

Magazine of ANDRITZ Hydro // 5-2019

# HYDRONEWS SPECIAL

A NEW OLD  
CONTINENT  
EUROPE

ЕНВОЪЕ  
СОИЛИЕИ  
ТААО

**ANDRITZ**



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**EUROPE** is a figure of Greek mythology, the daughter of the Phoenician king Agenor and the Telephassa. Zeus fell in love with her and abducted her disguised as a bull.



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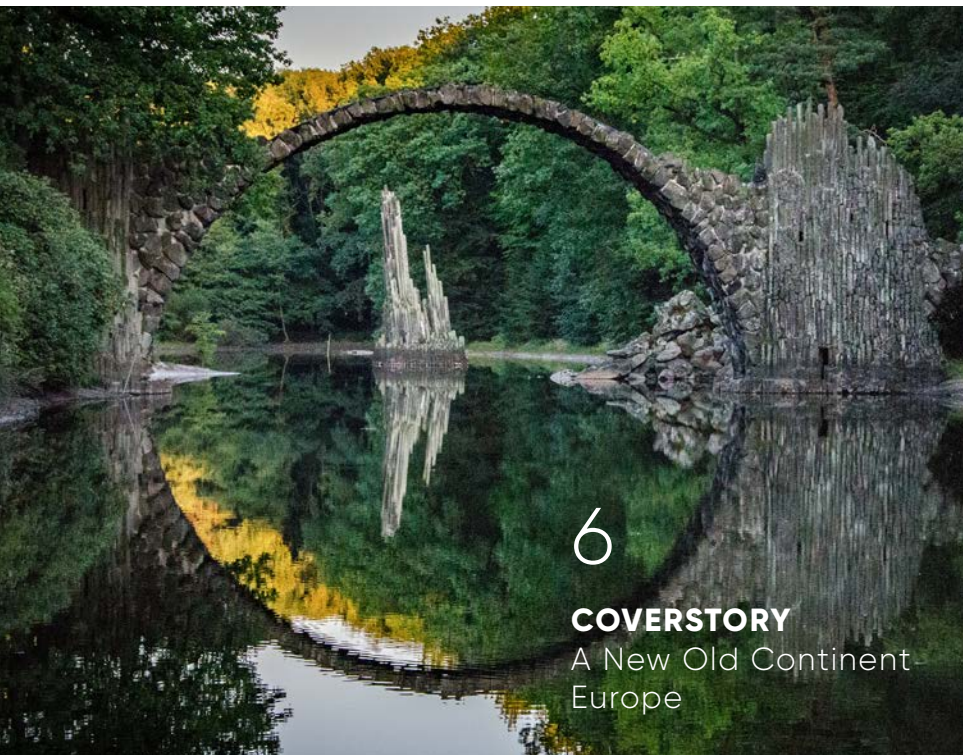
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6

**COVERSTORY**  
A New Old Continent Europe



38

# FACTS IN SHORT



**915 mio. people**  
third most populous continent

**225**  
indigenous languages



**Russia**  
(17,100,000 km<sup>2</sup>, 40% of Europe)  
largest country of the world



**Vatican**  
(0.44 km<sup>2</sup>)  
smallest country of the world



**10,180,000 km<sup>2</sup>**  
(3,930,000 sq mile)

**2%**  
of the earth surface

**6.8%**  
Land area

**6**  
Geographical territories

**47**  
Countries

**5 of top 10**  
Richest countries



**15,900**  
Employees

**113**  
Locations

## Hydro

**3,800**  
Employees

**29**  
Locations

**9**  
Manufacturing facilities

**5**  
Laboratories

**1805**  
Foundation year

## Dear Business Friend,

Europe is a small, diverse and wealthy continent. It is home to more than 900 million people. Widely considered the cradle of western civilization, European scientists and engineers led the world in the discovery and application of many of the scientific and engineering advances that we take for granted now – including pioneering hydropower engineering. Today, much of Europe's existing hydropower potential has already been developed and the bulk of this capacity is already 50 years old or more. Not only are their components reaching the end of their service life, there is also a growing need for hydropower to meet new demands from a changing energy landscape increasingly dominated by renewables like wind and solar. As a result, Europe's hydropower market is broadly characterized by the modernization and rehabilitation of existing plants. A few selected greenfield projects are being realized, in particular where there is a premium on flexible capacity like pumped storage – the only economically feasible method of large-scale energy storage.

Most of Europe's countries have committed to a sustainable, emission-free future and are widely expected to increase the use of renewables until at least mid-century. Hydropower and technologies like pumped storage do, and will continue to play an essential role in delivering clean, stable, and flexible capacity capable of balancing other renewable sources. Hydropower's position at the heart of the energy transition is therefore secured.

From its first foundations, ANDRITZ has always been at the forefront of the hydropower business and the development of innovative technologies. From large pumped storage plants in the alpine regions to run-of-river installations on major European rivers or the first Atlantic tidal-power applications, ANDRITZ has proven its expertise over more than a century of continuous engineering excellence and the 190 GW of European hydropower capacity that have already been installed or rehabilitated by ANDRITZ.

The origins of the modern hydropower story lie in Europe. Today, the next chapter is being written in this new, old, dynamic, and still-emerging continent.

This edition of Hydro News offers a glimpse into Europe's hydropower market, its role in a modern, low-carbon world and the continuing leadership of ANDRITZ in hydropower technology and project execution.



**Alexander Schwab**  
Senior Vice President ANDRITZ HYDRO GmbH

### IMPRINT:

**Publisher:** ANDRITZ HYDRO GmbH,  
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Eibesbrunnnergasse 20, Austria

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**Circulation:** 7,400

**Printed in:** English, German, French

**Coverpicture:** © Ronny Behnert-

stock.adobe.com

Printed on FSC paper;

ANDRITZ HYDRO GmbH;

Printed at WGA Print-Producing,

6911 Lochau, www.wga.cc

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Responsible use of personal data

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what kind of personal data we

process and why. For detailed in-

formation on our electronic data

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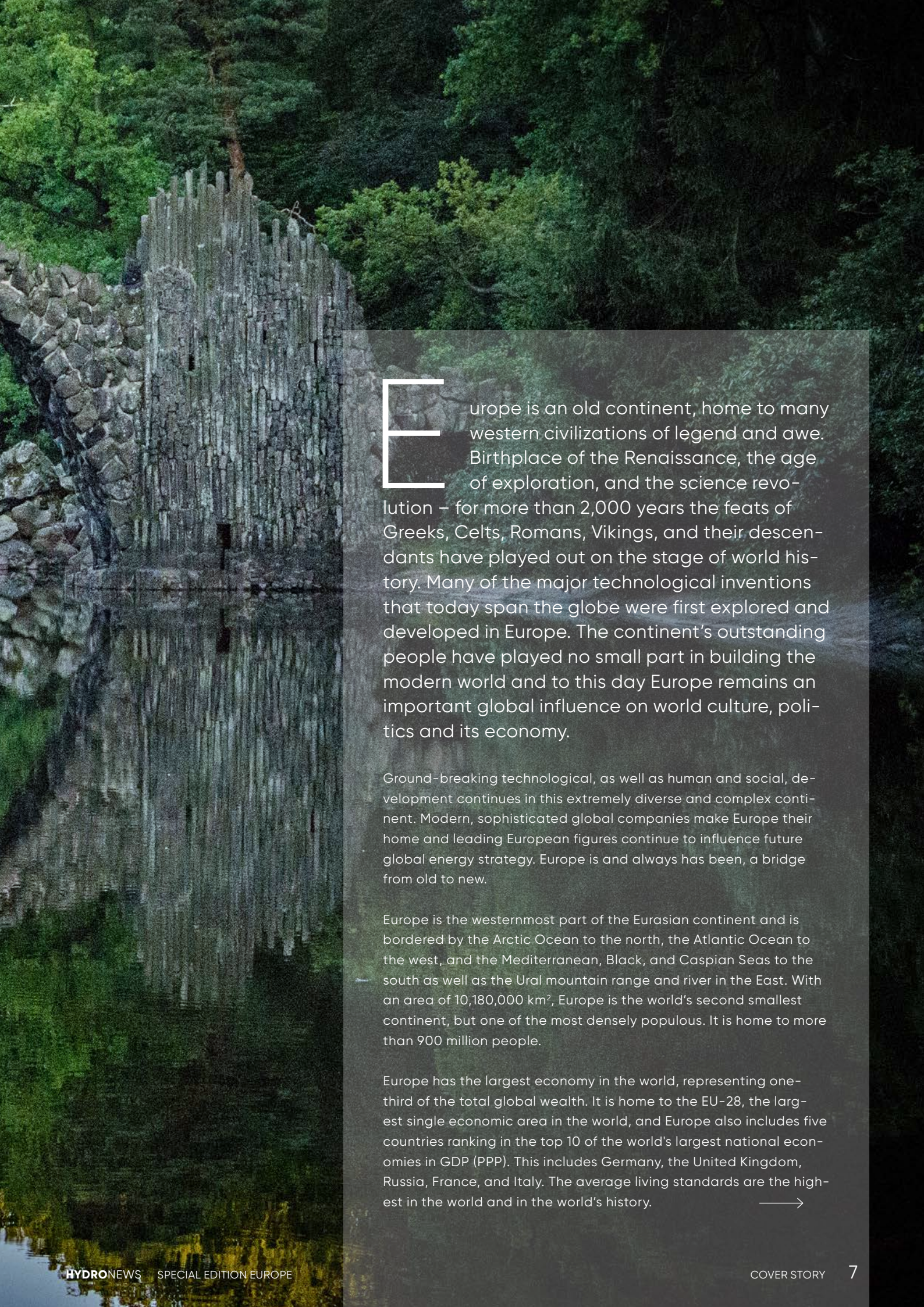
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# A NEW OLD CONTINENT EUROPE



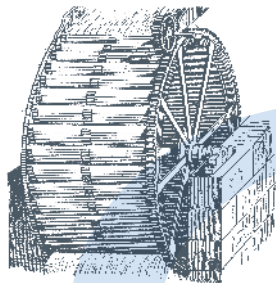
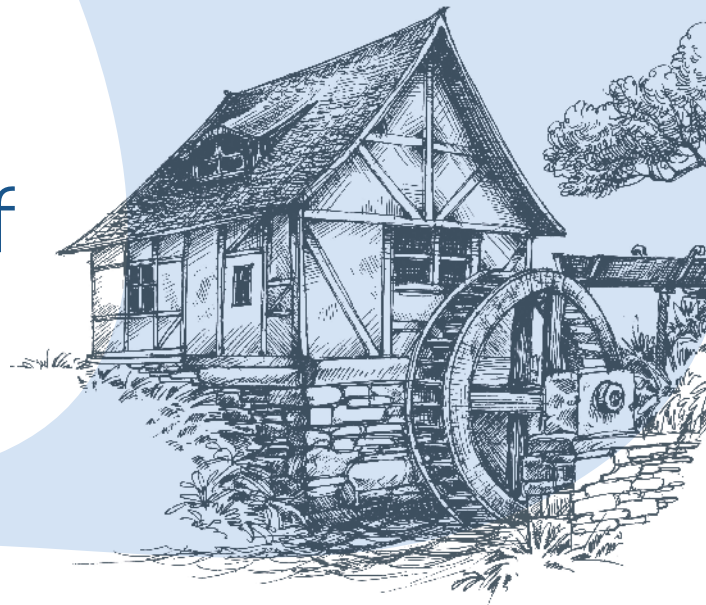
Europe is an old continent, home to many western civilizations of legend and awe. Birthplace of the Renaissance, the age of exploration, and the science revolution – for more than 2,000 years the feats of Greeks, Celts, Romans, Vikings, and their descendants have played out on the stage of world history. Many of the major technological inventions that today span the globe were first explored and developed in Europe. The continent's outstanding people have played no small part in building the modern world and to this day Europe remains an important global influence on world culture, politics and its economy.

