve
Flexibility
Cost-efficient
Fast reaction times
Load-balancing
High efficiency
Voltage regulation
Proven technology
Long lifetime
Black start capability

BALANCING THE PARAMETERS

Icy temperatures and an innovative bidding and design process add to the unique nature of the **Keeyask plant in Canada.**

In Manitoba, temperatures vary greatly and can drop to -40°C, making working conditions difficult.

Canada’s Manitoba Province: a new 695 MW hydropower project is being developed by the Keeyask Hydropower Limited Partnership (KHLP), a partnership between Manitoba Hydro and four Manitoba First Nations. Suppliers have been very early involved in the project definition phase to find the optimum solution, and the client, who has decided for Voith to equip the plant, opted for a fixed-blade propeller-turbine generating unit to harness the waters of the Nelson River, which is wide but provides only 18 meters of head. Voith will supply, manufacture, transport and install the units.

With early supplier involvement, the Keeyask project is a showcase for an innovative way of design and contracting in order to optimize costs and the efficiency of the completed facility. As the project manager contracted by KHLP to build Keeyask, Manitoba Hydro decided to seek early feedback on ▷

▷ the facility design and specification during project scoping with all potential bidders, says Laurent Bulota, Voith Hydro's proposal manager for Keeyask plant.

During the two-year proposal process, Manitoba Hydro invited potential bidders to come up with different solutions to optimize the powerhouse. "They gave each proponent a 3-D model where you could use different parameters to change the dimensions of the units," Bulota says.

The Voith Hydro team then set about defining the best combination of features and dimensions. It examined different designs via a range of metrics such as dollars per cubic meter of concrete poured or of rock excavated and ultimately the cost of the energy per unit produced, explains Bulota. "You can always go bigger and bigger to make it more efficient but at a certain point the costs are too high. It's a trade-off between parameters. We worked for months to find the best overall solution for the customer."

It was the first time that a customer had offered the chance for prospective main contractors to help define the parameters of the powerhouse in this way, rather than working out a design with consultants prior to the tendering process, says Dany Morin, the Keeyask project manager for Voith Hydro. "It is a large and complex project with many phases, and it meant they could guarantee the optimal design, sourcing and use of concrete as well as the cost of the project, which led to substantial financial savings." As such it may even become a template for comparable projects elsewhere in the world, especially mid-sized ones, adds Morin. Approaching the project in this way also set the tone for a highly collaborative approach between all parties involved. "We think all the time about the overall project execution, not just our part."

COPING WITH EXTREME WEATHER

Keeyask is a showcase for Voith Hydro's ability to deliver a range of best-in-class hydro solutions to suit different circumstances and requirements, such as the design decision to use the propeller-style units. This poses significant challenges, though. The project involves managing a global supply chain and with generator rotors of more than 13.5 meters in diameter, some very large and heavy components to ship to the remote site in extreme weather, with temperatures falling as low as -40°C.

The logistics and scheduling of construction is another challenge. The work requires Voith Hydro to build seven units

When completed, Keeyask will provide 695 MW of capacity and produce an average of 4,400 gigawatt hours of electricity each year.

with only two months between each one, says Morin. "Inside the powerhouse we have limited space in the erection bay to prepare and assemble the components. We had to review our schedule many times to make sure we had the right plan." These constraints are partly self-imposed, owing to the optimal design that Voith Hydro proposed, he adds. "Of course the construction team wants the largest possible area to work in, but the downside of that is that the customer will have to pour more concrete."

It meant making a careful plan for how to optimize the construction process on and off site, with work on many units proceeding at different stages. "We had to look at how many rotors we could fit on the erection area at the same time and do a day-by-day analysis of how we use the minimal area while maximizing the construction time," Morin says.

The project is progressing well and to schedule so far, with the first unit ready to turn in early 2019 and the last unit due to be in commercial service in spring 2020. //

THE SHARE OF COSTS TO EQUIP A HYDROPOWER PLANT

Did you know that the share of expenses for the electro-mechanical equipment of a complete new hydropower plant typically ranges between just 10% and 20% of the total cost? Higher and lower values can apply, though: the actual share depends on many factors like location, existing dam or infrastructure, size and type of plant and equipment, among others. For a newly built large hydropower plant in Africa or a cavern plant in the Alps, for example, a lot of new infrastructure is required, making the share of costs for electro-mechanical equipment considerably lower than for a dam upgrade in Europe or the United States. //

SMALL HYDRO, BIG IMPACT

Across Central and South America, **governments, public clients and private clients are** realizing the many benefits of small hydropower plants.

"It's a completely run-of-river project with no damming required. It is water that would otherwise be wasted."

Riccardo Volonterio,
Voith Hydro Latin America

When the energy comes, it changes everything," states Riccardo Volonterio, Sales Manager for Voith Hydro Latin America. "I have lived in some remote communities like this, and I have seen the difference it makes. When there is affordable energy you can have air conditioning, computers and Internet access. You can build a hospital where it was impossible before, and you have light in the schools. The local people are able to start their own businesses. Without energy there is no development."

Volonterio is discussing Colombia's Antioquia region, where the 44.4 MW San Miguel small hydropower plant is taking shape. Voith's role in the project developed and constructed by HMV Ingenieros Ltda. is to supply two Francis turbines, plus generators, protection valves, speed governors, voltage regulators and automation system. During the construction phase the project has already brought work to people in this remote region. When it starts generating power the facility will begin a much wider transformation of the communities it serves via the Colombian grid.

