

hypower

by Voith Hydro — N° 29.2017

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Unlocking Small
Hydro potential with
the StreamDiver

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150 years of Voith
innovation

p. 40

The rise of hybrid power
generation concepts

A celebration of hydropower innovation:
How exciting new ideas continue to shape our industry

Inspiring future generations



Editorial



Few businesses can look back on 150 years of growth, groundbreaking projects and successful customer relationships on a global scale. Fewer still can look forward to the future with confidence, in a rapidly changing world.

This edition of HyPower has one foot in the fascinating past of Voith Hydro's journey with its customers over the last century and a half. But the other is firmly in the future, facing forward to the new technologies and trends that will shape the evolution of our industry in the coming decades. That means, for example: hybrid plants that combine water and wind power to create exciting new opportunities for clean energy storage and generation; state-of-the-art pumped storage facilities; acoustic plant monitoring; and Small Hydro turbines that minimize environmental disruption.

Here's to the next 150 years of hydropower innovation – enjoy the issue!

Uwe Wehnhardt
President and CEO, Voith Hydro

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Where it is, how it forms, and what it means

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Oil-free performance

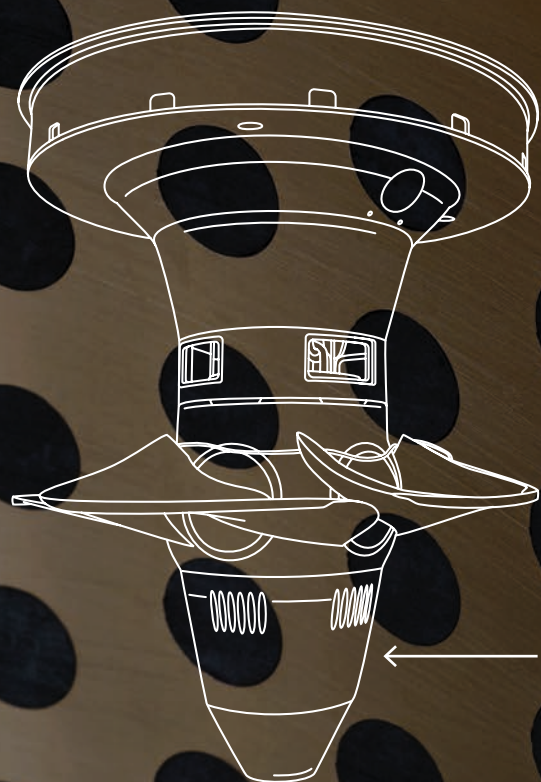
Ordinarily, adjustable blade runner hubs within Kaplan turbines are filled with oil to lubricate the bearings and the sliding parts of the operating mechanism. However, Voith has also been developing oil-free alternatives for over 30 years.

In the oil-free hub, the oil is replaced by self-lubricating bush bearings that eliminate the risk of oil leakage, maximizing environmental protection and simplifying maintenance, without compromising on performance.

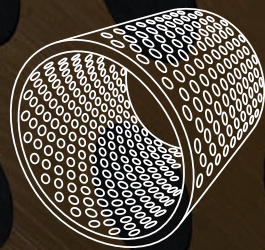
Self-lubricating bush bearings

1985

The year Voith began developing and installing oil-free solutions for Kaplan turbine runner hubs.



The self-lubricating bush bearings are located throughout the runner hub at, for example, the lower end of the turbine.



News

A quick round-up

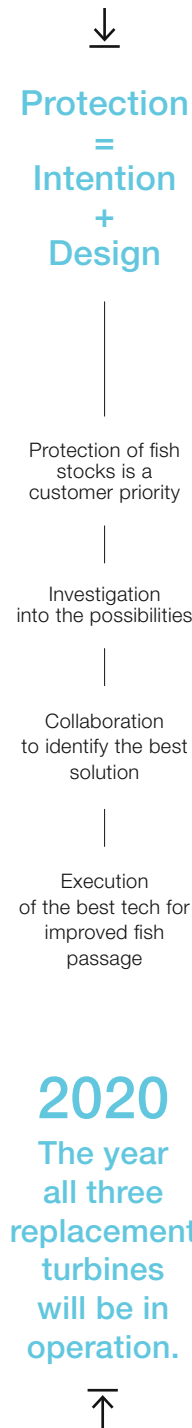
Adding automation with minimum outage

The key advantage enabled by pumped storage plants is reliable power generation. That is why it is so important for Belgian energy supplier ENGIE Electrabel to keep its six-machine Coo-Trois-Ponts plant running during the installation of new automation technology, supplied by Voith. "We have arranged to do this by shutting down one machine at a time for a period of about eight weeks," says Jürgen Häckel, Head of Service at Voith Hydro Germany. And the customer is delighted with the benefits it will bring: "The new automation technology ... will guarantee safe, reliable and economic power plant operation for at least another 20 years," explains Luc François, Project Manager at ENGIE Electrabel.

Miyashiro No. 1

114

The number of years the Voith turbine at Japan's oldest hydropower plant has been running.



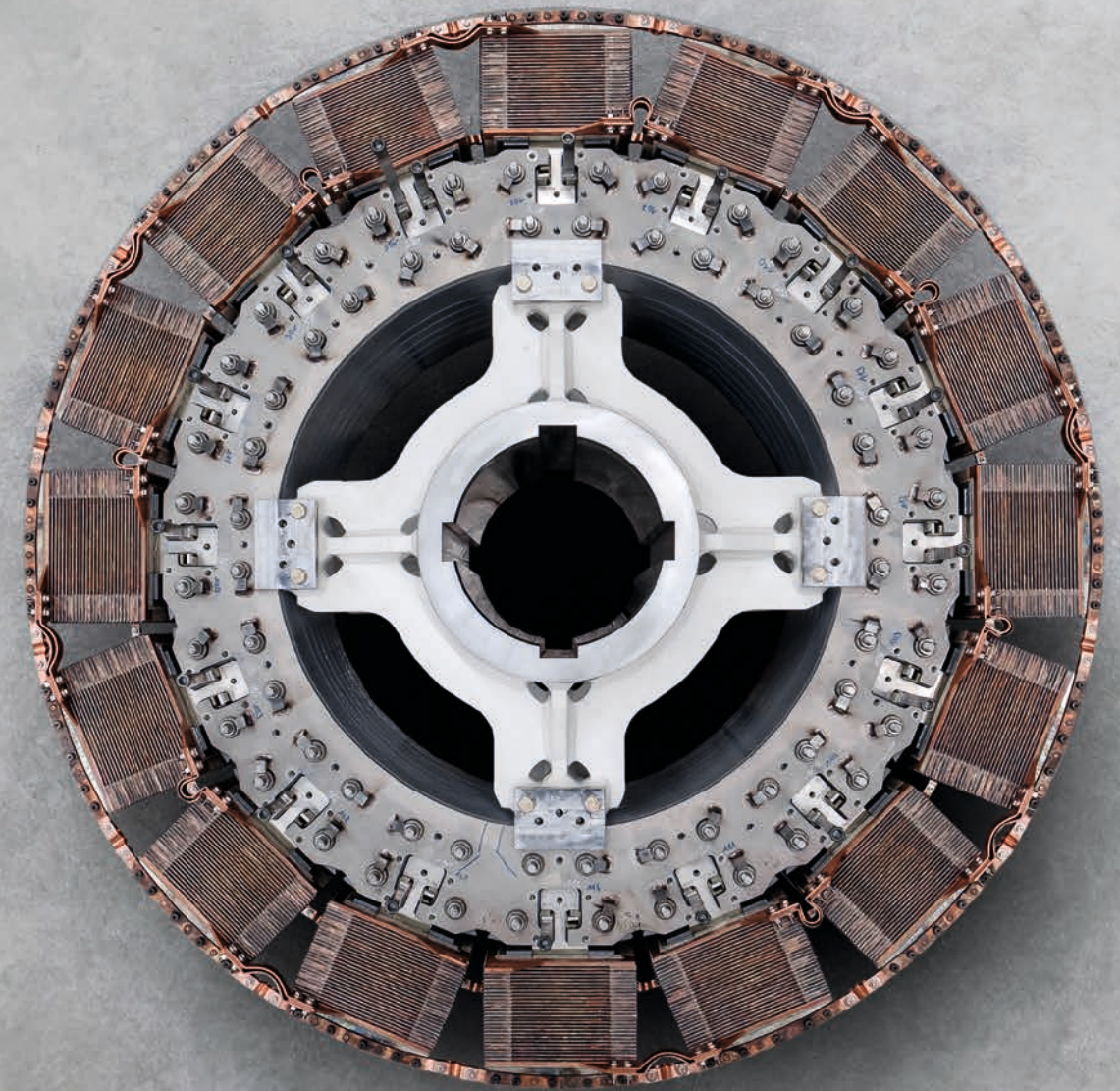
"I believe Ice Harbor represents the next step in turbine technology for improved fish passage."

Jason Foust,
Hydraulic Engineer, Voith

Turbine design for improved fish passage

Reducing the chance of injury to fish as they migrate downstream through hydropower facilities is an important issue on the Snake River in Washington State, United States. So, when the turbines at the Ice Harbor Lock and Dam needed to be replaced, this was the perfect opportunity to install machines designed to improve fish passage conditions. The design team, consisting of engineers, biologists and stakeholders, worked hard through many iterations of turbine design and testing to identify areas for fish passage improvement, including modifications to the turbine geometry that help minimize the injury rates of juvenile fish.

Jason Foust, Hydraulic Engineer on the Ice Harbor project, concludes: "I believe Ice Harbor represents the next step in turbine technology for improved fish passage. This concept and the resulting design process can contribute successfully to fish passage protection at hydropower sites around the world."