Ground-breaking technological, as well as human and social, development continues in this extremely diverse and complex continent. Modern, sophisticated global companies make Europe their home and leading European figures continue to influence future global energy strategy. Europe is and always has been, a bridge from old to new.

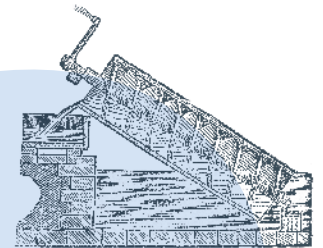
Europe is the westernmost part of the Eurasian continent and is bordered by the Arctic Ocean to the north, the Atlantic Ocean to the west, and the Mediterranean, Black, and Caspian Seas to the south as well as the Ural mountain range and river in the East. With an area of 10,180,000 km<sup>2</sup>, Europe is the world's second smallest continent, but one of the most densely populous. It is home to more than 900 million people.

Europe has the largest economy in the world, representing one-third of the total global wealth. It is home to the EU-28, the largest single economic area in the world, and Europe also includes five countries ranking in the top 10 of the world's largest national economies in GDP (PPP). This includes Germany, the United Kingdom, Russia, France, and Italy. The average living standards are the highest in the world and in the world's history. ———>

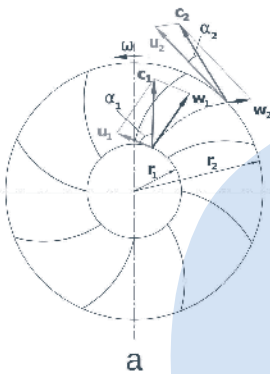
# Europe – the cradle of hydropower



Using the flow and fall of water to facilitate labor is as old as civilization. The first documented **water wheels** date back more than **2,500 years** and water has been used for agriculture, irrigation, and grist-, saw- and textile mills since ancient times. The ability to take advantage of water with technology goes hand in hand with the development of civilizations and economies throughout history.



Since the Greeks implemented the **Archimedes screw** in **about 200 BC**, the development of hydro-power technology has largely taken place in Europe. The Romans used water wheels and invented the boat mills, in use in Europe until the Middle Ages.



It was during the course of the science revolution in the **17<sup>th</sup> and 18<sup>th</sup> Centuries** that the evolution from the water wheel to the turbine took place. European academics set the course. German doctor and physicist **Johann Andreas von Segner** invented the **Segner water wheel**, a kind of reaction turbine. Ancestor to the modern turbine, the Segner wheel is still used for sprinkler systems today. Swiss mathematician and physicist **Leonhard Euler** came up with the "**turbine equation**" in **1757**. This describes the flow of frictionless elastic fluids, a fundamental calculation for turbine engineering. With his idea to arrange a guide wheel above the turbine, he is considered as the inventor of the **guide mechanism**, an important component of modern turbines to this day. In the **mid-1770s**, the French engineer **Bernard Forest de Bélidor** published his book "L'architecture hydraulique" describing vertical- and horizontal-axis hydraulic machines for the first time.



It took another 80 years of research and experimentation before **Jean-Victor Poncelet** developed an **inward-flow turbine** in the **1820s**. A break from the traditional undershot wheel, this new design had more than double the efficiency. In **1827** **Benoît Fourneyron**, another French engineer, built his horizontal **outward-flow turbine** of unequalled efficiency. Featuring two concentric wheels and the runner firmly connected to a shaft, his turbine was installed in numerous factories across Europe and elsewhere. It helped power the industrialization of the mid-19<sup>th</sup> Century and today its development is widely considered the **birth of the modern turbine concept**.





**James Bicheno Francis**, inventor of the **Francis turbine** in **1849**, was born in England. Irish engineer James Thomson contributed to the turbine control system and German **Carl Ludwig Fink** invented adjustable **guide vanes**, with which the Francis turbine could operate efficiently. Consequently, the Francis machine became the **most commonly used turbine** and is still the most widespread hydro machine in use today.



One of the founding fathers of the ANDRITZ Hydro family tree was not European but the American engineer **Lester Pelton**. Nonetheless, since their first construction in **1879 Pelton turbines** have been continuously developed in European laboratories ever since – first and foremost at ANDRITZ Hydro. The Pelton impulse turbine design has attained great importance as the best solution for high-pressure applications, especially in the Alpine regions and in Scandinavia.



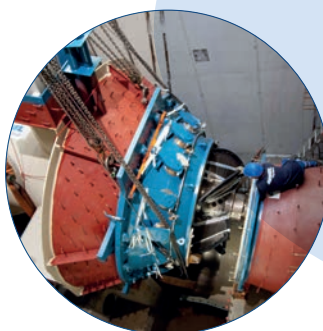
In the late **1840s**, **Ferdinand Redtenbacher** and **Julius Weisbach** both wrote essential books about scientific mechanical engineering and formulated mathematical turbine theories. Their work enabled the precise calculation of **energy conversion** and output when water strikes turbine blades – a crucial step in the development of modern hydropower technology.



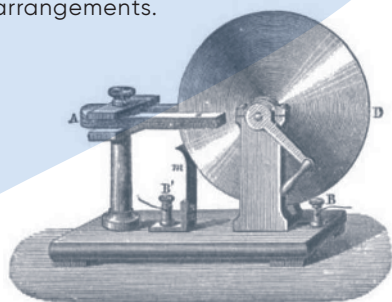
One other major turbine type has its birth in Europe – the **Kaplan turbine**. The demand for electrical energy, for more speed, and better efficiencies at low heads was rising and existing machines of the time could not meet these requirements. In **1913**, the Austrian professor for engineering – **Viktor Gustav Franz Kaplan** – invented the eponymous turbine. His design features wing-shaped blades, which are adjustable for optimal use across varying water volumes.



One of the most important milestones in hydropower history was the invention of **the first electric generator** by **Michael Faraday** in **1831**. This made it possible to generate electricity from hydropower. In **1837**, German technician **Carl Anton Henschel** built his axial high-pressure turbine, which French engineer Nicholas **J. Jonval** subsequently patented. Now known as the **Henschel-Jonval Turbine**, water leaves the turbine through a central suction pipe – the origins of the **draft tube design**. Today, the breakthroughs by Henschel and Jonval are found in most turbine arrangements.



Based on the Kaplan turbine, the **Bulb turbine** was developed by **Escher Wyss** (now ANDRITZ Hydro) in Zurich, Switzerland, in **1936**. An arrangement of turbine combined with generator – the Bulb machine marks another milestone in hydropower development and is the perfect application for high capacities and low heads. —>



**“For more than 135 years, the work of European inventors and scientists has enabled the power of falling water to be used for electricity generation.”**

# The market situation

For more than a century, hydropower was the main source of electricity production in Europe. It was essential for economic growth and wealth. Although other electricity generation technologies such as coal, gas, and nuclear power were developed later, hydropower has remained the most cost-effective – supplying affordable and sustainable energy to European consumers.

At the end of the 20<sup>th</sup> Century, climate change policies triggered the development of a renewable energy generation base, mainly wind and solar PV. As energy demand is continuously rising, renewable and sustainable energy sources are becoming steadily more important. Europe's governments (EU-28, Norway, Switzerland, Turkey, and Iceland) have all set binding targets to reduce greenhouse gas emissions by at least 40% by 2030 and to significantly increase the share of renewable energy use. To achieve these ambitious goals and to build an affordable, secure, and sustainable energy system, many European countries have launched numerous incentives and regulations to boost power sector decarbonization.

With its controllability, flexibility and storage capability, hydropower is playing a major role in the transformation of the European power system. In 2017, about 2.3 GW of hydropower capacity was added across the wider European region, including non-EU countries. This brings the total European hydropower capacity to 278 GW.

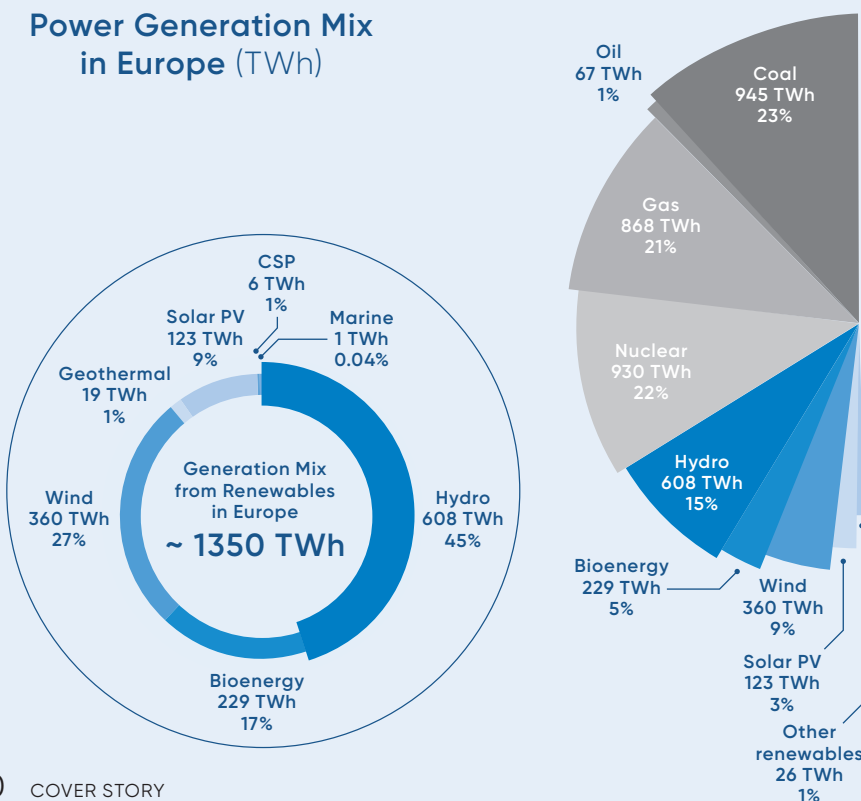
Despite unfavorable weather conditions with drought and low rainfall, hydropower generated more than 770 TWh (incl. Georgia, Kazakhstan, Russia, and Turkey) of clean electricity in 2017. While wind, solar and other renewable energy sources are increasing throughout Europe, these intermittent energy systems continue to benefit from and rely upon the balancing capabilities, storage potential and other grid services of hydropower. Thus, hydropower will remain the backbone of renewables development in the European power grid.