The potential for small hydro schemes is great, and governments and clients are waking up to this throughout South and Central America, explains Luiz Fontes, Small Hydro Manager for Voith Hydro Latin America. "The hydropower market in South America as a whole has significant potential indeed." There is a conscious move away from fossil fuel energy generation across the region and the ideal conditions for hydro, from the rainforests of the north to the Andean glaciers, make small hydro an obvious choice for its economic benefits, reliability, low costs and low environmental impacts. "The energy matrix is changing in all these countries. Colombia is a good example: the government is promoting the shift to renewable energy with feed-in tariffs, tax exemptions and fast-track licensing processes."

SIGN OF THINGS TO COME

To date, the greatest interest in small hydro in the region has come from outside Brazil. Given the country's more mature market and greater interest in solar and wind power, as well as fossil fuel energy generation, small hydro plants have, until recently, not always been the first choice.

1 Santo António do Jari in Brazil represents a smart and efficient source of clean energy.
2 Construction of the intake and sand trap structures for Colombia's San Miguel project.

However, things are changing. In December 2014, after Voith had completed its commissioning work, the switch was thrown on the Santo Antonio do Jari small hydropower plant in the Jari river, another less-developed region in need of clean energy. The plant is downstream from a 450 MW hydropower plant, capitalizing on the secondary flow to drive a 3.5 MW Kaplan-S turbine and replacing a fossil-fueled power station.

It is a sign of things to come. Building smaller plants like these near larger hydropower stations to take advantage of unused flows is logistically simpler, as much of the infrastructure is already in place. They are also relatively inexpensive and can be completed rapidly. In one case Voith Hydro helped a client with a project from inception to operation in only three years.

Favorable tax status, together with higher rates paid for the energy, further add to their appeal. "And it has almost no environmental impact at all. It is a completely run-of-river project with no damming required. Essentially, this is water that would otherwise be wasted," explains Volonterio.

Policymakers and energy firms are rediscovering the benefits of hydropower in general and of small hydro plants in particular. "They are coming back to hydropower. It is the only truly cheap, efficient, available and eco-friendly source of energy available now."

Voith Hydro is uniquely placed to be the partner of choice in small hydro, from the planning process right through to retrofitting decades after initial construction. "Customers lack experience in this area, and we can offer support and help them develop feasibility studies, with optimal design of plant, alternatives for electro-mechanical elements and also revenue," Fontes comments. "We can completely support them, from greenfield through to operation and maintenance. Our intention is to offer a complete solution, to be a complete project provider and supporter." //

CLEARER WATERS

Reservoirs and greenhouse gas emissions: **fresh perspectives** on an ongoing debate.

The influential journal *Nature* ran a startling headline in November 2006: "Methane quashes green credentials of hydropower." The accompanying report asserted, "Some of the latest findings point to a disturbing conclusion: that the global warming impact of hydropower plants can often outweigh that of comparable fossil-fuel power stations."

Like many studies into greenhouse gas (GHG) emissions from reservoirs published since, this report focused on findings from Balbina in Brazil, a vast, now stagnant reservoir built in the 1980s which is linked to high GHG emissions. But nearby Itaipu, on the border between Brazil and Paraguay, is an enormous power producer also built in the 1980s. Its emissions are not just low, they are below every other form of energy production, including estimated median emissions of wind power.

"There are a few reservoirs built in the past which create conditions which consume oxygen, resulting in carbon being degraded into methane rather than CO_2. You wouldn't dream of building in the same way today," says Dr. Jürgen Schuol, Head of Sustainability at Voith Hydro. "But they are the exception, not the rule."

COMPLEX PICTURE

In the eight years since the "green credentials" warning from *Nature*, much more research has been undertaken in an effort to provide an accurate picture of how much each type of energy production contributes to global warming. In 2014, a UN-sponsored scientific body, the Intergovernmental Panel on Climate Change (IPCC), published life-cycle GHG emissions for each energy source. Its findings indicate that GHG emissions of fossil fuels exceed those of renewable resources by a significant margin. Even natural gas, about 40% "cleaner" than coal, produces 20 times the emissions of hydropower.

The picture, however, is far more complex than simple direct comparisons of median emissions, points out Atle Harby, Senior Research Scientist at SINTEF Energy Research and Director of Norway's CEDREN research center. He believes there has been both misunderstanding and bias on the question of reservoir GHG emissions, particularly in respect of methane. The critical issue, he says, is the extent to which reservoirs create net additional emissions. To quantify the net change of GHG exchange in a river basin caused by the creation of a reservoir, it is necessary to consider emissions before and after its construction. The difference between the before and after emissions from the portion of the river basin influenced by the reservoir indicates its net GHG emissions. "Many factors affect the nature and levels of emissions," Harby states. "Some reservoirs, mainly confined to the tropics, do convert CO_2 into methane. But extrapolating gross data from these and applying them to all hydropower is completely misleading."

In fact, some reservoirs are carbon sinks, where a combination of slower water speeds and sediments can store carbon forever. Even within a single reservoir, different conditions may exist. The real challenge for scientists is to develop sufficient understanding of the interplay of these many variables in order to produce accurate figures for net emissions.

Another challenge is to determine what proportion of GHG emissions should be allocated to hydropower in a multi-use reservoir, of which there are many. China's Three Gorges Dam on the Yangtze River (see page 35), for example, reduces the frequency of major downstream flooding from once every 10 years to once every 100 years, as well as improving shipping navigation and aiding water supplies. So while it may be the world's largest hydropower facility, a number of other economic and social purposes should carry their share of the imputed GHG emissions in any meaningful life-cycle assessment.