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innovate

A closer look at how the next generation of hydropower technology is evolving

All-new generator lab

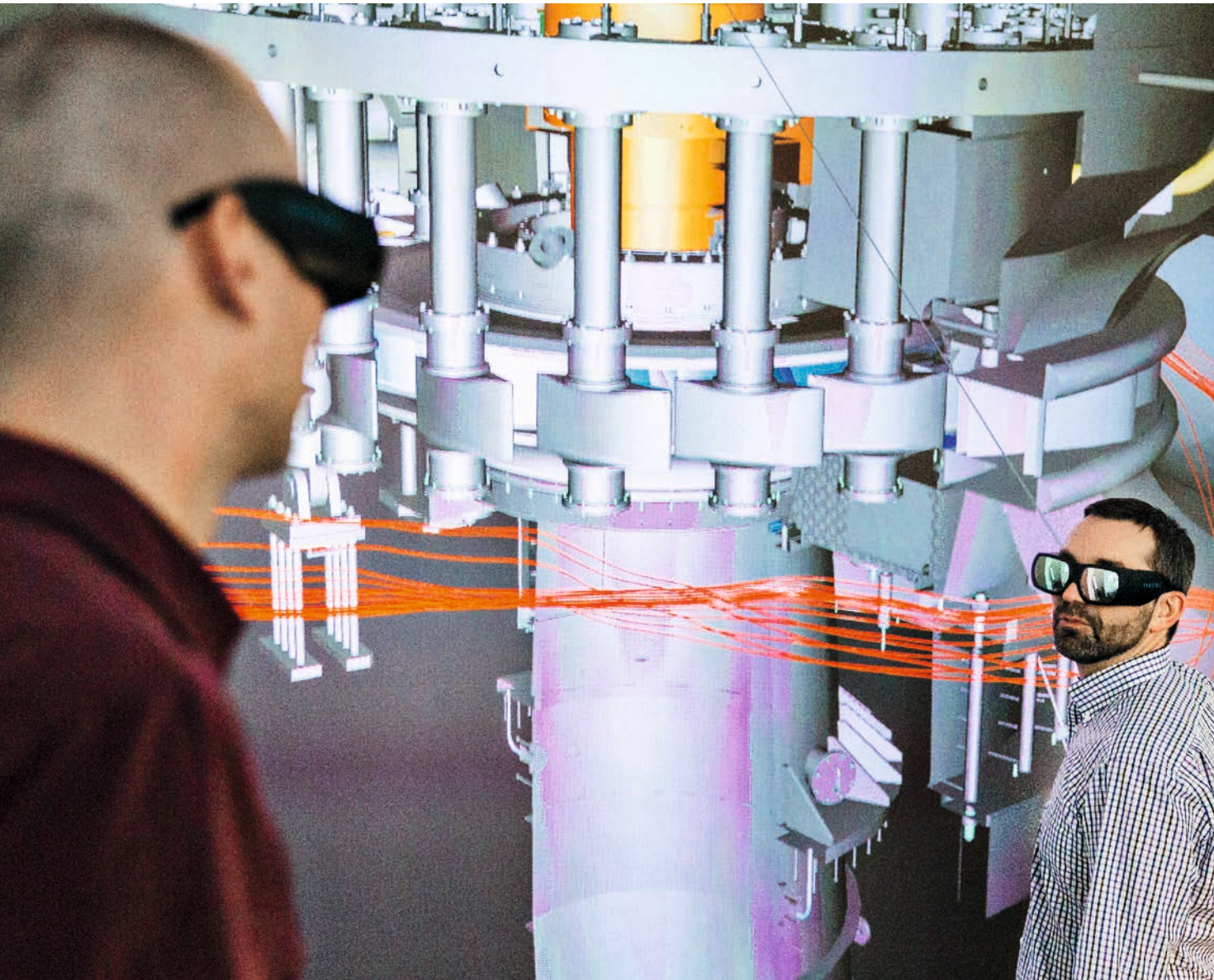
While Voith strives to increase product value through strategic R&D, the new generator-laboratory machine validates "beyond the edge" hydro generator simulation models and innovative designs. Since July 2016, the sensor-rich machine has been operating in the new Generator-Converter Laboratory at Leibniz University in Hanover, Germany. It offers unrivaled opportunities to study the physical effects of normal, intentionally faulty and extreme operating conditions. The result: a thoroughly tested foundation for creating advanced hydroelectric solutions.

REINTEGRITY

Dr. Roland Jester-Zürker, Head of Fluid Mechanics at Voith Hydro, explains how Voith experts are utilizing computational fluid dynamics to better understand and improve the operational efficiency of hydropower turbines and generators.

State-of-the art simulation technology is allowing Voith experts to improve their understanding of how hydropower machinery behaves in different operational conditions.





Voith experts use powerful computer hardware and software to predict and analyze fluid flow inside Voith machinery.



Turbine flow

Predicting how machinery and fluids interact ensures smooth operation.

Virtual testing

Enables performance, reliability and efficiency to be improved.

_____ **Successful operation of** new hydropower plants depends on accurately predicting how machinery and fluids will interact before the plant is built. Dr. Roland Jester-Zürker, Head of Fluid Mechanics at Voith Hydro, uses computational fluid dynamics (CFD) to research and plan optimal plant design and maximize operational performance.

_____ **Can you explain what CFD is and how it is used at Voith?** Essentially, a group of skilled engineers uses a combination of powerful computer hardware and software to predict and analyze fluid flow inside our machinery. CFD enables us to reliably investigate and evaluate complex physical relationships very early in the design process. It helps us to achieve high levels of performance, reliability and efficiency for our products. We can virtually test things such as the effects of geometric variations, performance limits during

operation or the stresses placed on components due to the pressure of fluid flow. Being able to carry out detailed, accurate analyses on the computer has also led to a major reduction in physical model testing, which reduces design lead time and makes the process faster and more cost-effective for our customers.

_____ **Are physical model tests still important?**

Absolutely. Validating numerical results of challenging flow regimes like off-design condition is crucial to achieve the required prediction accuracy. We work closely with our colleagues in the hydraulic lab at the Brunnenmühle research and development center in Heidenheim. Close collaboration between the teams is a big advantage – it enhances prediction accuracy, which speeds up the planning process and improves product performance.

_____ **Is all the expertise in-house?** To accelerate development, we look to the future with external partners such as the Institute of Fluid Mechanics and Hydraulic Machinery at the University of Stuttgart. With their support, we recently completed one of the largest computational investigations ever undertaken on a Francis turbine. It focused on part-load operation and its effect on water flow through the draft tube. Our main objective was to derive an improved CFD process to increase prediction accuracy, which is a challenging task in the case of part-load operation. It was an intensive effort involving extremely refined grid models with over 300 million nodes, using the computational power of 2,000 processors working in parallel.

_____ **Do you also investigate generators?** Generators are just as important, and we look at them intensively. Because they are electromagnetic machines and not designed with fluid mechanics in mind, fluid flow investigation is more complicated, but we've built a process that simulates air flow in an entire generator. This allows us to look at how to cool the machines properly, minimize energy loss and optimize heat transfer. It also enables us to improve overall machine behavior, extend its lifetime and minimize overall costs.

_____ **How is CFD evolving and what changes are on the horizon?** One of the most important assumptions in CFD is turbulence modeling. To date, there is no universal turbulence model, but we expect that scale-resolving approaches will improve prediction accuracy. Increasing the level of detail and including multi-physics aspects will also be a task for the near future. On a more general level, computing power has improved considerably since we started using CFD around 30 years ago. This has given us faster and more accurate results that have helped reduce design-cycle times. In the coming decades, we expect this accuracy and speed to improve further still.



Water flow analysis

The analysis, carried out in partnership with the University of Stuttgart, investigated how part-load turbine operation affects water flow through the draft tube at a hydropower plant.

Over 2,000 processors and highly refined grid models with over

300 million nodes were used.

The result:

An improved CFD process to increase flow prediction accuracy.

“CFD enables us to reliably investigate and evaluate complex physical relationships early in the design process.”

Dr. Roland Jester-Zürker
Head of Fluid Mechanics

Big innovation in Small Hydro

In the future, Small Hydro projects will be vital in unlocking hydropower potential. The StreamDiver helps realize that potential with minimum environmental impact.

_____ Around 75% of the world's viable hydropower resources remain untapped, but many potential sites are not well suited to building larger hydropower plants. That is one of the reasons Voith has invested in the development of its Small Hydro StreamDiver power unit turbine, which enables power generation for installations with a head of up to 8 meters. The standardized, modular power unit is suitable for outputs from 30 kW up to double-digit MW, and installation as well as operation requires minimal environmental disruption. Its benefits are illustrated perfectly at the new

StreamDiver site at Alte Bleiche, part of the River Brenz, inside Voith's own factory complex in Heidenheim, Germany.

Timo Mayer, Project Manager Small Hydro at Voith, explains: "The StreamDiver installation at Alte Bleiche combines a compact turbine-generator unit with a shaft-based hydropower plant concept developed by the Technical University of Munich. It is one of the few hydropower plants in the world that combines high efficiency with an ecologically aware design that is invisible and completely oil-free."

Minimizing environmental impact

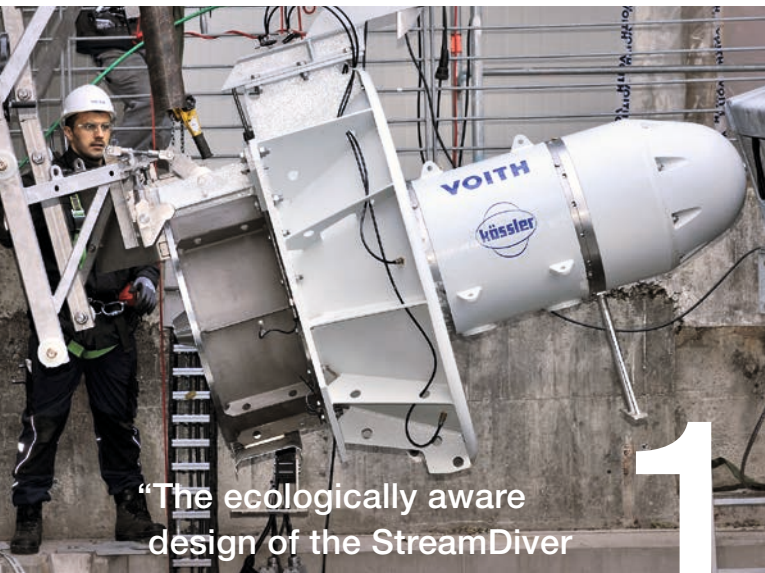
Development of the Alte Bleiche site was only permitted if environmental regulations covering noise pollution, the safe passage of fish downstream and flood prevention could be met in full. That is why the team decided to build the shaft and install the StreamDiver in a small weir that had been out of use since the 1980s. No building work – other than the underwater shaft – or any alterations to the river's flood-prevention outlets were required. The power plant is especially innovative in that it runs entirely without hydraulic oil. Additionally, because it sits below water level, it is invisible from ground level and virtually silent. In addition, the plant's technical controls are integrated within a small standardized container, with no need for a powerhouse.

Maintenance made simple

Speaking about the easy maintenance of the technology, Timo Mayer comments: "The StreamDiver removes the usual complexity of hydropower installations because the design does not need to take cooling water, drainage water and oil pipes into account. All the relevant operational parameters and system states can be monitored remotely. Combined

with the low proportion of moving parts, this reduces the need for manual inspection, allows for very predictive maintenance and maximizes unit availability. High performance, stable operations, long service intervals, reduced downtime and low-cost spare parts will ensure stable revenue over the project's lifetime."