With resource efficiency, flexibility, competitive costs, and low-carbon electricity for both peak and base loads, hydropower remains more than fit to meet the future challenges of the energy transition.

Another vast renewable energy resource is the ocean. The opportunities to generate power from our ocean basins are many and varied, whether through waves, streams or tidal range. Ocean energy can play an important role in the future, contributing to the development of trendsetting concepts. This is

**"Hydropower is still the backbone of the European grid and still a major player on the road to a carbon-free, zero-emission future."**

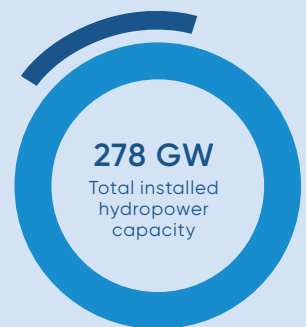
## Power Generation Mix in Europe (TWh)



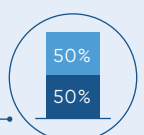
Source: IEA 2018. Data from 2017. Countries included: European Union regional grouping and Albania, Belarus, Bosnia and Herzegovina, Gibraltar, Iceland, Kosovo, Montenegro, Norway, Serbia, Switzerland, North Macedonia, Moldova, Turkey and Ukraine.

## General Facts Hydropower in Europe

53 GW thereof are from pumped storage



In 2017, 2.3 GW hydro capacity was added, half in pumped storage



especially true in Europe, where in many places geological and topographical conditions are ideal. Today, the commercial aspects of harnessing the power of the oceans are not satisfactorily advanced and thus require more political support. Nonetheless, the scale of the resource is a compelling argument for further development of ocean energy.

Refurbishment and upgrading of existing plants are the main hydropower activities in Europe today. This reflects conditions during the 1960s and 1970s, when the European economy showed impressive growth. Most countries invested in greenfield hydropower plants to meet rapidly increasing energy demand across both domestic and industrial sectors. As a consequence, almost 60% of Europe's total installed hydropower capacity is more than 40 years old and now needs to adapt to changing grid and environmental regulations, as well as new operational requirements. Modernization, rehabilitation and uprating are essential for existing hydropower plants to increase their efficiency and safety, prolong their lifetime and provide the required grid services.

Though throughout Europe only very few greenfield hydropower projects are being launched currently, there are notable exceptions. Decreased investment in view of very tough environmental stipulations, low electricity prices, and uncertain and inconsistent climate and energy policies, has been countered in European regions where there is a strong interest in boosting the economy and securing better water and electricity supplies. Another exception comes from pumped storage projects. Pumped storage is the most important and economic solution for large-scale energy storage today. It is used to balance the variable

output from renewable energy sources like wind and solar and therefore makes a significant contribution to future clean energy goals. However, even with pumped storage, economic and political uncertainties can lead to some projects failing to progress to fruition.

## SPECIFIC MARKETS

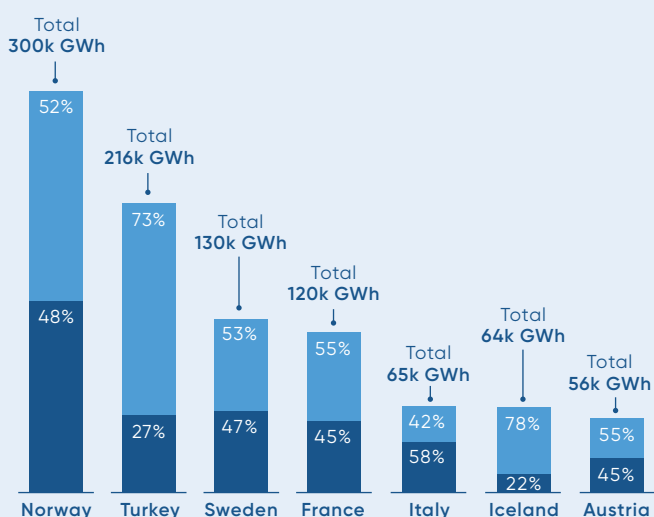
Europe is a very complex and diverse region with very different geological features. The high plateaus, numerous valleys and rivers of all sizes in the Alps offer different hydropower potentials than, for example, the low German or vast Eastern plains. About half of Europe's hydropower potential has already been developed, but some potential is still to be found in specific countries. Russia has an exceptional technically feasible hydropower potential of an incredible 1,670,000 GWh per year remaining, for example. Norway and Turkey follow with about 160,000 GWh a year each, whereas Sweden and France have a hydropower potential of between 60,000 and 70,000 GWh a year remaining. Even countries such as Austria, Italy or Iceland have about 30,000 to 50,000 GWh left. Meanwhile, countries like Belgium, Luxembourg or the Netherlands hold only a remaining potential of some hundreds of GWh.

Within Europe's mountainous regions, pumped storage projects are currently underway. In some cases existing hydro facilities are extended or refurbished, such as Obervermuntwerk II in Austria or Hongrin-Leman in Switzerland. Some projects are completely new, like Foz Tua and Gouvães in Portugal. Alongside pumped storage, conventional large hydro schemes are also being developed in certain selective, mainly non-EU European, areas. Projects include the Upper Kaleköy on the Murat River in Turkey and, in Central Europe, the Mur hydropower plant in Graz, Austria.

In recent years, the European market for small hydropower has steadily declined due to generally low electricity prices and the rapid expansion of solar. Again though, Europe's diversity reveals exceptions. In some countries numerous small hydropower projects have and are being realized where beneficial incentives exist, typically motivated by climate change or economic development policies. Examples are found in Norway, Italy, Turkey, Austria, Georgia, Switzerland, and in the UK.

Russia and the former Soviet Republics in Central Asia also offer multiple opportunities for the refurbishment of existing hydropower plants. Such installations typically suffered from neglect during the Soviet era. Examples include Dnipro 1 in Ukraine and Shardarinskaya in Kazakhstan. Numerous small hydro projects are also scattered throughout the Central Asian region, representing further interesting potential. —→

### Unexploited versus developed hydropower potential



Source: Hydropower & Dams, World Atlas 2018

# ANDRITZ Hydro in Europe

The pioneering hydropower engineers and manufacturers largely originated from Central and Northern Europe and the technology soon spread around the globe, but only a few can boast of an engineering heritage stretching back to those earliest days of commercial hydropower.

ANDRITZ Hydro, part of the ANDRITZ GROUP, is one of those pioneers of hydropower and can justifiably and proudly boast of a continuous line of advancement, expertise and competence spanning over three centuries. Prominent names such as Escher Wyss, Sulzer, Elin, Bouvier, Ateliers de Charmilles, Atelier de Constructions Mécaniques de Vevey, Kvaerner, Tampella, Nohab, and many more are now found rooted within the family tree of ANDRITZ Hydro, roots first planted in 1805.

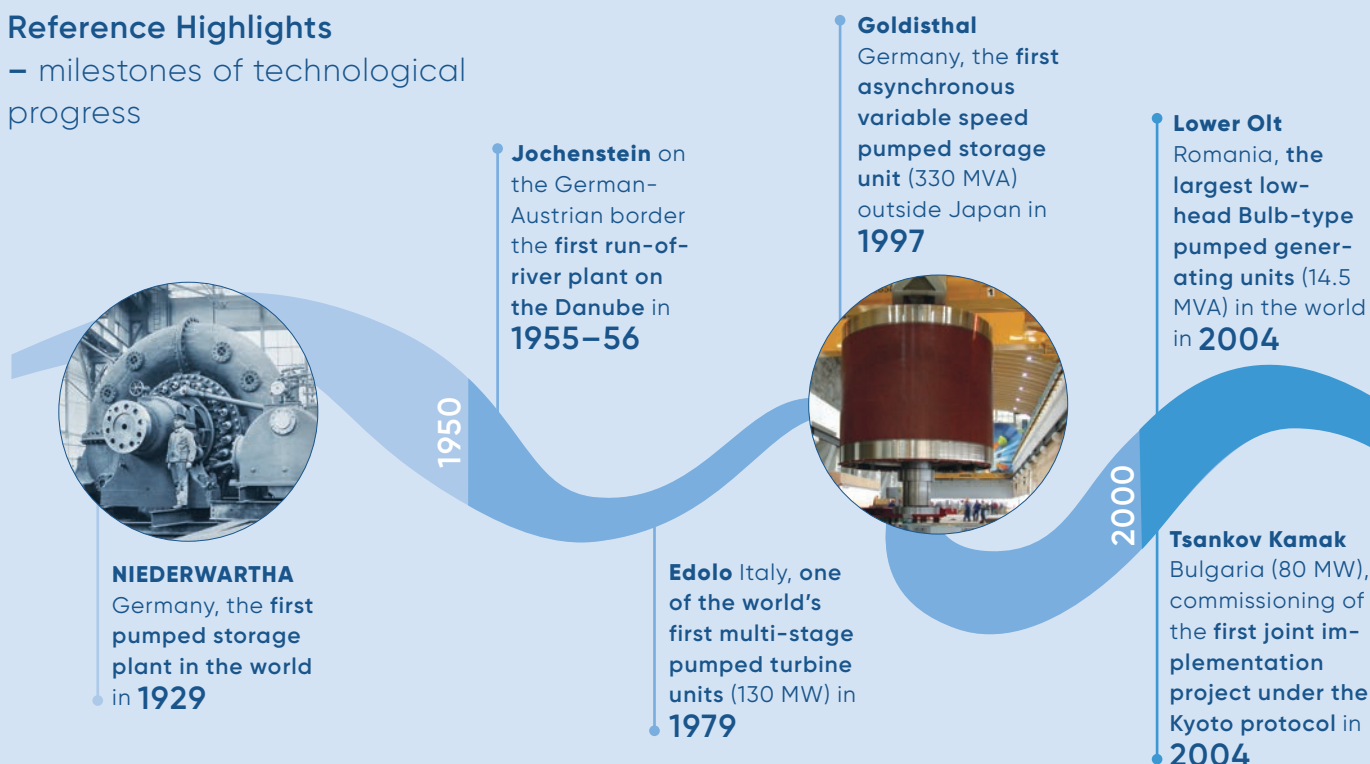
With accurate knowledge of today's hydropower markets, business and industry, a worldwide network, cutting-edge technology, and decades of expertise and experience from our first-class engineers, ANDRITZ Hydro establishes itself as a modern state-of-the-art company operating worldwide. Today, ANDRITZ Hydro is a global supplier of electro-, and hydro-mechanical equipment and services "from water-to-wire" for hydropower plants, turbo generators for thermal plants and large engineered pumps of all sizes. Of the 7,000 ANDRITZ Hydro employees worldwide, 3,800 work in our 29 locations in Europe. ANDRITZ Hydro European facilities include nine manufacturing workshops and five labs.