> "Many factors affect the nature and levels of emissions."
> **Atle Harby,** SINTEF Energy Research

RISK ASSESSMENT

As a member of the Hydro Equipment Association (HEA), Voith sponsors and supports the work of the UNESCO/International Hydropower Association GHG Research Project, which developed its "Measurement Guidelines for Freshwater Reservoirs" in 2011 and the GHG Risk Screening Tool in 2013. The project has now progressed to the development of a screening tool with three specific aims: a peer-reviewed approach to more accurately define the effect of a reservoir system and allow better communication of potential climate impact; to facilitate quantitative estimation of net GHG emissions so that early preventative action can be taken where appropriate on sites vulnerable to high emissions; and an approach that will allocate net GHG emissions to the different services that the reservoir provides.

Like every discussion on global warming, consensus among the scientific community on GHG emissions from freshwater reservoirs proves elusive and progress is slow. There are unresolved questions around quantification methodology and the competing virtues of Global Warming Potential, the metric of choice for the Kyoto Protocol, against Global Temperature Change Potential, considered by some to be more a more suitable metric for target-based climate policies.

Jürgen Schuol says that at this stage, "we at Voith are not so much interested in very detailed models and also not so much in global figures. What we would like to see is a simple but reliable model that helps us to estimate the risk of comparably high or higher emissions on a project-by-project basis. No one has the perfect model yet, but we are fully aware of the many issues that have to be taken into account and we are certainly on the right track." //

RESERVOIRS AND GHG – WHAT'S THE LINK?

When freshwater reservoirs are created, submerged vegetation decomposes, releasing the CO_2 it had been storing through photosynthesis. It also traps other organic matter brought by the river, although GHGs from the decomposition of this material would have been emitted elsewhere had the dam not been built. Influences on GHG production include the shape of the reservoir, water depth, soil types, climate and reservoir age. *Carbon dioxide (CO_2)* accounts for 80% of all GHGs released into the atmosphere, but the presence of a reservoir does not significantly change natural levels. With potentially 25 times greater effect on global warming over 100 years than CO_2, *methane (CH_4)* is the GHG of most concern with reservoirs: under certain conditions some reservoirs may create anoxic conditions under which methane can be produced and released.

Despite its size, GHG emissions from the Itaipu reservoir are below every other form of energy production.

GREEN ENERGY MIX

ON REFLECTION

NUO ZHA DU, SOUTHWEST CHINA
Voith Hydro supplied three of the six 650 MW Francis turbines that were commissioned in 2013. The turbines have an operating head of 187 meters and a runner diameter of 7.3 meters.

#HYDROPICTUREOFTHEWEEK
Scan the QR code below or visit **twitter.com/Voith_Hydro** to keep up with Voith Hydro news. Be sure to check out our feed every Friday when we share our hydropower picture of the week!

SAVING TIME, SECURING QUALITY

Continuous **process improvement** can bring considerable benefit to customers and the environment.

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"For us, every customer has the same priority," says Leonardo Nuzzi. "We strive for the highest quality and fast delivery in every project." Nuzzi is Director of Manufacturing and in charge of Operations Excellence (OPEX) at Voith Hydro in São Paulo. OPEX is a Voith-wide initiative focusing on continuous improvement, particularly in manufacturing processes. The idea: to establish processes as excellent as Voith's products and services, enhancing customer benefits still further. "Efficient processes save time, and time is of the essence in our business and for our customers," Nuzzi explains. The sooner a power plant goes online, the earlier it can generate energy and cash flow for the customer.

The first step in OPEX, the analysis of every single part of each production chain, is already complete. Now the action points from the findings are being implemented: steps in the production process that are not yet efficient enough or are even unnecessary will be optimized or removed and operational procedures streamlined.

One of these optimizations is the "One Piece Flow Line." Its first implementation was at Voith Hydro in São Paulo, then in the workshops in York, USA, and St. Pölten, Austria. Further locations will soon follow. The generator pole production line in São Paulo shows the potential that can be leveraged by the concept: to reduce waiting times in the seven-step production process and to be able to react to possible problems at short notice, the components are produced in line, at adjacent work stations, and not in parallel as before. This ensures the staff remains fully concentrated on one piece at a time, rather than switching from one job to the other, contributing to higher product quality for every customer.

Trouble-shooting has also been improved. The machines are supervised by a software program connected to all supervisors and to Nuzzi's computer. "If a problem occurs or the line is stopped, we can see this on-line, and we initiate further steps to solve the issue immediately," he says. "We stop the production, fix the problem and continue without causing further delay to other steps in the process."

These savings have already reduced pole manufacturing lead time by almost 50%. And as the pole is just one of the key components for a generator, more savings are possible when applying the one-piece flow concept to the others.

"We are already fast and efficient, but we want to become even better. We are always striving to achieve the ideal factory."

Dr. Udo Wunsch, Vice President International Projects at Voith Hydro

"Our workshops already look good, we are already fast and efficient, but we want to become even better. We are always striving to achieve the ideal factory," says Dr. Udo Wunsch, Vice President for International Projects at Voith Hydro, about the driving force behind the initiative. The ideal plant is based on four principles: stable processes, flow, timing, and customer focus.

Time is an important element in the One Piece Flow Line, as each step is clocked and given a certain time preset, as Wunsch explains: "We have split the entire process into individual steps and made them identical in length to help reduce over- or under-production. The next step cannot start without the preceding one being completed." Employees have also learned to be highly flexible and rotate from one workstation to the other. When one job is finished, they can support their colleagues in completing the next.

A change in mindset and regular, open communication are decisive in successful process optimization. Everyone involved, from factory workers to manufacturing managers or directors, is asked to communicate and encouraged to think about the complete process rather than just their own tasks. Shop floor meetings are held every day before a shift, where workers meet in small groups with their supervisor to discuss the daily time schedules, quality issues or problems that may have occurred. The focus is always to avoid repeating issues and to assure that all fixtures have been properly addressed. For Nuzzi these meetings play a crucial role: "We want to know about every irregularity to fix it immediately."