Supported by an enthusiastic team of apprentices and students in every phase, from design and manufacturing through to assembly and installation, the project was completed in December 2016, just eight months after construction work had started. Today, the installation produces energy for the Voith factory. Customers can now see the StreamDiver in action for themselves by visiting the installation and its special on-site exhibition.



"The ecologically aware design of the StreamDiver

is invisible and completely oil-free."

Timo Mayer
Project Manager Small Hydro, Voith

1
The StreamDiver power unit turbine is lowered into position at Alte Bleiche.

2
StreamDiver units can be installed individually or in a row.

3
The StreamDiver unit is submerged and exerts minimal environmental impact.



Low impact

Lower civil impact and civil costs compared with conventional solutions



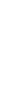
Low cost

Low operational and maintenance costs



Oil-free

Oil-free power unit and completely oil-free plant



Low noise

Lower noise level compared with a standard hydropower installation



Invisible

Submerged machinery for low visual impact



Nonstop innovation

For 150 years, new ideas have guided Voith's approach to serving its customers. Uwe Wehnhardt, President and CEO, and Dr. Norbert Riedel, Chief Technology Officer, discuss how innovation will help ensure customers' success in the future.

Not many businesses survive and thrive for 150 years. Why has Voith Hydro?

Uwe Wehnhardt: First of all, hydropower itself has a long and innovative history, in which Voith has played a leadership role since it began developing turbines in Germany in 1870. By 1903, Voith was already shipping its hydropower machinery abroad, including the delivery of the world's largest turbines to a new plant at Niagara Falls in North America. All the while, hydropower has become increasingly important in supporting economic growth, especially in Europe in the early 20th century and, more recently, in Africa and Asia. Hydropower as a renewable energy source also has a unique ability to provide base-load supply without dependence on the wind or the sun. This has also contributed to the sector's growth and significance.

Dr. Norbert Riedel: Because water is a natural and therefore varied source of

“Our competence is reflected in long-lasting partnerships with customers.”

Uwe Wehnhardt
President and CEO

energy, every hydropower plant must provide a bespoke technological solution to suit the specific characteristics of the location. It pays to plan every kilowatt of output from an economic perspective, and we can do that based on the standards we have developed, which have been proven over decades of successful project implementation. Establishing these standards requires

us to use the latest development methods and leverage huge volumes of reference data from existing projects. This is why customers can trust our technology that, while proven, will never have been installed in exactly the same way somewhere else. Our leadership is only possible through our significant investments in engineering and people, which allow us to combine technology, the exceptional skills of our professionals, and the experience generated through our reference projects.

Wehnhardt: Another important factor is that we have developed the breadth and depth of our products and services to become a full-line supplier in the sector. This even includes financing solutions from our internal partner Voith Financial Services, which are important for many customers – especially for Small Hydro projects. Moreover, everything we learn and develop for large projects feeds into our other business segments, including Small Hydro,

modernization and our service business. This represents a virtuous cycle of continuous improvement, which is enabling us to lead in both hydraulic and electrical equipment for hydropower plants. Ultimately, our competence in these areas is reflected in long-lasting partnerships with customers that have trusted our technological expertise and innovation for decades.

Why do you believe hydropower will become even more important in the future?

Wehnhardt: Hydropower can help meet the objectives of the climate agreement signed last year in Paris, because it is a clean, renewable, environmentally friendly energy source that also has a low carbon footprint. What's more, there is huge development po-

tential, because around 75% of available capacity remains untapped. And because we can use water to store energy, hydropower can also be combined with other energy sources to create hybrid energy-generation solutions. **Riedel:** Indeed, hydropower is ideal for supplementing the contribution of weather-dependent renewable energy sources like wind and solar, because it



Uwe Wehnhardt, President and CEO

Dr. Norbert Riedel, CTO

can compensate for fluctuations in supply and provide reliable available capacity. Combining pumped storage with wind or solar installations can create very effective solutions that allow for constant base-load supply.

_____ **What will be the key influences on the further development of hydropower technology?**

Wehnhardt: Digitization will be vital, not only for hydropower itself, but also for the energy sector in general. Digital solutions will help our customers run their hydropower plants even more efficiently or reduce operational costs. In addition, our ability to analyze and interpret data will give us a deeper understanding of our machines, make it easier to identify anomalies and allow our customers to utilize their hydropower assets more effectively.

Riedel: That is why we have integrated our automation and monitoring capabilities within Voith's new Digital Solutions Division to develop new products and solutions for our customers. For example, HyGuard, our new acoustic monitoring service, uses sound to help engineers identify problems at plants remotely before they affect operation. It is easy to install at new or existing plants, and it learns to spot anomalies more effectively through the structure of the cloud. In addition, using new sensor technologies all over the plant improves operational flexibility and efficiency, and helps our customers maximize profitability. Finally, digital solutions also enable plant owners to plan and execute maintenance work optimally, so shut-down periods have the lowest possible impact on operations.

_____ **Which solutions does Voith offer for developing untapped hydropower potential?**

Wehnhardt: Digitization is also a key driver here for maximizing the performance of new and existing plants. We

offer tailored digital solutions that improve efficiency and extend operational boundaries, based on reliable data analyses that help our experts advise customers optimally. In particular, we see a lot of potential in the sub-100-MW area, for which we also offer cost-effective solutions. Voith is a recognized leader in these Small Hydro technologies, which benefit from everything we learn and develop through the world's largest hydropower projects.

Riedel: Exactly – Small Hydro technologies exhibit the same sophistication and effectiveness as large installations, but add benefits such as lower environmental impact. One good example is Voith's StreamDiver – an adaptable, environmentally friendly and compact turbine-generator unit that enables stable, flexible power generation at a small scale.

Wehnhardt: And that expertise also informs knowledge transfer about sustainable hydropower development through, for example, our HydroSchool initiative. The Mount Coffee plant in Liberia – for which we trained 20 technicians and managers on site and in Heidenheim, while simultaneously carrying out technology upgrades – illustrates this perfectly. Worldwide, we have already conducted 13,000 hours of training across 50 courses, and helped 800 students from 100 companies improve their skills.

_____ **What else is Voith doing to enhance the future of hydropower?**

Riedel: The energy sector is changing rapidly and so are customer require-

ments – from optimal to flexible operation at the limit. As a result, simulation technology that helps customers make improvements while protecting resources is becoming more important. Our approach is to create a “digital twin” of the plant, to map its life cycle more accurately. We have been leading improvements in these simulation techniques across hydraulic and electronic technologies for decades.

Wehnhardt: And that leadership depends on our continuous investment in research and development. We have a precise road map of where we want to get to. One recent important milestone in that journey is the Geno-Lab in Hanover, Germany, opened in 2016 through cooperation with the local university.

Riedel: It is a good example of how we utilize our globally integrated network of R&D facilities and partnerships with universities around the world. This kind of collaboration is allowing us to, for example, make new demands on materials, and work on the future applications of our technologies in salt water.

Wehnhardt: Another important reason we are ready for the future is that we have become even better at understanding our customers' priorities and identifying their pain points. We learn which parts of their business models they want to optimize and extend, and use modern methodologies such as the design thinking process to find solutions. And by working even more closely with our customers, we're developing individual solutions for them that make the most of our expanding capabilities. _____

“Simulation technology helps customers make improvements while protecting resources.”

Dr. Norbert Riedel
Chief Technology Officer

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transform

Insight into the people and technologies shaping the future of hydropower

Training the world

Inna Kremza, who celebrates her 20th year at Voith Hydro in 2017, combines her primary job as Head of Engineering with a lead role in customer training. “About five years ago, customers started asking us to help them retain and extend their hydropower expertise. Now I run training courses for new and experienced engineers around the world. I love seeing the difference it makes to them. I only wish I could have started earlier,” she says.

Inna Kremza,
Head of Engineering,
Voith Hydro Mississauga, Canada

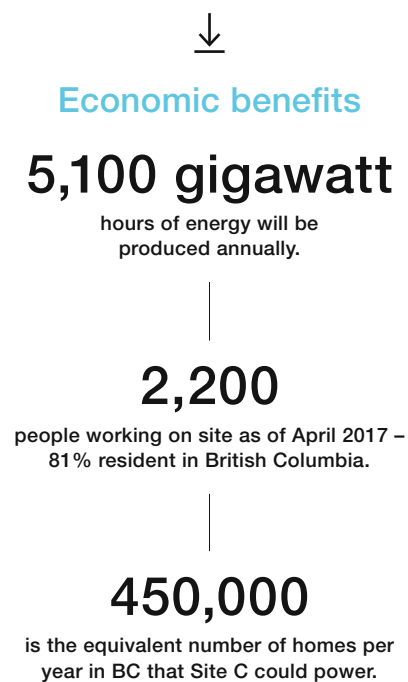


On-the-spot manufacturing

Voith is supplying six Francis turbines and generators for Site C, with a total output of 1,100 MW.

A creative on-site approach to machine manufacturing will boost productivity during the construction of the new Site C hydropower plant in British Columbia, Canada.

Almost five years after the initial introductory meeting with BC Hydro in Vancouver, April 2017 saw the completion of the Voith groundbreaking ceremony for the Site C hy-



dropower plant on the Peace River in British Columbia. It is the latest exciting milestone since Voith was awarded the contract in March 2016, after a competitive three-proponent bidding process, for the manufacturing and installation of the six Francis turbines and accompanying generators required for the project. By 2024, the plant will be operating with a capacity of 1,100 MW – enough to power the equivalent of 450,000 homes per year in British Columbia. The construction of Site C, located downstream of BC Hydro's existing W.A.C. Bennett and Peace Canyon dams, will also feature two innovations that were unique in Voith's proposal: on-site manufacturing and robotic welding.

Intensive evaluation

Over 18 months of collaborative bi-monthly meetings with BC Hydro, the parameters of the Site C plant were discussed, defined and adjusted. Each of the bidders then submitted proposals, including model turbines, which were tested independently at the EPFL (École Polytechnique Fédérale de Lausanne) in Switzerland with BC Hydro's supervision. It was an intensive process, as Voith Project Engineer Sebastian Mogl recalls: "The evaluation and testing process took well over a year, and we knew that winning the contract would be about striking a balance between the cost of the electrical/mechanical equipment, efficiency and the cost impact on the civil design. Ulti-

mately, finding the optimized solution for BC Hydro was the goal of the entire process." In the end, BC Hydro decided Voith had found that ideal balance, with BC Hydro President and CEO Jessica McDonald commenting, "Voith was selected because of its strong track record with similar complex projects, and its proposal offered BC Hydro the highest-value design, within budget."