Always at the forefront of industrial and technological development, our expertise and innovative drive to evolve hydropower technology and the hydropower market has seen ANDRITZ Hydro make globally significant contributions. In 1936, Escher Wyss invented and built the first Bulb turbine – an invention destined for low head applications around the world. Escher Wyss was also the first to introduce the Straflo turbine, the name derived from a combination of "straight" and "flow". This is a further development of the Bulb turbine in which the turbine and generator form one unit. These were groundbreaking developments for the worldwide hydropower business. ANDRITZ Hydro has also patented the Hydromatrix, a unique device combining several identical small turbines built within existing civil structures with a few modest adaptations. This enables the use of existing and widespread infrastructure for power generation. Furthermore, ANDRITZ Hydro has also developed and installed the first commercial tidal current turbine, setting a marvelous example of our continued search for the next generation of future-oriented solutions.

With a wealth of new performance records and decades of delivering new, groundbreaking technological achievements, ANDRITZ Hydro is left with a dilemma: Which of the long and interesting list of important firsts and world records within its reference list should be showcased first? From the first unit at the world's first commercial pumped storage plant, the first asynchronous variable speed

## Reference Highlights

– milestones of technological progress



units outside Japan, and the most powerful single-phase motor generators, on through to the most powerful Peltons with the highest heads – ANDRITZ Hydro's proven provenance of quality, expertise and competence puts it on the top table as a leading supplier and the company's global technological impact cannot be understated.

ANDRITZ Hydro is constantly investing in research and development in order to meet new demands for environmentally-friendly energy production and to provide top quality and modern solutions for our customers' needs and requirements. The solutions and applications emerging from this R&D focus are not only optimized and tailor-made, but also environmentally-friendly. Examples include oil-free Kaplan runner hubs and fish-friendly manufacturing methods such as HiWeld, MicroGuss or SXH coatings, which were developed in our European manufacturing workshops.

As a leading global supplier with its roots in Europe, ANDRITZ Hydro has been meeting the needs of the market and those of our demanding customers for more than a century. From its earliest origins, to the present day and on into the future – ANDRITZ Hydro is making major contributions to the development of a safe, stable and sustainable energy system right across this new old continent.

Sources: Wikipedia, Hydropower & Dams World Atlas 2018, DNV GL, IHA Hydropower Status Report 2018, EEA report Renewable Energy in Europe 2017, Eurelectric and VGB Facts of Hydropower in the EU.

**“Europe is home to the world’s most important hydropower equipment manufacturers and another 50 key players in the supply chain, representing two thirds of the world market.”**

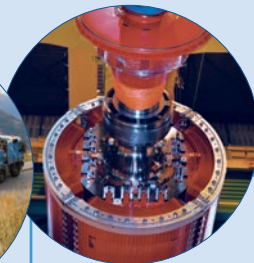


• **Ashta I** (24 MW) and **II** (45 MW), Albania, 90 modules for the **world’s largest Hydromatrix power plant** were put into operation in **2008**

• **Reisseck** Group, Austria, the **most powerful eight-pole generators** with one of the highest heads (240 MVA, 1234 m) in **2012**

• **MeyGen** Phase 1A, Scotland, UK, **tidal stream turbines** for the **world’s largest tidal energy project** commissioned in **2017**

• **Cleuson-Dixence** Switzerland, which combines two world-records – **the most powerful Pelton turbines** (3 × 423 MW) and **the highest head** (1,833 m) in **2009**



• **Langenprozelten** Germany, has the **world’s most powerful single-phase motor generators** (2 × 94 MVA) in **2015**



• **La Coche** France, the **largest 10-pole generating unit** in the world, in **2019**

2019



# AUSTRIA

## AT THE HEART OF EUROPE

Austria is ranked as one of the richest countries in the world with a strong economy showing GDP growth of 2.9% in 2017. The country is very well developed and characterized by a high level of industrialization. It features a large service sector, a solid industrial sector, and a small but highly developed agricultural sector. International tourism is also among the most important businesses for the country.

With more than 3,000 plants in operation, Austria has one of the most developed hydropower industries in Europe. A total installed hydropower capacity about 14.1 GW represents about 56% of the national total. Of this, some 5.7 GW are run-of-river and 8.4 GW are pumped storage plants. Only about 160 plants, some 5%, have a capacity larger than 10 MW but they nonetheless provide around 86% of total hydropower generation.

The estimated technical and economic hydropower potential is about 56.1 TWh, 75% of which has already been exploited. According to the Austrian Electricity Strategy – Empowering Austria – another 6 to 8 TWh could be developed by 2030 to meet steadily increasing power demand.

Furthermore, a new energy strategy, known as #mission-2030, stipulates that 100% of Austria's electricity is to be derived from renewable sources by 2030. Implementing this policy will require an additional 30,000 GWh annually. As a result, an additional 10,500 MW of solar PV, 4,500 MW of wind and 1,500 MW of hydropower capacity are anticipated. However, the growth of renewable energy resources is causing grid fluctuations, leading to high grid loads and bottlenecks. This is posing a major challenge for Austria. Expansion and strengthening of the transmission grid is required alongside more responsive reserve power capacity.

About 100 MW of hydropower capacity are under construction and there are also some interesting future projects planned. These include the 900 MW extension of the Sellrain-Silz hydropower plant and the 180 MW Kühtai 2 plant in Tyrol. But not only large hydropower plants are in the planning stage. There are a number of interesting opportunities for small hydropower as well, especially in the western part of the country. Through to 2025 there are about 48 hydropower projects under development to meet Austria's ambitious targets.

### ANDRITZ HYDRO IN AUSTRIA

The 1892 founding of the manufacturing facility in Weiz, Styria, marks the start of our company's on-going story. Since then we have supplied or rehabilitated about 14,000 MW of hydropower capacity in Austria alone. Throughout our history we have been involved in all the country's major hydropower projects. The Risseck-Kreuzeck-Malta-Group, Kaprun, Silz, Kops, and Kaunertal are all impressive references. Every one of the run-of-river plants on the Danube – Freudenau, Aschach, Greifenstein, Ybbs-Persenbeug, and Melk for instance – use ANDRITZ equipment as do numerous other projects on all the major rivers in Austria. Large engineered pumps complete our portfolio. Our competence is shown through our supply

of a storage pump for the Innerfragant pumped storage plant in Carinthia, one of the most prestigious pump projects to date.

### GRAZ-PUNTIGAM, STYRIA

The contract for this new hydropower plant comprises the supply of two Bulb turbines of 8.85 MW each. In addition, turbine governors, generators, excitation and control system also form part of the supply contract. Commissioning is planned for the first half of 2019.

### YBBS-PERSENBEUG, LOWER AUSTRIA

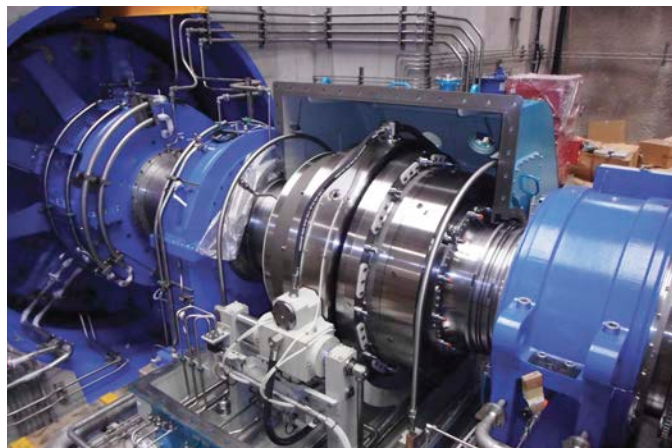
“Project Ybbs 2020” is a program of extensive refurbishment for Austria’s oldest run-of-river power plant on the Danube, Ybbs-Persenbeug. The objective is to achieve an increased output with an additional 77 GWh of clean, sustainable electricity anticipated annually post-rehabilitation. As part of this program ANDRITZ has received a contract for the refurbishment of six vertical Kaplan units, to be commissioned sequentially through to 2020.

### OBERVERMUNTWERK II, VORARLBERG

This underground power plant is providing Austria with peak power to improve grid stability and additional bulk energy storage capacity. ANDRITZ received a contract for the supply of two Francis turbines with accessories, including design, manufacturing, transport, installation, and commissioning. Commissioning of the units took place in June and September 2018, respectively.

### TRAUNLEITEN, UPPER AUSTRIA

At Traunleiten an existing hydropower station will be replaced with a completely new plant. The project is targeting



Obervermuntwerk II, Vorarlberg

an 80% increase in power output with a hydroelectric power production of 91 GWh annually. ANDRITZ was awarded a contract for the delivery of the two Compact Bulb turbines and auxiliaries. Completion is scheduled for November 2019.