The meetings have already proved successful. As an example, one employee responsible for tape-wrapping generator components detected an error. She couldn't figure out the problem, but notified her supervisor, who detected the failure: the tape was contaminated. "This sense of responsibility for the whole process helped avert a major issue," says Dr. Wunsch, pointing out that a steady flow of communication, a high level of transparency, and discussions based on facts and figures are essential for the OPEX idea of continuous improvement.

DATA-DRIVEN ACCURACY

Close to the generator pole production site in São Paulo is the foundry. As one of Voith Hydro's key workshops it is a natural location for the OPEX initiative. The "Shop Floor Management" principle has been introduced here as well, ▷

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1 The One Piece Flow Line helps speed up manufacturing processes and increase product quality.
2 Leonardo Nuzzi (far right) in discussions with OPEX colleagues at Voith Hydro in São Paulo.
3 Open and transparent communication, synchronized processes and clearly visible tasks are key components for the success of OPEX.

and an elaborate statistical process control measures more than 80 sets of performance data, from temperature to sand grain size. “Foundry sand, for example, must have a certain size and consistency to manufacture products with the right quality,” explains Nuzzi. Tracking and visualization are key components in OPEX: more accurate data gives employees greater insight into each element of a production process, allowing them to set benchmarks and meet stringent goals. In the foundry, this has led to improvements throughout the casting process and better cast parts.

At the same time, process quality is also reflected in the strong sustainability of the foundry. The foundry sand, for example, is used more than once – recycled and reprocessed to reduce waste but maintain quality. A closed-circuit system for water supply helps reduce freshwater consumption, while improved insulation and coordinated energy consumption between different production areas have cut down on electricity usage.

Nuzzi and his team are proud of the changes that have been implemented in São Paulo and the positive effects they have already had on the products they make. “These are our own products; Voith products,” he says smiling. For OPEX, this is just the beginning, though, and the initiative is being adapted and rolled out across Voith Hydro locations worldwide; improvement is a continuous process. //

OPEX has already brought a number of improvements to the foundry in São Paulo, Brazil.

OPTIMIZING OPERATIONS

A global overview of OPEX from **Voith Hydro Chief Operating Officer Uwe Wehnhardt**

What are the main objectives of the OPEX initiative?
It’s a program for continuous improvement that focuses mainly on manufacturing. The aim is to establish production processes that are as excellent as our products and services. This is based on a mindset change of all our employees in manufacturing, towards a culture of continuous improvement: by identifying and realizing potential for savings and improvements, by standardizing the way we operate. Every employee is integrated in the initiative and asked to contribute ideas.

How will customers benefit?
OPEX focuses on our internal processes in manufacturing, but by continuously improving these processes we can also enhance our service levels. An example: by processing parts faster through the workshop we improve our overall delivery schedules, which can lead to a faster startup of a hydropower plant – a real benefit for customers.

Can you provide examples of changes that have been initiated by the OPEX program?
Overall Equipment Efficiency (OEE) is a good example: improving OEE means fewer unplanned shutdowns and faster parts machining. We have successfully improved our OEE across all large machines in our workshops around the world by 50% during the last business year. And the “One Piece Flow Line” [see main article], which streamlines manufacturing processes, has improved lead time by more than 40%.

What is the current status with OPEX and what are the next steps?
OPEX is in its second year. All the basics are in place, such as trained OPEX experts, clear targets and KPIs, and a master plan at every site on how to achieve them. The continuous improvement cycle in manufacturing is well and truly under way. This year, we will carry out further assessments, allowing us comprehensive benchmarking of the different locations to stimulate further improvements by learning from each other. //

UNRIVALED

Twenty years after construction began, the **Three Gorges Dam** keeps setting record after record.

The Three Gorges Dam recently celebrated 20 years since construction work started on the world’s largest hydropower plant. During that time, it has broken numerous records, and to celebrate its 20th anniversary, the Three Gorges Corporation recently announced another milestone as it generated 98.8 terawatt hours of electricity in 2014, the most ever produced by a single hydropower plant in one year. Due to the project’s size there were numerous suppliers involved. Voith, in a consortium with GE and Siemens, has won the bid and supplied six water turbine-generating units and auxiliary parts, each with an installed capacity of 700 MW, and provided onsite technical service as well. Voith Hydro locations in Germany, China and Brazil were involved: for leading the project and model tests, manufacturing of the Francis runners and generator components, as well as excitation and auxiliary systems.

Looking back, Dr. Thomas Aschenbrenner, today Head of Turbine Layout at Voith Hydro’s Brunnenmühle center, says the Three Gorges Dam was a huge technological and logistical challenge for the company that brought valuable lessons for subsequent projects. “It set new standards in efficiency and reliability and certainly drove forward our hydraulics expertise in Francis turbine design,” he says. “And it was the first in a series of Chinese mega-projects for us; we’re really benefiting now from the knowledge and experience gained from Three Gorges in terms of execution and customer interaction.”

GREATER FLOOD PROTECTION

While the dam’s output performance cannot be questioned, it has generated mixed publicity during its 20-year life span. The creation of a reservoir 660 kilometers long has, for example, affected sediment levels and downstream fish populations, but a lot has been done to optimize the dispatching system, and with regard to monitoring, research and appliance of ecological issues. Also, local inhabitants and 14 million other Chinese along the banks of the Yangtze River now enjoy protection from floods that have killed thousands and made millions homeless down the years. And in the dry season, several droughts have already been averted thanks to the control over the water levels brought by the ▷

1 The dam has improved irrigation and helped protect farmland from flooding.
2 Once shallow and fast-flowing, the Yangtze is now easier to navigate, vital for the transport of people and goods.
3 The world's largest lock system allows boats to travel past the dam.