On-site innovation

One way Voith is delivering additional value is through the construction of an on-site manufacturing facility. Voith Project Manager Leila Britel explains: "Some of the turbine components we are supplying – including the welded sections of the draft tube elbows and cones, the draft tube bulkheads, and the spiral case sections for the six units – are very large. That makes them difficult, time-consuming and expensive to transport over long distances. Building an on-site manufacturing facility enables us to assemble and weld these parts together on site. This reduces the risk of delays, lowers installation and transport costs, and enables faster implementation of changes." Not only that, the facility will use new robotic welding technology for the first time, increasing productivity, ensuring maximum part quality and reducing the risk of rework.

Benefiting local communities

Importantly, Voith is also working with BC Hydro and local communities to minimize disruption and maximize the employment and economic benefits of the project for local people, including Aboriginal populations. Thousands of jobs will be created by the Site C project. At the peak of the turbines and generators project, 200 Voith employees will be on site, working with local talent to ensure Site C goes into full operation on schedule, in 2024.



2012

Initial introductory meeting to discuss project



2013/14

Development of turbine models



2015

Independent testing of models in Switzerland



2016

Voith selected to supply six Francis turbines & generators



2017

Plant construction begins, and the on-site manufacturing hall is completed



2018

Powerhouse construction begins



2022

Machine manufacturing completed



2023

First Voith unit goes into service – all six will be running by 2024



1867
Friedrich Voith
assumes control of his
father's business –
the "official" inception of
Voith as a company,
with 30 employees.

Then ————— Now

Over the last 150 years, Voith Hydro has become a global leader in full-line hydropower solutions. Innovation has guided every step of its journey, and will continue to do so in our digital future.



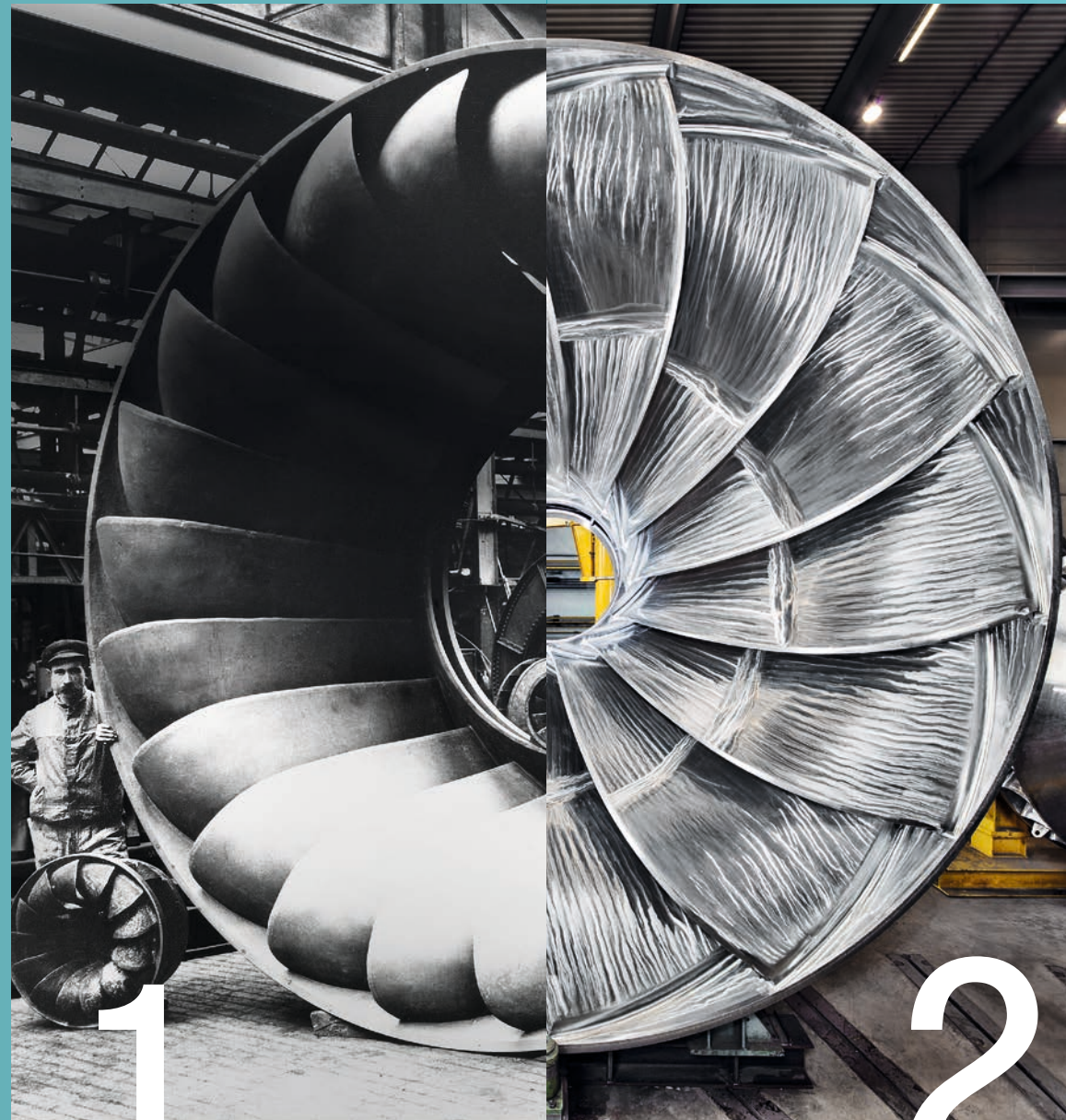
Welcome
to the Next
150 Years

→ | www.voith.com/150years-en/index.html

Did Friedrich Voith know in 1867 that the company his father started would become one of the world's most enduring businesses? Or that the organization he built would still be driving hydropower innovation a century and a half later? We can't know for sure, but we can say that the innovative spirit he brought to his work has echoed across the decades in every new technological development, customer relationship, milestone project and strategic acquisition. Since the company delivered its first turbine, Voith has played a key role in supporting the world's industrial development and economic growth with clean, renewable power. It has survived two world wars, and numerous global booms and slumps, by focusing on what it does best: delivering solutions that solve its customers' challenges in innovative and highly effective ways. Because innovation should always have a practical purpose – defined by what our customers need.



① **Early 20th century:** This Francis runner was manufactured in 1920 to generate power for a paper mill in Kuusankoski, Finland. Friedrich Voith was the first to design and produce a Francis turbine in Germany, in 1873.



② **Early 21st century:** This modern Francis runner was delivered to the Bratsk hydroelectric plant, situated by the Angara River, the only outlet from Lake Baikal in Russia, in 2014. It has a diameter of 5.6 meters and weighs 73 metric tons.

Today, Voith is driving the next stage of its evolution in the digital age. Of course, automation, modern technology and computer-aided design have transformed turbine manufacturing. But Voith is applying digitization to every aspect of hydropower plant design, construction and operation.

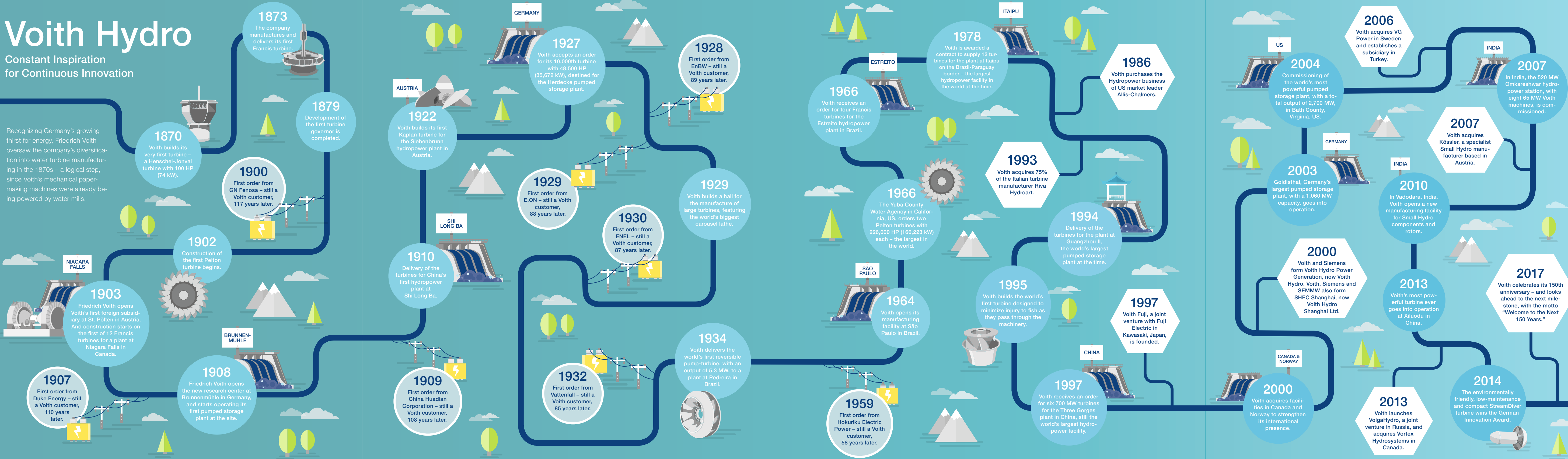
For example, state-of-the-art simulation technologies allow Voith to accurately predict machine behavior, giving customers peace of mind before plants go into operation. And acoustic monitoring systems help energy providers proactively maintain facilities without the delay, expense and potential risks of sending engineers to remote sites.

And alongside these digital approaches, Voith continues to innovate in machinery, developing environmentally friendly solutions that minimize environmental impacts, protect fish stocks, and unlock Small Hydro generation potential. In other words, innovation will drive the next 150 years of the Voith story – just as it has always done.

Voith Hydro

Constant Inspiration
for Continuous Innovation

Recognizing Germany's growing thirst for energy, Friedrich Voith oversaw the company's diversification into water turbine manufacturing in the 1870s – a logical step, since Voith's mechanical paper-making machines were already being powered by water mills.



Turbines
Voith has made a habit out of turbine technology innovation, designing, building and installing a wide range of Francis, Kaplan, pump, Pelton and bulb/pit turbines, and supplying a total of 40,000 units to its customers.

Generators
Voith has built a complete portfolio of generator solutions for all speeds, vertical and horizontal designs, and air-cooled and water-cooled windings – including the world's largest and most powerful water-cooled generators.