#### GENERAL FACTS

- Population: **8,82 Mio.**
- Access to electricity: **100%**
- Installed hydro capacity: **14,130 MW**
- Hydro capacity under construction: **106 MW**
- Share of generation from hydropower: **57%**
- Hydro generation per year: **38,540 GWh**
- Technically feasible hydro generation potential: **56,000 GWh**

#### ANDRITZ HYDRO IN THE COUNTRY

- Installed and/or rehabilitated capacity: **13,947 MW**
- Installed and/or rehabilitated units: **712**
- Locations: **Vienna (Headquarters), Weiz, Graz, Linz**

TO KNOW

Ybbs-Persenbeug, Danube, Lower Austria





# GERMANY

## ENERGY TRANSITION TO THE FUTURE

The fourth largest economy in the world and Europe's largest, Germany is a global leader in several industrial and technological sectors. A developed country with a very high standard of living, Europe's second most populous nation is the world's third-largest exporter and importer of goods. Germany holds a very strong position but is facing significant demographic challenges to sustained long-term growth.

Germany has the largest annual electricity demand and generation capacity in Europe, and the largest power system. At roughly 14.7 GW, hydropower installations including pumped storage account for around 7.5% of the total national generation. They produce approximately 20,000 GWh net electricity generation annually.

Within a fleet of about 7,300 hydropower plants, 94% have an installed capacity of less than 1 MW. Around 86% of Germany's annual hydropower energy production comes from the 436 plants with an installed capacity of more than 1 MW, corresponding to a share of some 6%.

Currently, several new hydropower projects are under development and were expected to come online by 2020. However, due to current market and policy conditions, some projects have been postponed or canceled. Nevertheless, there are notable requirements for modernization and large overhauls at a number of facilities over the next few years.

Germany is committed to the Paris Climate Agreement and has set medium-term targets for CO<sub>2</sub> emissions and renewable energy sources that are even more ambitious. They include plans to reduce CO<sub>2</sub> emissions by 40% and achieve an 18% share of gross energy consumption from renewable sources by 2020. The energy transition (Energiewende) is the transition to a sustainable economy by means of energy efficiency and renewable energy. Alongside wind and solar PV, hydropower will play a major role here.

### ANDRITZ HYDRO IN GERMANY

The foundations of our Ravensburg location were laid in 1856 as subsidiary of Escher, Wyss & Cie Switzerland, now part of the ANDRITZ technology group. Today, the ANDRITZ Hydro workshops in Ravensburg are among the biggest hydropower turbine workshops in Europe.

Our products and services make a significant contribution to environmentally-friendly, renewable power generation. The latest modern ecological concepts are combined with 160 years' of extensively documented experience building hydropower plants. Our employees are providing excellent and highly-skilled international service.

As well as almost all the hydroelectric plants on the river Rhine, projects such as Goldisthal and Markersbach – the two largest pumped storage power plants in Germany – and the oldest commercial pumped storage plant of the world, Niederwartha, are among the impressive references of ANDRITZ Hydro in Germany.

### CONTROLLABLE PITCH PROPELLERS

Since 1934 our Escher Wyss controllable-pitch propellers have provided outstanding performance for naval and coast guard vessels, mega yachts, and special marine vessels.

### LANGENPROZELTEN, BAVARIA

Two of the world's most powerful single-phase hydropower motor generators (94 MVA apiece) were put into operation at the Langenprozelten pumped storage power plant in July 2016 and February 2018, respectively. The contract





Erzhausen, Lower Saxony

for the modernization of Deutsche Bahn's primary peak-load power plant posed a huge challenge as the generators are specifically designed for the railway's 16.7 Hz traction power network. Featuring a superlative pre-forged shaft raw weight of about 150,000 kg, world record-breaking mechanical pole loads of 34,000 kg each and centrifugal forces on the poles of 27,000 tons at 756 rpm, these engineering masterpieces are a unique worldwide achievement.

### ERZHAUSEN, LOWER SAXONY

The Erzhausen pumped storage power plant is located near the small town of Erzhausen between Hannover and Göttingen in Lower Saxony and was first commissioned in 1964. In 2011 and 2016, ANDRITZ received orders for the general rehabilitation of units #2 and #4, which were successfully completed in 2012 and 2017, respectively.

### GARS, BAVARIA

In order to increase the production potential of the existing barrage, it was decided to build a further hydropower plant at Gars. ANDRITZ was awarded a contract in 2011 for the supply of a compact Bulb turbine with a rotor diameter of 3,650 mm and an output of 5 MW. The contract included a directly coupled synchronous generator (6.3 kV) as well as the complete process control and electro-technical equipment. Using an additional 100 m<sup>3</sup>/sec of water flow some 13.7 million kWh was produced. About 3,400 households have been supplied with electricity from renewable energy ever since, saving around 11,000 tons of CO<sub>2</sub> each year.

### RAG WALSUM

ANDRITZ supplied three large heavy-duty mining (HDM) submersible motor pumps for a German mining company for a prestigious project to save millions of liters of drinking water. (→ see article page 55)



Langenprozelten, Bavaria



#### GENERAL FACTS

Population: **82,695 Mio.**  
 Access to electricity: **100%**  
 Installed hydro capacity: **14,782 MW**  
 Share of generation from hydropower: **3%**  
 Hydro generation per year: **19,700 GWh**  
 Technically feasible hydro generation potential: **24,700 GWh**

#### ANDRITZ HYDRO IN THE COUNTRY

Installed and/or rehabilitated capacity: **6,761 MW**  
 Installed and/or rehabilitated units: **2,257**  
 Locations: **Ravensburg, Berlin**

TO KNOW



# SWITZERLAND

## THE WATER TOWER OF EUROPE

Switzerland is one of the most developed countries in the world, with the highest nominal wealth per adult and the eighth-highest GDP per capita globally. With a modern, prosperous market economy and a strong financial business and services sector, the country's manufacturing industry focuses on high-tech and knowledge-based production. As an economically stable country with efficient capital markets, Switzerland – the epitome of neutrality – ranks as one of the world's most competitive economies.

Today, there are about 643 hydropower plants of more than 300 kW capacity in operation with a total installed capacity of about 15,200 MW. Hydro produces an average of 36,600 GWh per annum, representing almost 60% of the nation's total generation capacity. Run-of-river power plants are producing 25.9% of the total hydro production, with storage power plants contributing 33.7% and approximately 4.3% coming from pumped storage hydropower plants.

Roughly, 63% of the country's hydroelectricity is generated in the mountain cantons of Uri, Grisons, Ticino and Valais, while Aargau and Bern also generate significant quantities. About 11% of Switzerland's hydropower generation comes from facilities situated on bodies of water located along Switzerland's borders.

The federal government has launched an Energy Strategy to 2050. Its main objective is to reduce nuclear power generation and to instead focus on the development of hydropower and other renewable energy sources such as wind and solar PV, as well as reducing consumption.

Under the terms of the strategy, Switzerland aims to increase electricity generation to reach 37,400 GWh by 2035 and 38,600 GWh by 2050 through a variety of measures. For instance, in order to exploit the technically feasible hydropower potential alongside the installation of green-field projects, existing power plants are to be rehabilitated and expanded – whilst taking the related environmental requirements and restrictions into account. Policy instruments to be used include cost-covering remuneration for

feed-in to the electricity grid for hydropower plants with a capacity of up to 10 MW.

There are about 1,000 MW of hydropower capacity under construction currently. Projects include examples like the new Nant de Drance pumped storage scheme. In total more than 25 projects were under construction in 2017.

### ANDRITZ HYDRO IN SWITZERLAND

Electro-mechanical equipment construction in Switzerland forms part of the very foundation of ANDRITZ with pioneers such as Escher, Wyss & Cie (1805), Bell Maschinenfabrik (1855), or Ateliers de Constructions Mécaniques de Vevey (1842) and Ateliers des Chamilles (1921).

Today, with its highly skilled employees and experienced hydro engineers, ANDRITZ in Switzerland serves the service and rehabilitation market and is the Pelton turbine competence center for the entire ANDRITZ Group. Its modern state-of-the-art manufacturing facility in Kriens is responsible for the domestic market. Meanwhile, the Vevey location, with a hydraulic lab and an advanced research and development department, works on export markets. The Jonschwil site is responsible for small hydro turbines.

ANDRITZ has been engaged in almost all Swiss hydropower projects to date with demonstrable success in all market sectors – from large new installations to small and mini hydro to extended service and rehabilitation projects.

### INNERTKIRCHEN/HANDECK, CANTON BERN

For the Innertkirchen/Handeck plant ANDRITZ supplied two complete generating sets (Pelton turbine and generator) for the enlargement of the underground powerhouses. Both contracts were awarded in April 2013 and the units were handed over to the client on schedule in July and September 2016, respectively. Since then, the units have proven their high reliability. The Final Acceptance Certificates were received 2018.

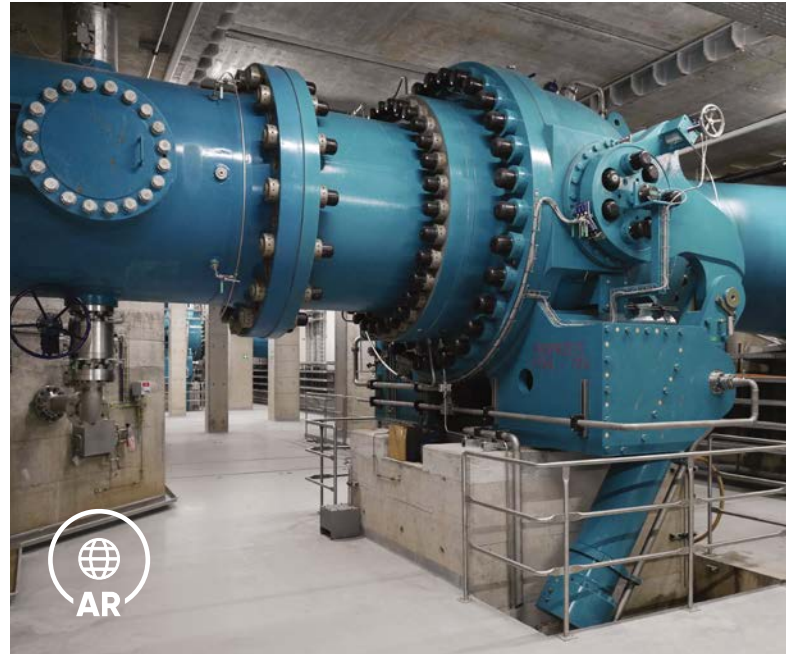
### HONGRIN-LÉMAN (FMHL+), CANTON VAUD

ANDRITZ received the contract for the supply of two generating sets for the extension of this important pumped storage scheme. Scope of supply consisted of vertical six-jet Pelton units, motor-generators, as well as spherical valves. The units were successfully handed over to the client in December 2016 and February 2017, respectively. Now in commercial operation, these plants represent a significant energy development in Switzerland.