▷ dam. Previously shallow and fast-flowing, the Yangtze is now – thanks to the dam – deeper, slower and easier to navigate for the thousands of ships that use it every day. As the most cost-effective means of long-distance travel for passengers and freight in the inland region, this has been a major benefit for local economies. "I see a lot of new buildings every time I come back to the dam site," comments Aschenbrenner. Facilitating travel past the dam is the world's largest lock system, which will be enhanced by the completion of a special ship lift later this year capable of hauling 3,000-ton vessels over the dam, speeding up traffic and marking yet another remarkable development in the project's history. //

Did you know…?

2% The Three Gorges Dam generates approximately 2% of China's electricity

1.8 million tourists visit the site on average per year. On public holidays, up to 200,000 a day

660 km Its reservoir is 660 km long, the same distance as Los Angeles to San Francisco or Berlin to Amsterdam

22,500 MW The hydropower plant's 22,500 MW capacity is the equivalent of 10 modern nuclear plants

GLOBAL EXPERTISE

REFLECTIONS FROM THE CHINA THREE GORGES CORPORATION ON THE SUCCESS OF THE PROJECT

Twenty years after construction began, how significant has Three Gorges been in securing a clean energy supply in China?
Three Gorges is the world's largest power plant in terms of installed capacity: In 2014 the plant generated 98.8 billion kWh – a world record in annual energy output for a single power station. From 2003, when the first generating unit was put into operation, to the end of 2013, the plant produced 711.97 billion kWh of power. This has saved a raw coal consumption of 400 million tons, reducing CO_2 emissions by 800 million tons and sulphur dioxide emissions by more than 8 million tons – a great contribution to China's environment.

Besides hydropower generation, what have the other main benefits been for the region?
The project is a backbone for the development and control of the Yangtze River basin and is based on the most comprehensive functional tasks in hydraulic and hydroelectric engineering in the world. Through scientific dispatching, it can bring huge benefits not only in power generation, but also in flood control, navigability, water resource allocation, energy savings and emission reduction, as well as environmental protection. The project has also promoted the interconnection of the national power grid and effectively eases the strained situation of power supply in Central and East China, the Guangdong Province and other areas.

Flood control is an important and life-saving aspect of the Three Gorges Dam. What has improved?
Flood control is the primary task of the project. Historical records show a severe flood every 10 years on average. The large floods in 1931 and 1954 each damaged thousands of square kilometers of farmland, with tens of thousands of people losing their lives. Now, the situation has fundamentally changed: the flood control standard has increased from "once a decade" to "once a century." The dam can effectively protect 15 million people along the middle and lower reaches as well as prevent huge areas of farmland from flooding.

The dam has improved navigability on the Yangtze River. What have the benefits been?
Tens of thousands of tons of cargo can now reach Chongqing directly from Shanghai: transport costs have been cut by a third. In 2014, the throughput of the ship locks was nearly 120 million tons, a record for the dam. Employment has also benefited: up to 150,000 people work directly in waterborne transportation in Chongqing, 80,000 of them from the reservoir area.

How has the Three Gorges Dam contributed to the development of China's economy?
The major benefits already mentioned, such as flood control, power generation and navigation, have contributed strongly to economic development. Infrastructure in the reservoir area has been constantly improved, urbanization has increased, and the income and living standards of residents have been significantly enhanced. Between 1996 and 2013, the per capita net income of urban residents in the reservoir area increased by 12.7% per annum on average, and that of rural residents by 18.8%. The employment structure has gradually evolved into a tertiary-industry-dominated type, and the economic structure has gone from agricultural to diversified industries.

What role does hydropower play in the energy matrix of China – both currently and in the future?
The current energy supply in China is dominated by coal, and development is restricted by resource shortage and environmental pollution. Adjusting the energy structure and reducing the share of coal in primary consumption is very important. Hydropower resources in China are vast. If the estimated technically available hydropower potential of 2.47 trillion kWh in China is fully developed, approximately one billion tons of raw coal can be replaced each year. The installed capacity and power production of hydropower plants in China will continue to grow rapidly, and China has already committed itself to increasing the share of non-fossil primary energy to 15% by 2020. To realize this, the focus will be on the further development of hydropower. //

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1 Temples dot the mountainous landscape of the Kinnaur district.
2 The 1,000 MW Karcham Wangtoo dam houses four Francis turbine-generators.
3 Jeev Chand's five-year-old granddaughter studies at the Jay Jyoti school.
4 A hospital provides valuable employment and medical care for the region.

IN THE LAND OF GODS

Local inhabitants describe the **many benefits the Karcham Wangtoo hydropower plant has brought** to rural northern India.

Resting on the lap of the Zanskar, Greater Himalayas and Dhauladhar mountain ranges, Kinnaur district in the northern Indian state of Himachal Pradesh is often referred to as the "Land of Gods." In ancient mythology the local people were known as Kinners, considered halfway between men and gods. Many ancient temples and monasteries are dotted throughout the area, which has remained fairly remote, rural and lacking in infrastructure. Roads, bridges, schools and medical care remain less developed compared with many parts of the country. It is a far cry from the vibrant economic hotspots of Delhi, Bengaluru or Mumbai.

But things are changing. The Karcham Wangtoo hydroelectric project, commissioned in 2011, not only brings a stable, renewable power supply to northern India, it is also improving the local infrastructure. The 190-kilometer main road connection from Shimla, the capital of Himachal Pradesh state, to the site has been widened, while five new bridges have been constructed and others renovated and strengthened to enable transportation of heavy equipment for the project. A further 25 kilometers of roads were constructed by Jaypee, the project developer.