Pumped storage
Voith Hydro is a leader in pumped storage hydropower plants that ensure reliable available capacity by storing excess energy and releasing it whenever it is needed. It is also the perfect foundation for hybrid energy generation solutions.

Automation & Digital Solutions
Digitization is taking hydropower automation to the next level. Voith Digital Solutions enables deeper insight into machine behavior, and faster identification of anomalies or improvement opportunities, empowering energy providers to operate more efficiently.

Small Hydro
Only 25% of the world's potential hydropower capacity is being used. Voith's leadership in innovative Small Hydro technology is helping to unlock this potential in locations where large hydropower projects are not economically or geographically feasible.

Full-line solutions
Voith Hydro has evolved its portfolio to meet and exceed customer requirements across the entire life cycle of new and existing hydropower plants, whatever their size and scope – from plant design and construction, to financing and service.

HyService
Voith HyService teams provide fast, high-quality, proactive maintenance and repair services, wherever and whenever they are needed. Customers benefit from reliable power generation and maximum return on existing investments.

Environmentally friendly solutions
Voith develops solutions that help minimize the impact of hydropower projects on the environment – from submerged, oil-free Small Hydro turbines that reduce water pollution, to enabling safer fish passage through machinery.

Meeting the change challenge

Voith contributes to the International Hydropower Association (IHA) through its Platinum membership and Voith Hydro CEO Uwe Wehnhardt's work as a board member. Richard Taylor, CEO of the IHA, shares his views on our industry's challenges and opportunities, and on the recent World Hydropower Congress.

_____ Mr. Taylor, you've been involved in hydropower for 30 years. Why does it still fascinate you, and what new challenges is the industry facing? Hydropower covers so many disciplines and is so varied in terms of its geographical, technical, financial, environmental and social facets. Nobody can ever become a complete hydropower expert. I am always learning, and the search for better solutions never ends. In terms of challenges, it is about staying relevant in the face of rapid technological, political and economic change across the world, and being dynamic and flexible enough to adapt. We need to ensure that hydropower can meet future energy and water needs even more competitively.

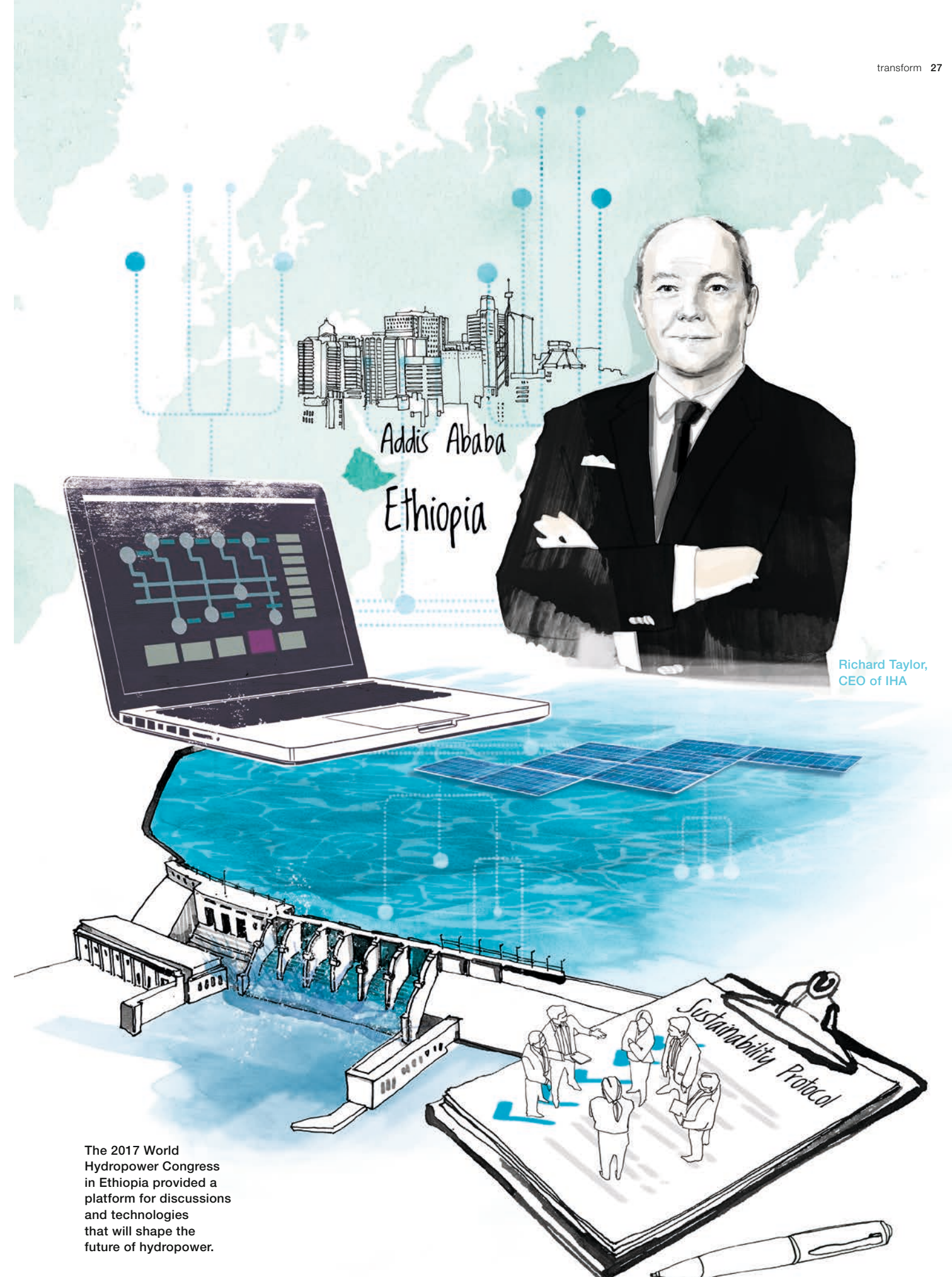
_____ How is the role of IHA changing in the face of new challenges? The organization started out

“The IHA is an excellent organization that represents the industry in the best possible way, mainly through the diversity of its membership.”

Uwe Wehnhardt,
President and CEO, Voith Hydro

as a group of interested members seeking stronger representation for the hydropower sector in the policy landscape. Today we're an organization spanning 100 countries that identifies gaps in hydropower knowledge, searches for solutions and shares insight as widely as possible. We're becoming more of a creator and distributor of knowledge that helps all stakeholders have greater confidence in the hydropower-related decisions they make.

Over the last decade, we have also begun working much more closely with our peer organizations in the wind, solar, geothermal and bio-energy industries. This collaboration is intensifying because the integration of different sources of renewable energy is becoming increasingly important for guaranteeing reliable energy supply.



Richard Taylor,
CEO of IHA

The 2017 World Hydropower Congress in Ethiopia provided a platform for discussions and technologies that will shape the future of hydropower.

In many countries, it is reliability and quality, rather than growth in capacity, that is the key issue right now. In addition, the increasing number of hybrid renewable projects – for example, floating solar on hydro reservoirs – is quite extraordinary.

How important is the Hydropower Sustainability Protocol to the development of the industry?

The protocol has been developed to provide a way of defining and building a consensus around proven good practice for key topics in hydropower activities, in terms of environmental, social, economic and technical performance. The information defined by the protocol supports project stakeholders, and makes for more informed decision-making. The protocol is continuously being reviewed to see if it can be made more useful and efficient, which benefits everyone involved. For example, together with Voith, we are currently working on a methodology for measuring project performance in relation to climate resilience. Another initiative is finding ways to increase the speed with which information can be gathered in the field and presented to decision-makers. We are also looking to increase the number of independent accredited assessors who measure project data against the protocol. Our goal is to ensure that every verification company providing due diligence on hydropower projects has at least one full-time assessor on their staff.

The recent 2017 World Hydropower Congress was in Ethiopia. Why is that, and what were the highlights of the event?

The mandate to bring the congress to Africa was established at the 2015 World Hydropower Congress in Beijing. Africa has a similar

**Voith and the IHA:
Key Facts**

Voith is a Platinum Member of the IHA, and CEO Uwe Wehnhardt serves as a board member.

Voith was a key sponsor of the 2017 World Hydropower Congress, and provided two speakers for its workshops and breakout sessions:

Dr. Norbert Riedel, CTO
("Workshop 4: Strategies to Foster Sustainable Operation and Maintenance" and "Renewable Energy Storage")

Heike Bergmann, SVP Sales Africa
("Capacity-Building and Skills Shortages")

hydropower potential to that of Europe, but 90% of it remains untapped, so the "local" interest is very high. Addis Ababa is where the African Union and the United Nations Economic Commission for Africa are headquartered, so Ethiopia was the logical choice.

In terms of the highlights, there were several areas. Firstly, the launch of our new tool for measuring the greenhouse-gas footprint of hydro-power projects. This is a real landmark for the sector. Secondly, the discussion around green labels and what the climate bonds initiative means for the hydropower industry was very interesting. And thirdly, the debate about setting up a hydropower preparation support facility was important. Such facilities could give host countries and developers a well-defined blueprint for preparing and implementing future projects. This will significantly reduce the risk premium for developers, align the projects to system needs, and could steer the way we do hydropower in the future, in an increasingly interconnected world.

Finally, the overall theme of the conference was "Better Hydro." To complement that, we published case studies developed together with the World Bank. These cases prove how hydropower best practice has been achieved and checked through sustainability assessments, and they include some examples that are really inspirational. All this made for a very exciting congress, where the world met to shape hydropower's future. On behalf of all the organizing partners, I would like to take this opportunity to acknowledge and thank Voith as a sponsor for helping us make the congress happen.

reflect

Technologies and approaches that demonstrate how the industry is evolving

Sound Innovation

Hydropower facilities are so large and complex that sometimes you can hear a problem before you can see it. The easy-to-install HyGuard™ acoustic monitoring system uses microphones to detect unusual sounds from around the plant. Special algorithms are then used to analyze them in the cloud and discover whether there is a potential problem. Best of all, it is a self-learning system that continuously improves the accuracy with which anomalies can be detected.



A six-year project to expand and improve the performance of an existing Austrian hydropower installation marks a high point for pumped storage technology.



A Voith engineer inspects a turbine on site at Reisseck II.

Recharging the 'green battery'

The impressive dam wall at Reisseck II in southern Austria.