### WETTINGEN, CANTON AARGAU

For this run-of-river project, ANDRITZ was awarded a contract for the complete modernization and upgrade of all three units. The scope of supply comprises the development of new runner blades, including a model test, and the full rehabilitation of the turbines and generators, which have been in service since 1938. In April 2018, the first unit was re-commissioned after an intensive half year servicing campaign. During this program, all major components were dismantled and rehabilitated in the Kriens service workshop. This project is an impressive example of the full-liner hydro service capabilities of ANDRITZ in Switzerland covering the entire shaft line of the machine.

Hagneck, Canton Bern



Hongrin-Léman extension, Veytaux

#### GENERAL FACTS

Population: **8,5 Mio.**  
 Access to electricity: **100%**  
 Installed hydro capacity: **15,295 MW**  
 Hydro capacity under construction: **964 MW**  
 Share of generation from hydropower: **59,6%**  
 Hydro generation per year: **36,666 GWh**  
 Technically feasible hydro generation potential: **41,000 GWh**

#### ANDRITZ HYDRO IN THE COUNTRY

Installed and/or rehabilitated capacity: **31,277 MW**  
 Installed and/or rehabilitated units: **2,435**  
 Locations: **Kriens, Vevey, Jonschwil**

TO KNOW

“About 60% of the national power generation is covered by hydropower, making it one of the most important domestic sources of energy in Switzerland.”



# CUTTING

## Manufacturing for a Demanding Market

**A** NDRITZ Hydro currently operates nine major manufacturing facilities across Europe. Our workshops have two different types of configuration – manufacturing units and service workshops. Though both may exist at a single location, six out of the nine facilities across Europe are purely service workshops.

Our strategy is to deliver state-of-the-art capabilities at the manufacturing units for worldwide supply. At our locations in Europe, we produce highly advanced core components that are assembled by our superbly qualified, well-trained and highly experienced employees.

The service shops throughout Europe have a more flexible set-up in order to focus on customer requirements in their local home market. All our locations have a very productive and well-organized structure that promotes ANDRITZ Hydro through dedicated professionalism. Additionally, due to excellent collaboration and strong relationships with our supply chain and preferred suppliers and partners, we ensure delivery and assembly of products and services of the highest quality – at competitive prices, and on time.

**“In the early 19<sup>th</sup> century, the pioneers of turbine manufacturing in Central and North Europe lay the cornerstone for the modern company ANDRITZ is today. They are still the heart of the manufacturing business and provide highly-skilled and well experienced engineers catering not only Europe, but also the world-wide market.”**

# EDGE

To date, ANDRITZ Hydro manufacturing and service locations worldwide have executed more than 2.5 million direct labor hours in their workshops and almost 800 thousand of additional direct labor hours on site. The manufacturing units and service workshops in Central Europe alone have carried out almost 1 million direct labor hours and close to 500 thousand hours on site. This large number of manufacturing hours means that a safe and nurturing environment is among the highest priorities for ANDRITZ.

To ensure this, the ANDRITZ Production System (APS) has been implemented to create a continuous improvement culture and achieve excellent operational results. It is a system designed to define, describe, quantify and increase the performance levels of production organizations, as well as to generate a common understanding of manufacturing principles and methods. A business-specific handbook is also available and training of employees is continuous, ensuring the competitiveness of each of the manufacturing and service locations by increasing their productivity and performance.

## WIRE AND ARC ADDITIVE MANUFACTURING

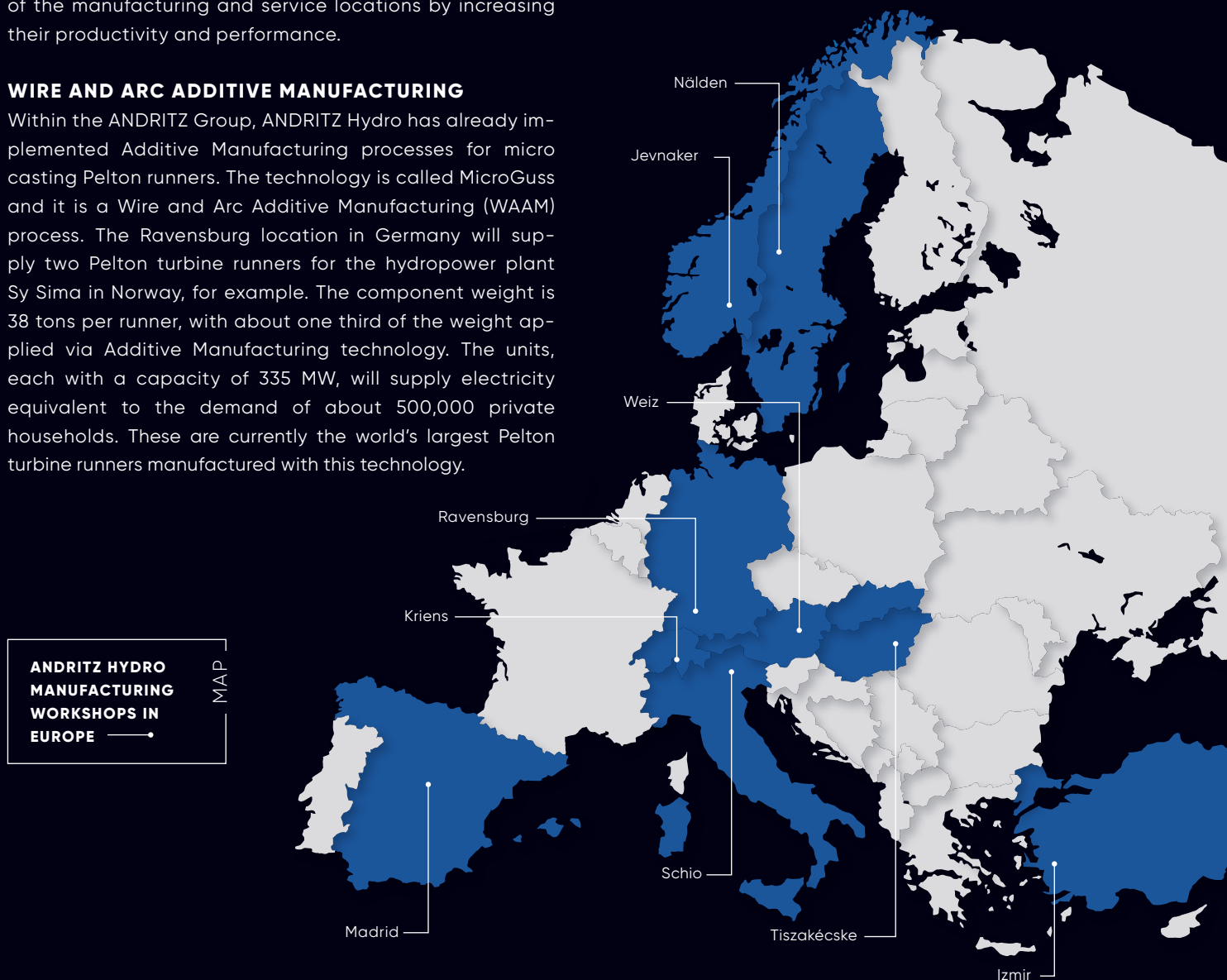
Within the ANDRITZ Group, ANDRITZ Hydro has already implemented Additive Manufacturing processes for micro casting Pelton runners. The technology is called MicroGuss and it is a Wire and Arc Additive Manufacturing (WAAM) process. The Ravensburg location in Germany will supply two Pelton turbine runners for the hydropower plant Sy Sima in Norway, for example. The component weight is 38 tons per runner, with about one third of the weight applied via Additive Manufacturing technology. The units, each with a capacity of 335 MW, will supply electricity equivalent to the demand of about 500,000 private households. These are currently the world's largest Pelton turbine runners manufactured with this technology.

## MOBILE COATING

Mobile Coating is an alternative solution to overhauling surfaces and damaged impeller coatings directly at customer sites. Preparatory work can be carried out by the client, saving both time and costs. The actual coating repair operation is executed by ANDRITZ Hydro engineers based at the Kriens site in Switzerland. This flexible production technology offers a key advantage by increasing competitiveness within the local service market.

## REVERSE ENGINEERING OF STATOR BARS

In the second half of 2018, a new stator bar forming machine was put into operation in Weiz, Austria. This enables ANDRITZ to produce stator bars with shorter cycle times and more competitive prices. This machine will also be used by the service business. Reverse engineering of stator bars and fast, efficient and competitive processing of even small orders (as little as one stator bar) is now possible.





# CZECH REPUBLIC

## TRADITION MEETS FUTURE

With an economy based mainly on services and industry, the Czech Republic or Czechia is a prosperous market economy with one of the highest GDP growth rates in the EU (4.5%). Exports account for more than 80% of GDP with the automotive industry particularly significant – one of Central Europe’s largest automobile companies calls Czechia home, for example.

Czechia has some 2.2 GW of installed hydropower capacity and a yearly production of about 2,000 GWh, making the Czech hydropower market relatively small. Hydroelectric energy covers only 2% of national production but the country’s three pump-storage plants – with an installed capacity of 1.2 GW – produce some 1,200 GWh of flexible energy annually, which is highly regarded for balancing during peak-load and low-consumption periods.

The technically feasible hydropower potential is only about 3,380 GWh/year, of which some 60% has already been developed. Hence, major upgrades and modernization of the existing hydropower plant capacity is the current industry focus for the Czech Republic.

### ANDRITZ HYDRO IN CZECHIA

The history of ANDRITZ Hydro in the Czech Republic started in 1991, when a subsidiary of SAT-Automation was

established in Prague and started to develop control systems for the energy transmission and distribution sector. All significant Czech hydropower plants have been modernized during the subsequent years with a control system supplied by ANDRITZ Hydro. Prague-based engineers have since expanded their activities into international projects. Indeed, as our engineers share their experience with international commissioning teams worldwide, Czech footprints are found in hydropower plants around the globe.

### CESKE BUDEJOVICE, SOUTH BOHEMIA

After 80 years of operation, the old units at this plant reached the end of their lifetime and had to be replaced. We received a contract for three double-regulated vertical Kaplan turbines, including oil supply units, supervision of installation, commissioning and training. Design adaptations and modifications were necessary to enable delivery via ship navigation on the Vltava River and to increase the output of the plant. České Budejovice was successfully re-commissioned in 2012.