The company also undertook massive afforestation works, with tens of thousands of trees planted in the area, and drinking water and irrigation facilities were subject to improvement. All these measures have brought significant and, above all, sustainable development to the region.

AFFORDABLE IMPROVEMENTS

Karcham Wangtoo has also brought social and educational improvements to the Kinnaur district. To improve the social conditions in the vicinity of the project, a 40-bed hospital and a school have been built. The hospital is manned by very competent doctors and more than 60 support staff and provides inpatient treatment, while many others receive outpatient treatment daily in the various clinics associated with the hospital.

The local people are grateful for such developments. Sushil Negi, from nearby Ramni village, recently received treatment for a fractured leg after an accident: "The hospital offers fast, affordable treatment in a very hygienic environment. I was provided immediate attention as soon as I arrived." Dr. Suman Dhar, lead doctor at the hospital, says, "I am very happy to work there, as it provides great working conditions and an opportunity to work for the benefit of the rural people."

At the nearby Jay Jyoti school, run by the project, quality education is provided to the poor and underprivileged from the 40-plus villages of the Kinnaur district. It teaches students up to the higher secondary standard and currently serves about 400 students and employs 23 full-time teachers. Jeev Chand, whose five-year-old granddaughter studies at the school, says it provides "very good academic facilities at very affordable cost," ▷

The Jaypee Industrial Training Institute was set up to improve the skills and job opportunities in Kinnaur.

and is a real boon for people from his village as well as several others in the vicinity. Sheela Devi, from the adjoining village of Sarahan, concurs wholeheartedly.

TRAINING FOR THE FUTURE

In order to improve the skills and employability of the local people in the region, the Jaypee Industrial Training Institute has been set up at the village of Urni. “This is the only institute that offers training and skill development in this area, and I aspire to get a good job once I complete the training next year,” says Chandrashekhar, a student who is training to be an electrician and comes from Kakasthal, 20 kilometers away.

As of December 2014, the plant has already generated more than 15,135 million units of power and has provided 1,812 million units of power free to Himachal Pradesh. It has generated a revenue of around 6,000 million rupees ($97 million) for the state with promises to continue to bring many more benefits in the future. //

> “This is the only institute that offers training and skill development in this area, and I aspire to get a good job once I complete the training.”
>
> **Chandrashekhar,** trainee electrician, Kakasthal village

Karcham Wangtoo Hydroelectric Project

Located between the villages of Karcham and Wangtoo, the dam and power station are run-of-river, with only diurnal storage available behind the river diversion structure to harness the power of the Satluj River. The project was developed by Jaypee Karcham Hydro Corporation Limited, part of the Jaypee Group.

The electro-mechanical work was awarded to a consortium led by Voith. Voith’s scope included four 277.8 MVA synchronous generators, bus ducts, SCADA and cooling water systems and some electrical balance-of-plant equipment. The electro-mechanical scope was delivered in a record time of 42 months. The first unit of the project went on stream in May 2011, closely followed by the subsequent units, with the fourth commissioned in September 2011, 65 days ahead of schedule. This success was the result of strong project management and excellent collaboration between the companies involved and close interaction with the civil construction firm.

A total of 4,805,288 cubic meters of underground excavation works had to be executed, including the construction of 45 kilometers of tunnels and more than 800,000 cubic meters of concrete. At the peak of the works, nearly 15,000 workmen worked on site, at times braving daunting weather conditions in the mountainous setting.

WORLD OF VOITH

The latest news from **across the divisions** of the Voith group.

QUICK TURNAROUND

VOITH INDUSTRIAL SERVICES is continuing to extend its competencies on the turnaround market. With the Energy-Petro-Chemicals division, Voith is active on an international scale for turnarounds in order to shut down refineries and chemical plants and to repair them within the shortest possible time. At the end of 2014, Voith was able to win projects at a refinery in Finland as well as for the St1 refinery in Gothenburg, Sweden. Meanwhile, in Angola, Voith recently completed its first ever offshore turnaround. The oil-carrying ship FPSO Greater Plutonio, owned by the British energy company BP, was ordered into harbor for maintenance and repairs. The Voith specialists completed their first project in Africa four days before the defined deadline. //

IN CONTROL

VOITH PAPER has supplied a new shop floor air conditioning system to the German cheese maker Bayernland. In the milk processing sector, hygiene standards and air purity requirements are highly stringent, making standards for ventilation and refrigeration technology equally high. The new Voith system ensures a controlled and hygienic indoor climate. Plant manager Erich Schaller is happy with its performance so far: “The system concept and the quality delivered have proven themselves in practice and are making an important contribution to the quality assurance of our products.” //

PROVEN PERFORMER

VOITH TURBO recently manufactured its 1,000th fluid coupling type TPKL, one of four that will go to the DaTong Coal Mining Group in China. The couplings will be used in a 6.4 MW belt conveyor drive with demanding requirements. More than three kilometers long, the underground belt conveyor is driven by four 1,600 kW motors, with a planned capacity of 4,000 tons an hour. Coal will be transported uphill at a 14-degree angle. The DaTong Group is one of China’s biggest mining enterprises and operates a large number of coal mines across the country. Many of them already use Voith fluid couplings in diverse underground applications like belt conveyors, stage loaders and crushers. //

FROM THE ARCHIVES

MILESTONES IN PAST HYDROPOWER DEVELOPMENTS

Voith has played a **leading role** in the early development of hydropower technology.

18th century

The history of modern hydropower starts around the mid-18th century. The power of water had been used for thousands of years, before Johann Andreas Segner, a doctor and physicist, invented a more efficient upright water wheel based on one of Newton's laws of motion. It was one of the forerunners of the modern water turbine.