Located amidst the wonderful Alpine setting of Mölltal, a southern Austrian valley in the province of Carinthia, the redeveloped Reisseck II pumped storage plant is as innovative as it is ambitious. After six years of construction, this new facility creates a hydraulic connection between two groups of existing power stations, Malta and Reisseck-Kreuzeck. As such, it makes energy generation in the Alps even more efficient and sustainable. And it marks a real high point in the development of pumped storage hydropower plants. "From a technology point of view," says Martin Nussmüller, a Voith project leader on Reisseck II, "we can say it is one of the most modern pumped storage plants in the world."

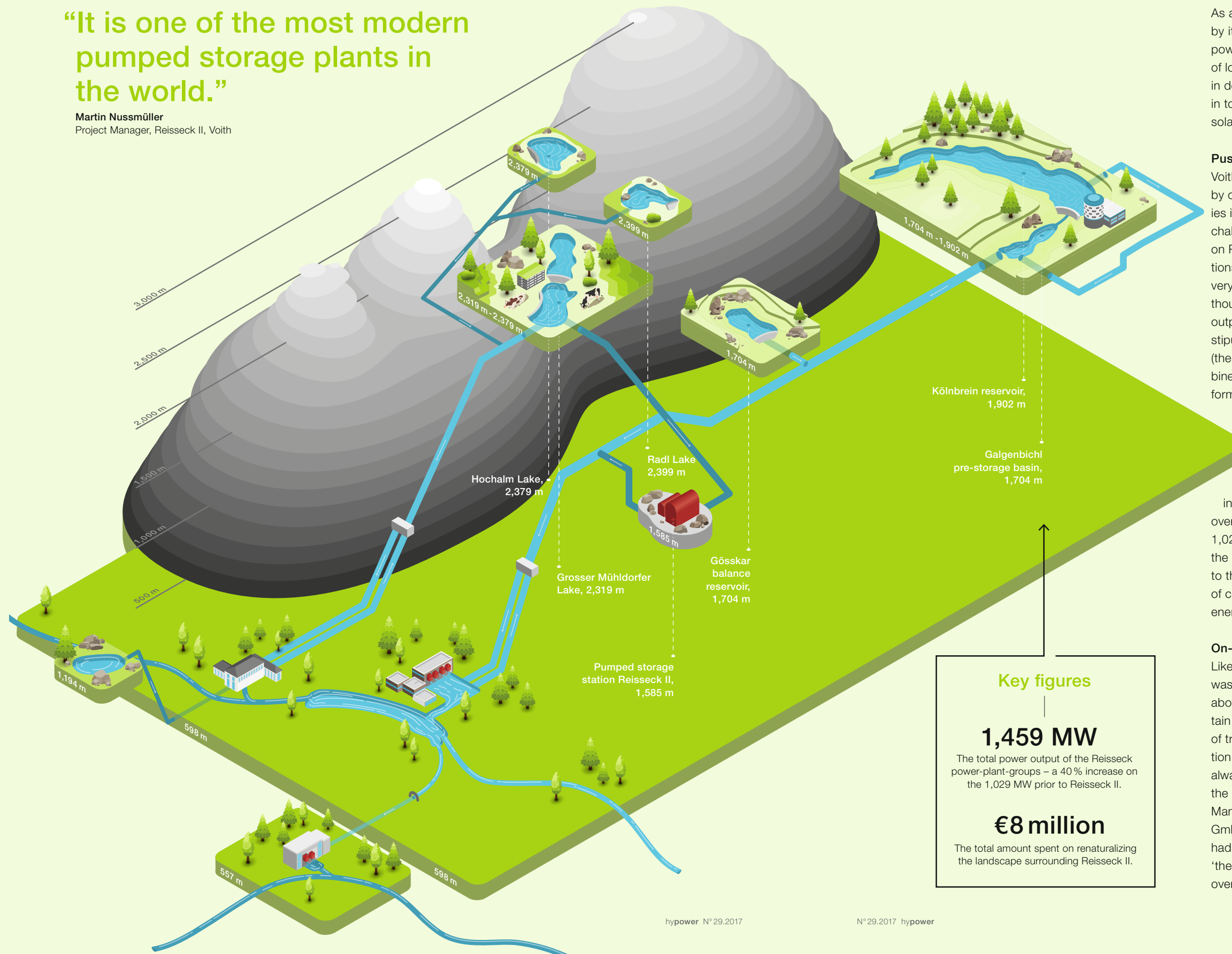
Environmentally sound foundations

The original Reisseck-Kreuzeck system was created between 1948 and 1961, with Malta opening in 1978. This means that Reisseck II required no major additional environmental changes. Indeed, though up to 250 people, huge machinery and underground tunnels were integral to its completion, the landscape has been returned to its idyllic Alpine aesthetic. "Around €8 million has been spent on renaturalizing the area," says Nussmüller.

Now complete and operational, Reisseck II increases the efficiency of the area's energy generation system, ensuring that the installation is as environmentally friendly as possible.

“It is one of the most modern pumped storage plants in the world.”

Martin Nussmüller
Project Manager, Reisseck II, Voith



As a result, it is known by those who worked on the project by its nickname – the “green battery.” Whenever wind-powered or solar energy sources are compromised because of local weather conditions, Reisseck II comes into its own: in double-quick time, the pumped storage plant can step in to supply power, and then be throttled back when wind or solar conditions improve.

Pushing the limits of design

Voith innovations facilitated the optimal operation of the plant by creating two pump turbines that really push the boundaries in terms of design and functionality. “This was a great challenge,” says Anton Huber, also a Voith Project Manager on Reisseck II. “We had to go beyond the usual specifications, but we showed we could complete the project to a very high standard.” The central tenet of the design is that though the turbines are small, they provide a very high power output, which equates to exceptional efficiency, as stipulated by the customer, Verbund Hydro Power GmbH (the Austrian energy provider). Huber adds: “The pump turbines have been labeled ‘Grenzleistungsmaschinen,’ or ‘performance-limit machines.’ This refers to the fact that the power output of the turbines relative to their size is right at the limit of what is currently possible. Therefore, from an efficiency and technological viewpoint, they really are cutting-edge.”

The result: Reisseck II has an output of 430 MW in both pumping and turbine modes, and increases the overall output of the two power-plant-groups by 40%, from 1,029 MW to 1,459 MW. The beauty of the technology and the overall design is that energy generation can be adapted to the prevailing conditions almost instantaneously. And of course, as a pumped storage plant, Reisseck II can store energy for use whenever it is needed.

On-time delivery, despite the challenges

Like any other hydropower site in a remote region, the project was a complex undertaking. Construction at 1,600 meters above sea level and up to 200 meters deep inside a mountain presented considerable challenges, particularly in terms of transporting huge machinery to the right place. In addition, delays caused by avalanches and forest fires were always a risk. Nevertheless, nothing was allowed to endanger the completion of the project, as David Giefing, Project Manager for the Pump Turbine at Verbund Hydro Power GmbH, concludes: “Throughout the project, I always felt I had found a trustworthy partner in Voith. With our credo, ‘the technical solution always comes first,’ we were able to overcome every project challenge together.”

Key figures

1,459 MW

The total power output of the Reisseck power-plant-groups – a 40% increase on the 1,029 MW prior to Reisseck II.

€8 million

The total amount spent on renaturalizing the landscape surrounding Reisseck II.

Always-on service

Voith Hydro's global service-center strategy gives customers fast access to local support. Here's how it is working in Brazil.

65% The proportion of Brazil's total energy mix derived from hydropower generation.

2 HyService Centers and counting!

25% The proportion of electrical energy projects currently under construction accounted for by hydroelectric power plants.

“The idea behind our HyService Centers is that we want to be close to our customers and provide services wherever they are,” explains Luiz Fontes, Head of HyServices for Latin America. “In the past, long journeys to plants sometimes caused delays for our customers. The solution was to create small, effective local service facilities in the form of HyService Centers.”

Well placed: HyService locations

At present, Brazil has two HyService Centers, both opened in 2016, which are well positioned to support hydropower stations across the region. One is located at Porto Velho in Rondônia, on the Madeira River, and close to the power plants at Jirau and Santo Antônio. The second is in the state of Tocantins, located at Miracema on the Tocantins River, near two other major plants: one at Lajeado and the other at Peixe Angical.

On site within hours

Fontes is clear about the essential role the new centers will play. “Our customers get added value through the confidence and trust they have in Voith,” he says. “They want to know that, in the unlikely event of a problem with any machine, even if it wasn't manufactured by us, they can rely on Voith engineers to respond quickly. Our service experts can be at any of the plants in the region within a few hours.”

Each service center is staffed by a supervisor and teams of technicians, engineers and mechanics that specialize in plant repair and maintenance. Importantly, experts at Voith headquarters in São Paulo are always on hand to provide additional specialist support, if required.

Proactive support

In addition to rapid response, service specialists also visit customer plants regularly to offer advice and perform proactive check-ups on turbines, generators and other equipment. “The idea is to provide corrective maintenance when the customer needs us in an emergency, but also preventative technical support that can save them a lot of time and money.”

Continued expansion

The two sites in Brazil are models for building similar facilities in the future. “We are currently conducting assessments for other potential sites in Brazil and other countries in Central and South America,” says Fontes. This expansion will provide the perfect platform for Fontes and his colleagues to keep energy flowing for customers across the region. _____

Voith service engineers survey a local hydropower installation.