Ceské Budejovice, South Bohemia



#### GENERAL FACTS

- Population: **10,6 Mio.**
- Access to electricity: **100%**
- Installed hydro capacity: **2,264 MW**
- Share of generation from hydropower: **2.2%**
- Hydro generation per year: **1,870 GWh**
- Technically feasible hydro generation potential: **3,380 GWh**

#### ANDRITZ HYDRO IN THE COUNTRY

- Installed and/or rehabilitated capacity: **2,150 MW**
- Installed and/or rehabilitated units (incl. control systems): **38**
- Locations: **Prague, Ceske Budejovice**

TO KNOW



“First electric light of northern Europe was installed in a weaving shed at Finlayson, Tampere, back in 1882.”

# FINLAND

## LAND OF A 1000 LAKES

Finland is the most sparsely populated country in Europe with one of the highest per capita incomes of the world. It has a highly industrialized economy with the largest industries being electronics, machinery, vehicles, and engineered metal products. The country’s vast forests make Finland one of the world’s leading wood producers too.

Total net electricity production in Finland is about 65,000 GWh/year, of which some 14,637 GWh/year or 22.5% comes from hydropower. The overall technically feasible hydropower potential is 16,915 GWh/year, 77% of which has already been developed. Now, because of the Wild River Act designed to protect the natural environment, the building of new hydropower plants is prohibited. This results in a strong focus on rehabilitation and uprating of existing hydropower installations.

By 2016, Finland had already reached its 2020 target of a 38% share of renewable energy in final consumption. Nonetheless, a national energy and climate strategy to become carbon neutral and powered 100% by renewables has established a favorable market environment for hydropower development. Under these strategic plans, the target is to increase the hydropower production by several hundred GWh/year within the next decade.

### ANDRITZ HYDRO IN FINLAND

Finland’s first ever operational hydro turbine was manufactured by Tampella (now ANDRITZ Hydro) in 1856. ANDRITZ Hydro has been involved in all the major hydropower plants in the country supplying or rehabilitating about 2,300 turbines to date. This represents a fleet share of about 87%.

ANDRITZ Hydro Finland is specialized in low head axial turbine refurbishment projects and axial turbine technology development. The main office, hydraulic laboratory and assembly facility for runners are all located in Tampere. Beyond the domestic market, axial turbines

are delivered mainly to Scandinavian ANDRITZ locations in Sweden and Norway.

### UTANEN, OULUJOKI RIVER

The output of the Utanen hydropower plant is 58 MW, producing enough electricity for about 13,000 households and with a head of 15.7 m. With a target to increase efficiency and output of the plant, this project consists of refurbishment of two Kaplan turbines and two generators. It is the first large generator supply of ANDRITZ to the Finnish hydro market for some time. The first refurbished unit is expected to be commissioned in 2020.

### TAIVALKOSKI, KEMIJOKI RIVER

ANDRITZ received an order for the refurbishment of three Kaplan turbines, including the supply of new four-bladed oil-free runners and servicing existing components at Taivalkoski. Following the completion of the rehabilitation program in 2017, the hydropower plant now has an average annual energy production of 550 GWh/year.

#### GENERAL FACTS

- Population: **5,511 Mio.**
- Access to electricity: **100%**
- Installed hydro capacity: **3,241 MW**
- Hydro capacity under construction: **30 MW**
- Share of generation from hydropower: **22.5%**
- Hydro generation per year: **14,637 GWh**
- Technically feasible hydro generation potential: **16,915 GWh**

#### ANDRITZ HYDRO IN THE COUNTRY

- Installed and/or rehabilitated capacity: **3,641 MW**
- Installed and/or rehabilitated units: **221**
- Locations: **Tampere**

TO KNOW

Source Facts: The World Bank, IHA, CIA Factbook, Hydropower & Dams World Atlas 2018

# TECHNOLOGY LEADERSHIP & INNOVATION



## Meeting the challenges of the future

**A**s one of the world's leading equipment manufacturers, ANDRITZ continually invests in research and development. Our R&D investment philosophy is driven not only by a requirement to meet today's market needs, but also to prepare for the challenges of the future energy transition.

Innovative research and development is a long-held tradition at ANDRITZ and our R&D activities cover a host of the technologies. Areas such as turbines and pumps, penstocks and gates, generators, Electrical Power Systems (EPS), and automation are all key to our R&D program. Supporting our customers to develop new large hydro-power plants with specific requirements or refurbishing existing installations which are in need of a particular updating solution – for every application, ANDRITZ develops and designs optimized solutions.

### TARGETS DRIVEN BY MARKET NEEDS

Our research and development addresses major market concerns, delivering highly efficient units that remain cost-effective over their operational lifetime. In addition, flexible and rapid response energy systems are needed to meet the need for safe grid operation and the stable integration of non-dispatchable renewable energy sources like wind and solar. Furthermore, new environmentally-friendly solutions which preserve aquatic life such as fish, enable natural sediment transportation through the power



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**ANDRITZ HYDRO TEST RIGS,  
TEST FIELDS AND LAB PLANTS  
FOR GENERATORS, TURBINES  
AND BEARINGS**

MAP

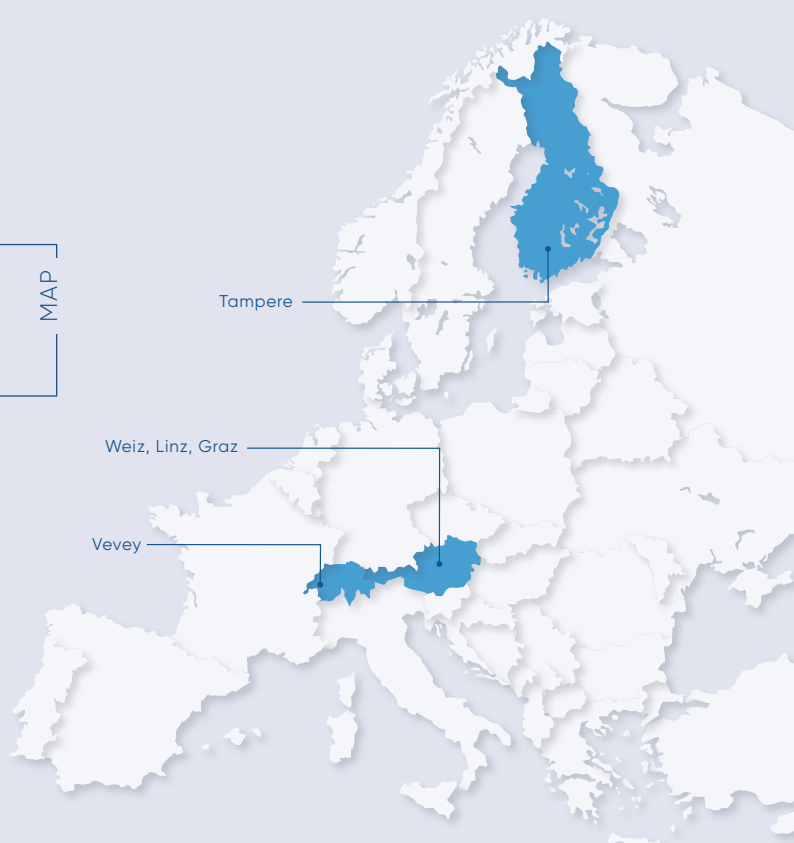
### THE DIGITAL TWIN

Development of the digital twin marks the start of hydropower project development. The entire electro-mechanical system, including automation and EPS, is digitally modelled and simulated. Major tools used during this phase are dynamic electrical and hydraulic network simulation, flow simulation (CFD) in pumps, turbines and generator ventilation, as well as simulation of heat transfer (CHT) in cooling systems, electromagnetic simulation and optimization of the structure by means of finite element analysis (FEA).

Development work continues based on interaction between the physical world and the digital world. High-end test rigs for turbines and pumps enable hydraulic development with the aim of achieving the most flexible operational characteristics across a broad range of operating conditions. The digital twin also supports the development of designs that are capable of delivering flexibility alongside a rapid response and stability – all while supporting the production of the necessary documentation needed to prove hydraulic and electrical performance targets according to IEC (International Electrotechnical Commission) standards.

Further measurements for design advancement are for example bearing optimization and high efficiency generator insulation development. Site measurements complete the development process and are a valuable source of information with regard to fulfillment of guarantees, feedback on designs and assessment of existing equipment. ANDRITZ uses world-leading measurement technology in order to cover the full range of site measurements needed for optimal designs and appropriate operational characteristics.

Subsequently, measurement data both from the test rig as well as from the site are systematically fed back to the digital twin for optimizing the products over the entire life cycle.



station, and protect water quality are also imperative for modern hydropower plants. Innovation – especially with regard to product life cycle management and operational optimization – is essential for transforming and improving the development process of new products and services.

### CUSTOMER-DRIVEN DEVELOPMENT

Collaborative development with our customers is a core tenet of the ANDRITZ approach to hydropower development. Each hydropower project has unique requirements which have to be thoroughly assessed and transformed into reality using tailor-made and world-leading technology solutions. Only in this way can we fully support our clients.

### DIGITALIZATION

The growing digitalization is a driver for many new developments especially in the field of operational optimization and predictive maintenance, for which ANDRITZ is developing the Metris DiOMera system. (→ see article page 30) Co-development with customers, rapid prototyping and improvements based on feedback from on-site experience are made possible too, enabling an agile and lean development process.

### AUTOMATION

With the development of the new HIPASE platform, ANDRITZ is able to actively respond to the changing market environment for secondary systems. Major goal of this development is the conflation of multiple disciplines into one common platform. This supports a common engineering workflow, as well as a single common workflow for commissioning. With the new HIPASE platform, ANDRITZ has developed a solid foundation to meet all future market requirements.



# FRANCE

## BIG ON ELECTRICITY

France is a developed country with the world's sixth-largest economy by nominal GDP and the third largest in Europe. One of the most modern countries in the world, France holds a leading position among European nations. Key sectors of its diversified economy are the chemical industry, a developing manufacturing industry and tourism – France is the most visited destination in the world.

As one of the world's largest producers of electricity, France is primarily reliant on nuclear power, which accounts for about 72% of total national electricity production. Though renewable energies have generally been slow to take off, France does use a significant volume of hydroelectric power to produce electricity with a production share of about 20%.

In 2018, France was ranked third in Europe for its hydroelectric production with 11% of the continental total, behind Norway and Turkey. Total installed hydropower capacity is about 25.5 GW from the country's roughly 2,400 hydropower plants. Annual hydropower production of 69 TWh sees France ranked 10<sup>th</sup> in the world. In order to increase the use of renewable energy resources, France is seeking to increase hydropower capacity by at least 3,000 MW by 2020. Currently, there are about 330 MW of hydropower capacity under construction.