1832/1835

The development of hydro turbines made significant progress during the 19th century, culminating in the invention of a turbine by Frenchman Benoit Fourneyron. This was patented in 1832 and installed in the first commercially operated hydropower plant in Germany's Black Forest in 1835. It was five times more efficient than conventional turbines, but engineers and scientists wanted more.

1849

The great breakthrough: James Bicheno Francis had been testing several types of turbines for years and in 1849 he finally presented a model he was convinced of. The first Francis turbine came with innovations like a spiral and adjustable blades and was the starting point of a turbine type that is still installed in many hydropower plants around the world.

1866

Werner von Siemens invents the generator, allowing the power of water to be transformed to electrical power.

1870-1879

Voith entered the world of hydropower in 1870: the demand for energy was high and the company's existing paper machine business already had similarities with hydropower. Voith introduced its first water turbine in 1870, and just three years later the company seized the invention of James Francis and delivered the first Francis turbine from Voith. Development soon flourished: in 1879, Voith made its first turbine governor.

1880

Driven by an innovative spirit, intensive testing and a little chance, Lester A. Pelton invented the Pelton turbine, which remains one of the common turbine types today and is often used for high heads.

1901-1910

With industry booming, energy was in demand and in 1901 Voith sold Francis turbine no. 1,000. It was also a global business and in 1903 Voith won the contract to install the world's largest turbines at the time in one of the first big hydropower plants: Niagara Falls. China was also already an export market and in 1910 Voith supplied the turbines for the country's first plant in the country, Shi Long Ba.

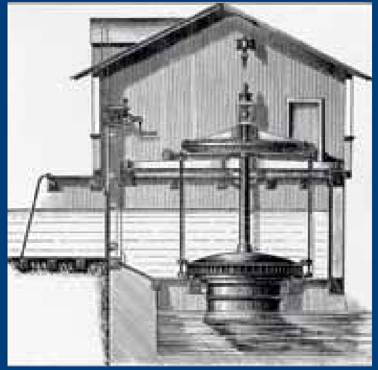
1908

With hydropower established as a means of generating electricity, Voith was at the forefront of using it to save energy. In 1908, the first pumped-storage plant in Germany was installed at its Brunnenmühle testing facility in Heidenheim.

1912-1922

Another of today's common turbine types was invented and registered for patent in 1912. Austrian Viktor Kaplan experimented with existing Francis turbines and developed his own, which was particularly appropriate for low head applications. Voith realized how important his invention was, and together Kaplan and Voith enhanced the design, improving efficiency. The first Kaplan turbine was eventually delivered in 1922. //

1870



The first water turbine from Voith: a 100-horsepower Henschel-Jonval turbine

1873

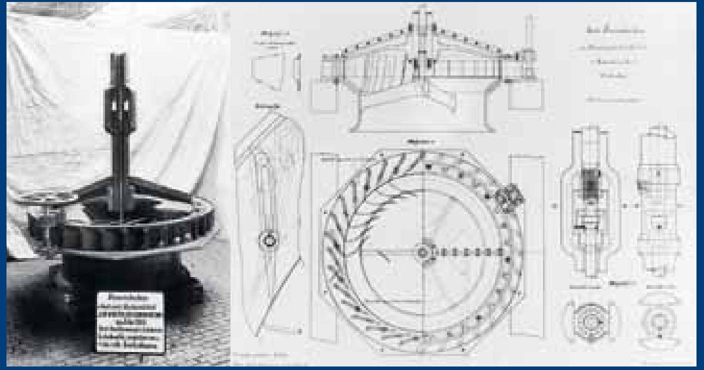
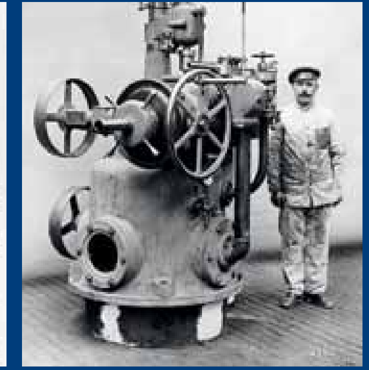


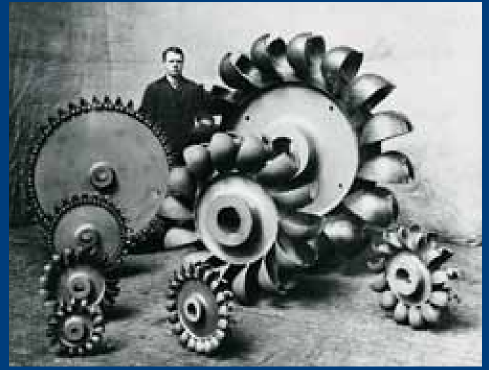
Photo and diagram of the first Francis turbine from Voith

1879



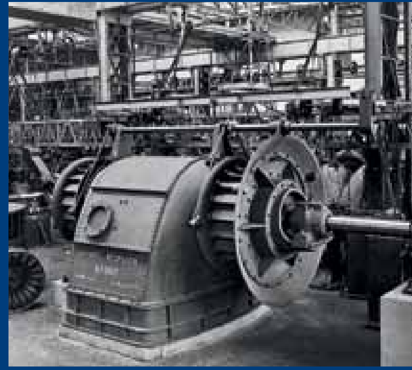
The first Voith turbine governor

1880



Presenting the Pelton turbine

1901



Francis turbine no. 1,000 by Voith

1903

Voith wins the contract to supply the world's largest turbines for the hydropower plant at Niagara Falls

1908

Germany's first pumped-storage plant in Heidenheim/Brenz

1910

Turbine delivery for China's first hydro plant, Shi Long Ba

1922

Delivery of the first Kaplan turbine

THE WATER WARRIOR

Social activist Mary Jordan uses art to bring attention to the global water crisis.