Ensuring grid stability

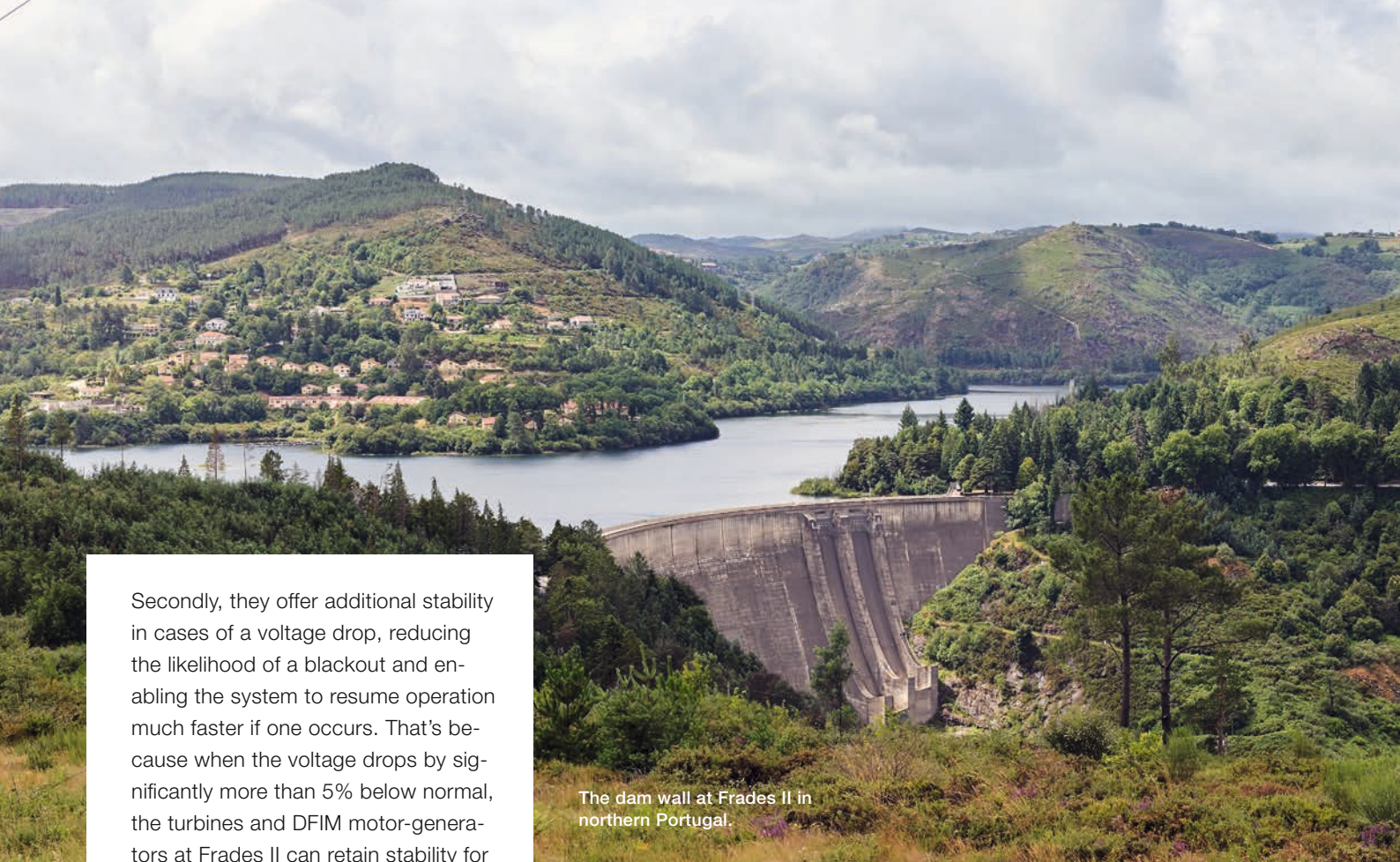
Europe's most relevant installation of variable-speed, reversible pump-turbine and motor-generator units is now in successful commercial operation at EDP's Frades II hydropower facility in northwestern Portugal.

Solar and wind power make a significant contribution to Portugal's electricity generation capacity and, because these technologies are weather-dependent, the grid is vulnerable to fluctuations in supply. This makes it the perfect place to build a pumped storage plant powered by a state-of-the-art technology that helps ensure grid stability. Nevertheless, Portuguese energy company EDP Produção took a brave step when it decided to implement a solution based on two Voith variable-speed, reversible pump-turbine/motor-generator units that, at the time, had no reference projects to prove their effectiveness. EDP's trust in Voith's technology has now been rewarded, as the new Frades II pumped storage plant began successful commercial operation on April 1, 2017.

Variable speed, constant reliability

"The key element of this plant is a special asynchronous motor-generator: the DFIM, or doubly fed induction machine," says Thomas König, Electrical Balance of Plant at Voith Hydro. Explaining how the technology works in more detail, he adds "A conventional synchronous machine turns at a fixed speed in time with the 50 Hz grid frequency. In contrast, the mechanical rotation speed of the DFIM machines can vary, which has two main advantages. Firstly, the new systems allow a fast and flexible response to active and reactive demand from the power grid – supply can be varied to meet demand.





The dam wall at Frades II in northern Portugal.

Secondly, they offer additional stability in cases of a voltage drop, reducing the likelihood of a blackout and enabling the system to resume operation much faster if one occurs. That's because when the voltage drops by significantly more than 5% below normal, the turbines and DFIM motor-generators at Frades II can retain stability for up to 600 milliseconds – four times longer than a fixed-speed power unit. This can mean the difference between normal operation and a widespread power outage.” Ultimately, DFIM technology delivers optimal operation in both turbine and pump modes, while fulfilling TSO (role assumed in Portugal by REN) requirements for grid fault behavior by injecting fast active and reactive power when it is needed in both modes. Another key aspect of this technology (and perhaps the most relevant in terms of value creation) is the ability to provide power variation in pump mode, which can deliver the grid's needed teleregulation during off-peak hours, making Frades II the only plant in Iberia to do so without having to generate surplus power.

Innovation at scale

The Frades II project required Voith engineers to innovate in several areas. For example, the motor-generator's rotor had to be designed to cope with high centrifugal forces and a much higher current and voltage from the frequency

converter. This converter is larger, heavier and 25 times more powerful than that of a fixed-speed facility with an equivalent output. And because the converter is much faster than conventional models, a new electrical protection system also had to be created.

All this innovation is now delivering important benefits to the customer EDP, as Lars Meier, Head of Technical Sales & Proposal Management at Voith Hydro, explains: “The variable-speed motor-generator technology at Frades II provides enhanced flexibility,



Frades II

The Frades II plant is located approximately 40 km northeast of Braga in northern Portugal.

390 MW

The capacity of each variable-speed reversible pump-turbine unit at Frades II.

Voltage drop

Voltage is significantly more than 5% below normal.

Grid stability must be maintained in order to prevent a widespread power outage and blackout conditions for customers.

600 milliseconds

DFIM maintains grid stability for 600 milliseconds.



One of the asynchronous motor-generator units being installed at Frades II.

That's four times longer than a fixed-speed power unit.

which increases the plant's total number of operational hours. More operational hours and higher availability generate more revenue, which in turn means more profit. This is one of the reasons why other similar facilities have amortized the required investment very quickly. Another nice side effect of the technology is greater operational efficiency overall. It really is a win-win for the customer.”

António Ferreira da Costa, member of EDP Produção Board of Management, agrees, commenting, “EDP is the company in Europe now able to provide a solid reference for the technology at this huge scale. Voith proved itself able to meet the most stringent grid code requirements in Europe and to overcome the challenges posed by the units' large rated power. We're highly satisfied that the plant is running as planned, and even in the first two months of operation, we have used al-

most the full potential of the technology to ensure continuous renewable energy generation, balanced against demand.”

A model for the future

Since the Frades II plant entered commercial operation, it bears Europe's largest variable-speed units. And because grid stability and ensuring energy supply reliability are becoming more important everywhere, Frades II has provided a template that will be replicated around the world. Indeed, Voith is already involved in discussions about similar projects in China and Canada. Meier concludes, “The technology we have deployed at Frades II is extremely sophisticated, and we are proud that we have been able to master all the electrical and mechanical engineering challenges we faced along the way. We're looking forward to using that knowledge to provide other energy suppliers with similar benefits.”



“It's the difference between normal operation and an outage.”

Thomas König
Electrical Balance of Plant, Voith Hydro

A stable grid

Dr. Klaus Krüger believes hybrid power generation plants are key for a cleaner energy future.

Stronger together

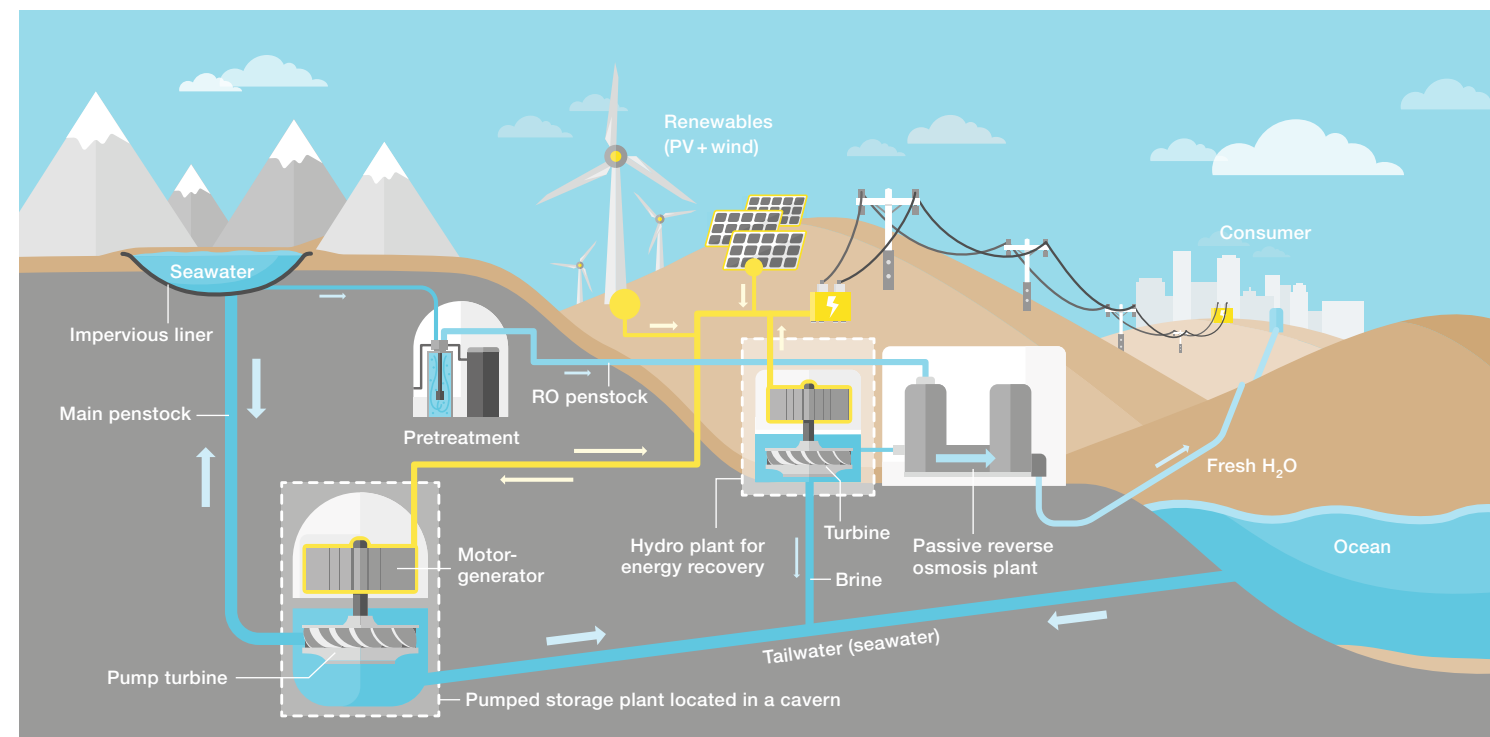
Dr. Klaus Krüger, Head of Plant & Product Safety and Innovation at Voith Hydro, explains why hybrid solutions will become increasingly important for generating and storing clean, renewable energy.

_____ In a forest overlooking the small town of Gaildorf in southwestern Germany, a unique renewable-energy project is underway. The "Naturstromspeicher" (natural electricity storage plant) combines a pumped storage hydroelectricity power station with a wind farm. The base of each of the farm's four wind turbines acts as a reservoir. To generate electricity, this water is released downhill through pump turbines. If there is a surplus of power in the grid, the water turbines switch to pump mode and drive the water back up to the wind turbine reservoirs. An adjacent area of the Kocher River will be used for the lower reservoir, which can also be used as a retention pond in flood seasons.

Built-in flexibility

In September 2016, Voith was selected to supply three reversible Francis pump turbines for this groundbreaking project. Dr. Klaus Krüger, Head of Plant & Product Safety and Innovation at Voith Hydro, says the 16 MW Naturstromspeicher plant makes it easier to integrate renewable energy into the grid. "Pumped storage plants are a proven solution for flexible

Combining seawater pumped storage, plus wind and/or solar power generation, with a desalination plant creates a highly efficient way of generating and storing energy, and producing drinking water.





“The hybrid concept could also be applied to small grids, on islands, for example.”

Dr. Klaus Krüger

Head of Plant & Product Safety and Innovation,
Voith Hydro

bulk energy storage, which is crucial when using more volatile sources of electricity generation like wind and solar.”

Combining pumped storage with a wind farm provides a new way to generate and store clean energy. The extra height provided by the reservoir bases results in taller wind towers that allow the wind turbines to generate more energy. Planning and infrastructure costs, and environmental impact, can be reduced as the two technologies use the same service access, grid connection and substation. “The storage,

fast start-up times and load control options of the three speed-variable units will also allow the operator to profit across different energy trading markets, such as balancing energy, control power and spot markets. And pumped storage can avoid wind curtailment in case of negative energy spot market prices,” adds Krüger.

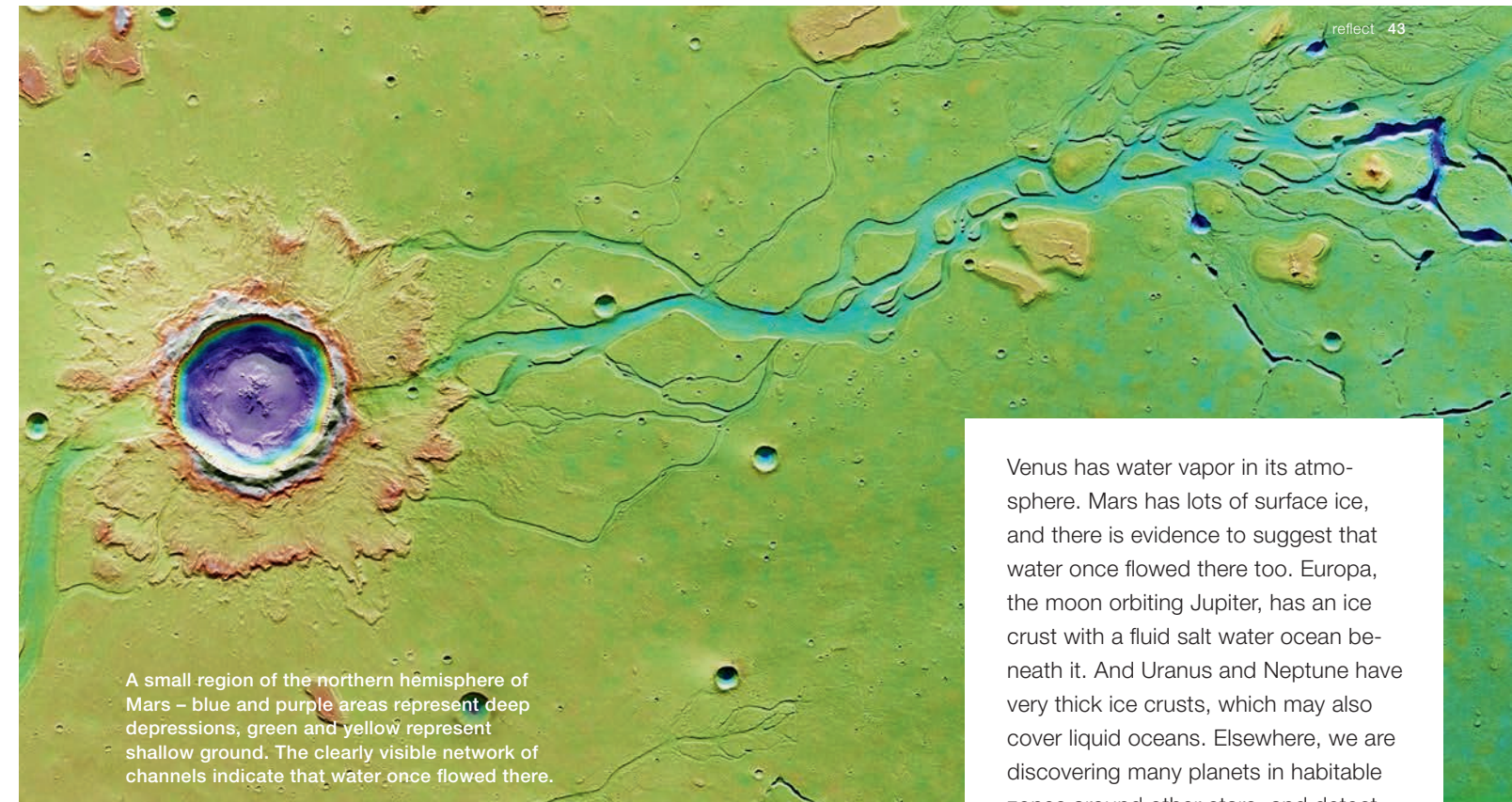
What’s more, by using the wind towers as upper reservoirs, geography becomes less of a limiting factor, opening the potential of decentralized pumped storage to more sites served by municipal utilities. “The hybrid concept could also be applied to small grids, on islands, for example,” Krüger explains. “Then you could even use salt water, with the ocean as the lower reservoir, instead of precious fresh water.”

Symbiotic saltwater applications

Using salt water for pumped storage plants presents other technical challenges, particularly protecting equipment against corrosion, which can be solved technically. Krüger and his colleagues are researching how to realize the huge potential of combining seawater and pumped storage economically, with the possibility to provide more than just electricity. This could be accomplished with symbiotic approaches.

One exciting symbiotic solution could help provide two vital resources: renewable power and clean fresh water. Around the world, desalination plants use reverse osmosis (RO) to turn seawater into drinking water by forcing it through semi-permeable membranes. However, it is an energy-intensive process that requires large amounts of electricity, often produced by fossil-fuel power plants. Instead, Krüger says, “Combining a seawater pumped storage system, powered by solar or wind energy, with a passive RO desalination plant could present an effective, environmentally friendly solution. The ocean would be used as the lower reservoir, with the upper reservoir in nearby coastal mountains. Rather than using high-pressure pumps and motors to push water against the membrane, as in classic RO plants, this would work passively: the pressure comes from the head of the upper reservoir. And the constant pressure allows the RO plant to run 24/7.”

Just like the hydro-wind hybrid, this concept reduces costs by co-locating and simplifying systems, and generates zero CO₂ emissions during operation. Such large-scale pumped storage solutions could convert volatile wind or solar energy into an economical, controllable base load generation source, with quality and availability similar to coal- or gas-fired plants. Krüger summarizes: “They could bring greater grid stability, skilled jobs and hope for a decarbonized future. And solar photovoltaic (PV) and wind turbines feeding saltwater pumped hydro, co-located with passive RO plants near the ocean, could provide power and fresh water for coastal regions with water scarcity.”



Q&A

questions and answers

**Dr. Arnold Hanselmeier,
Professor for Astrophysics
at the Karl-Franzens-
Universität in Graz,
Austria, explains the what,
where, how and why
of water in the universe.**

Why does water exist?

When the Big Bang occurred 13.7 billion years ago, only two elements existed – hydrogen and helium. All the other heavier elements, including oxygen, were created later through fusion within stars. At some point, oxygen and hydrogen combined to create water.

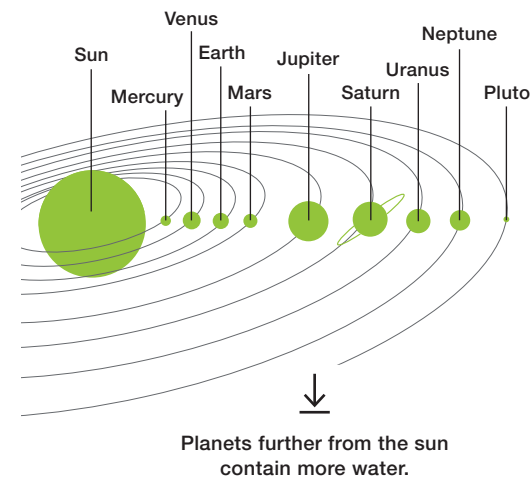
How common is water in the universe? Water is everywhere – from the vapor and droplets found in galactic gas clouds, to the ice within comets, and the atmospheres, oceans and ice fields of planets. The further you travel from a star, the more prevalent it becomes.

How does water form on planets? It is likely that it arrives in the form of ice when comets crash into the surface of planets. For example, 10 million years is more than enough time for comet impacts to have created all the water found on Earth today.

How common is water on planets within our solar system and elsewhere? It is very common. Shaded craters on Mercury contain ice, and

Venus has water vapor in its atmosphere. Mars has lots of surface ice, and there is evidence to suggest that water once flowed there too. Europa, the moon orbiting Jupiter, has an ice crust with a fluid salt water ocean beneath it. And Uranus and Neptune have very thick ice crusts, which may also cover liquid oceans. Elsewhere, we are discovering many planets in habitable zones around other stars, and detecting water vapor in their atmospheres. But they are all too far away to tell whether liquid water is also present.

Is the presence of water necessary to support life? Water is the ideal solution medium for supporting life because it is stable across a wide temperature band. As far as we know, life requires water, but that doesn’t necessarily mean life is present wherever water is found. We won’t really know for sure until we are able to examine samples of liquid water on other planets!





Welcome
to the Next
150 Years

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Inspiring Technology
for Generations