1 American artist Marilyn Minter's design is framed by the Manhattan skyline.
2 A close-up of British photographer Tessa Traeger's canvas.

Mary Jordan is an artist, filmmaker and activist with a passion for human rights. She is the founder of Word Above the Street and Creative Director of The Water Tank Project.

I've always been a rebel," says the effervescent filmmaker, performance artist and social activist Mary Jordan, whose projects to stir the public conscience have taken her off the beaten track. The Canadian, who studied both art and social anthropology, made her first film at aged 18 on female circumcision in North Africa. She has produced human rights documentaries in Burma, Africa, Indonesia and India. In 2005, she was named one of the 25 new faces of independent film-making by the magazine *Filmmaker*.

Jordan's latest venture, The Water Tank Project, in her current home of New York City, is bringing attention to the global water crisis. She has enlisted more than 50 contemporary artists to wrap water-themed works of art around the city's water towers. It is the largest public art project to cover New York real estate since Christo and Jeanne-Claude created their orange 'gates' in Central Park in 2005.

"New York is a highly visual society so art is a powerful medium for social messages," says Jordan. Participants include conceptual artist John Baldessari, neo-pop artists Jeff Koons and Ed Ruscha, and the Iranian stencil artists Icy and Sot.

EXPRESSING GRATITUDE

The project originated after Jordan became ill with a water-borne disease while shooting a documentary on the Hammer people in Ethiopia in 2007. She was taken in a wheelbarrow to a nearby village for medical treatment. Afterwards – she no longer remembers how long – she lay in a mud hut, being looked after by Hammer women. When she tried to thank them by offering money and gifts, they refused, saying she should rather tell the world about their water problems.

> "I suddenly realized that the New York water tank was an icon – a little temple in the sky carrying water for our eyes."
> **Mary Jordan,** social activist

Ethiopia suffers from drought and limited access to clean water, but Jordan began to realize just how much water was related to other global crises: overfishing, melting glaciers and rising sea levels. At first she thought of making a film. But one day, her eye fell on one of the 15,000 wooden, barrel-shaped water tanks perched atop New York's buildings. "I suddenly realized that it was an icon – a little temple in the sky carrying water for our eyes. It would look beautiful wrapped in artwork," she says.

In 2010, after 18 months of groundwork, Jordan founded the non-profit organization Word Above the Street to launch The Water Tank Project. Then she plugged into her well-connected network. "The artists loved the idea," she says. "Who doesn't want to do a water tank?" Funds came from the Booth Ferris Foundation, the Ford Foundation, the Rockefeller New York City Cultural Innovation Fund and the Agnes Gund AG Foundation, with Swatch, Deutsche Bank and Hearst becoming sponsors. A big part of the job was "tanking" – identifying the best water tanks.

Another challenge was getting people to look up at the artworks. Jordan developed an app with a map of the artworks. An advertising agency designed billboards and also drew chalk water tanks on the sidewalk to mark locations.

The project began in August 2014 and tanks are still being wrapped. "If we had it our way, they would not stop until we have solved the water crisis," Jordan states. She also plans to take the project to other parts of the world, such as Indonesia and the Middle East.

There have been low points in her campaign. "No one should have to beg to do things to better the world," she says. "But every 22 seconds a kid dies of a water-borne disease. So I can't let these insignificant things affect my focus."

In the meantime, she and her partner, Jon Rose, who runs Waves for Water, are raising funds to help connect the Hammer to a waterline. "We are secret warriors doing everything possible to protect the greatest life force we know of: water." //

For more information on The Water Tank Project, including a map of the artworks' locations, visit: **thewatertankproject.org**

FIVE QUESTIONS FOR …

Bob Gallo,
new CEO of Voith Hydro in York, USA

1 What is your fascination with hydropower?
There are so many fascinating aspects: Many hydropower sites are impressive feats of engineering utilizing an abundant natural resource. The operation of the plant leaves a very low carbon footprint. Also, hydropower is very flexible, with the unique ability to quickly start and stop power generation, which offsets the intermittency of solar and wind power.

2 What are your earliest memories of hydropower?
I remember being about 10 years old on a family trip to see Niagara Falls, both the US and Canadian sides. It was the first time I visited another country and the first time I learned about hydropower. Niagara Falls was a beautiful and fascinating sight. Remarkably enough from today's perspective, the original supplier of the turbines in the early 20th century was: Voith.

3 What are your main goals as the new CEO of Voith Hydro in York, USA?
I'm fortunate to join a business staffed with excellent people and in very good shape, even during the challenging market situations we face today. My goal is to further enhance our after-market services and modernization business in order to offer the best solutions to our customers – for all components, all brands and across the country. And, by further developing our portfolio and processes, we want to offer our customers even more beneficial products and services.

4 Is there something special about working at Voith?
I started at Voith Paper in 1999 via an acquisition and I immediately discovered Voith to be a very special place to work. If you perform at a high level you will soon find new and challenging opportunities in different function areas, business lines or countries. Now, I am very excited about my new career opportunity within the hydropower division.

5 Can you share some insights on current challenges and developments in the hydropower sector in the US?
Our customers often face a long and difficult permitting process for hydropower investments and installations. In addition, the US government has provided large subsidies to the wind and solar power industries and gives these forms of power generation the highest priority to operate. Hydropower, on the other hand, because it has the unique ability to flexibly stabilize the grid, bears much of the burden in balancing the grid load. //

Bob Gallo took up the position of CEO Voith Hydro in York at the start of 2015. He began his career in the Voith Group more than 15 years ago and has held various senior positions in the Voith Paper division. Gallo holds a bachelor's degree in chemical engineering and has experience of many functional areas, including manufacturing, engineering, R&D, field service and sales.