Because of the mountain ranges of the Alps, the Pyrenees, and the Massif Central, the hydroelectricity sector in France has great potential with about 120,000 GWh. Though this potential has already been exploited to a very large degree, there is still a remaining commercial potential estimated at about 10 TWh/year. This potential largely comes from small hydropower and pumped storage hydropower plants, as well as rehabilitation of existing facilities.

### ANDRITZ HYDRO IN FRANCE

ANDRITZ Hydro history in France started in 1874 with the foundation of predecessor company Ateliers de Bouvier in Grenoble. Since then, ANDRITZ Hydro has had a major role in the supply of electro-mechanical equipment with over 1,000 references in the country. The company has been also involved in large-scale projects such as the supply of Bulb turbines for the world's first tidal power plant at La Rance in 1968 (240 MW). ANDRITZ Hydro also served as supplier of original electro-mechanical equipment for major power plants such as Sisteron (240 MW), Villarodin (600 MW), Bort les Orgues (230 MW), Grand Maison (1800 MW), and many more. Today, the activities for the service and rehabilitation market in France are attended to, and coordinated by ANDRITZ Hydro in Switzerland.

Our set-up in France has become one of our leading sites for small hydropower, engaging specialists with long-term international experience. Over recent months, we have been awarded with contracts for more than 10 units for our new Mini-Grid range of products (turbines below 69 kVA). Among these projects are Breuche, Membrey, Cessey, Dienay and Lucenay.

### LA BATHIE, SAVOIE ALPS

In 2013, a program to increase the total power of the La Bathie plant by 100 MW was initiated. ANDRITZ received a contract for the supply of six Pelton runners

MicroGuss at 20 tons and 103 MW each as well as 12 injectors. The power increase was achieved through numerical flow simulations combined with model tests. With the first five units already successfully commissioned and exceeding performance expectations, the last unit will be commissioned in 2019.

### LA COCHE, ISÈRE VALLEY

ANDRITZ received in 2016 the order to supply a turbine generator unit with an output of 240 MW for the extension of the La Coche pumped storage power station. The new Pelton turbine completes the existing four reversible pump turbines and features extremely good part load behavior. Due to the high sand content in the water and the resulting severe abrasion, the turbine will receive a high-grade, erosion-resistant coating extending its life cycle significantly. Works are currently well advanced, the commissioning is scheduled for 2019.

### RENOUVEAU PROGRAM

In 2013, a major 10-year rehabilitation program was launched involving more than 230 hydropower units in France including the renovation of the speed governors and excitation systems. In 2014, ANDRITZ signed a frame agreement for more than 100 units. To date, 25 units have already been successfully commissioned. A further 10 units are being manufactured.

The project also includes an innovative service contract called "MCO", aimed at maintaining the equipment in good operational conditions and extend its lifetime. This contract comprises the provision of a centralized web-based platform to store all project data, spare parts inventory management, services and support, as well as monitoring material life cycles.

Roselend Dam, La Bathie, Savoie Alps



Valve in manufacturing, Grand Maison, Romanche Valley

### GRAND MAISON, ISÈRE, ROMANCHE VALLEY

With two powerhouses and a total of 12 units, Grand Maison is currently the most powerful pumped storage hydropower plant in France. It can inject up to 1,800 MW into the French electricity grid within three minutes. ANDRITZ has executed several orders during the course of a recent rehabilitation program; for example, the upcoming supply of static excitation systems capable of performing back-to-back starts between all Pelton and Francis units.

#### GENERAL FACTS

- Population: **67,118 Mio.**
- Access to electricity: **100%**
- Installed hydro capacity: **25,517 MW**
- Hydro capacity under construction: **301 MW**
- Share of generation from hydropower: **10%**
- Hydro generation per year: **53,600 GWh**
- Technically feasible hydro generation potential: **120,000 GWh**

#### ANDRITZ HYDRO IN THE COUNTRY

- Installed and/or rehabilitated capacity: **11,029 MW**
- Installed and/or rehabilitated units: **1,150**
- Locations: **Grenoble, Paris**

TO KNOW





# GEORGIA

## BETWEEN ORIENT AND OCCIDENT

Located in the Caucasus region between the Black and Caspian Seas, both geographically and culturally Georgia is part of Europe. The economy traditionally revolves around tourism and agriculture. There is also a relatively small industrial sector. Though economic growth has still not recovered fully, it is in an upswing – driven by markets characterized by low-regulation, low-tax, and free market policies, as well as social spending.

The country produces most of its energy needs through hydropower, which is the only significant energy resource in Georgia. Natural gas and oil products have to be imported. A total installed hydropower capacity of about 3,164 MW produces some 9,210 GWh annually, covering 80% of national electricity supply. Nonetheless, with several hundred rivers Georgia still has an impressive technically feasible hydropower potential of about 80,000 GWh/year.

To boost economic growth, reduce dependency on imported fossil fuels and strengthen and stabilize the national grid, Georgia has signed memoranda of understanding with the EU and China. These deals are designed to enable the financing of new hydropower projects and the rehabilitation of existing hydropower plants. By the end of 2017, Georgia had signed agreements with developers for 124 hydropower projects, representing a total capacity of some 3,747 MW and a combined output of almost 15,000 GWh annually.

As a result, numerous hydropower projects are currently under construction or in the development and planning phase as Georgia intends to at least double the national power output. Georgia wants both domestic and foreign investments to not only harness the national hydropower potential, but also to take advantage of a newly-commissioned Black Sea transmission line for power exports to Turkey.

### ANDRITZ HYDRO IN GEORGIA

Since the 1950s, ANDRITZ Hydro and its predecessor companies have been executing hydropower projects in Georgia. In total, we have delivered 28 units with a total capacity of 362 MW across 14 hydropower plants. With the

interesting investment potential in Georgia ANDRITZ Hydro decided to open a representative office in the capital city of Tbilisi. This office supports local activities and allows the company to closely follow the hydropower project landscape. Currently, four hydropower plants with eight units and a total capacity of 352 MW are under construction in Georgia. Major projects such as Avani, Dashbashi, Orozmani, Khadori, and Zhoti have to be mentioned in the context of modern Georgian hydropower development and ANDRITZ Hydro.

### DARIALI, TERGI RIVER

For the Dariali hydropower plant the scope of the supply for ANDRITZ Hydro comprised the entire electro-mechanical equipment including three 37 MW Pelton turbines and generators, GIS switchgear and the generator step-up transformers. At the time the contract was signed, Dariali was the largest privately owned hydropower plant in Georgia. Since commissioning, the plant has been providing renewable and sustainable electricity to the Georgian national grid.

#### GENERAL FACTS

- Population: **3,717 Mio.**
- Access to electricity: **100%**
- Installed hydro capacity: **3,164 MW**
- Hydro capacity under construction: **1,505 MW**
- Share of generation from hydropower: **80%**
- Hydro generation per year: **9,210 GWh**
- Technically feasible hydro generation potential: **80,000 GWh**

#### ANDRITZ HYDRO IN THE COUNTRY

- Installed and/or rehabilitated capacity: **362 MW**
- Installed and/or rehabilitated units: **28**
- Locations: **Tbilisi**

TO KNOW



# KAZAKHSTAN

## FROM FOSSIL FUELS TO RENEWABLES

Kazakhstan is the world's largest landlocked country and is the ninth largest in the world. The bulk of the country is located in Asia, but the most western parts are in Europe. The country is the economically dominant nation in Central Asia, generating more than half of the region's GDP through its enormous oil and gas industry and vast mineral resources. On the back of these natural resources, Kazakhstan's economy has shown considerable growth over the last decade.

The total installed generation capacity is 21,673 MW. Of this, some 80% is provided by coal-fired plants. Only 10% is generated by hydropower, with about 2,456 MW. Supply and distribution of electricity through Kazakhstan is problematic because most of the energy is produced far from demand centers and the bulk power grid is in significant need of modernization.

presentative office in Almaty was established as a regional hub to support better access to the market and to be able to explore the excellent business opportunities not only in this huge country, but across the entire Central Asian region.

A stand-out reference is the Moinak hydropower plant (2 × 153 MW), where ANDRITZ delivered two Pelton turbines and a spare runner. Electro-mechanical equipment for two small hydropower stations on the river Issyk, each with a capacity of 5.25 MW, have also been delivered and installed in Kazakhstan.



Shardarinskaya, Syr-Darya River

Although Kazakhstan has an estimated technically feasible hydropower potential of about 62,000 GWh per year, only 13% of this potential has been developed so far. To meet future demand and address ambitious targets to increase the share of renewables to about 50% by 2050, the country needs to increase investment in the power sector. Even if measures regarding decentralized electricity, trading markets, and new tariffs are beginning to show results, more energy market reforms are required.

### ANDRITZ HYDRO IN KAZAKHSTAN

For about 10 years, ANDRITZ Hydro has been active in the promising hydropower market of Kazakhstan. In 2017, the re-

### SHARDARINSKAYA, SYR-DARYA RIVER

In December 2013, ANDRITZ signed a contract for new electro-mechanical equipment at the Shardarinskaya hydropower plant. ANDRITZ is replacing four Kaplan turbines with new runners, new generators, automation, and auxiliary systems. The power output will be increased by about 20% – from 26 MW to 31.5 MW per unit. The first two units are already in commercial operation, refurbishment of the remaining two units is scheduled for completion at the beginning of 2020.

#### GENERAL FACTS

- Population: **18 Mio.**
- Access to electricity: **100%**
- Installed hydro capacity: **2,456 MW**
- Hydro capacity under construction: **<200 MW**
- Share of generation from hydropower: **11%**
- Hydro generation per year: **11,160 GWh**
- Technically feasible hydro generation potential: **62,000 GWh**

#### ANDRITZ HYDRO IN THE COUNTRY

- Installed and/or rehabilitated capacity: **607 MW**
- Installed and/or rehabilitated units: **9**
- Locations: **Almaty**

TO KNOW

# FOR BETTER PERFORMANCE

Digitalization  
with a focus  
on **data-driven**  
solutions

In a unique multidisciplinary approach, ANDRITZ Hydro core technology experts work hand-in-hand with software developers to create predictive maintenance modules for advanced O&M services. ANDRITZ Hydro developers merge decades of expert hydropower knowledge with data analytics methods. This unique combination builds into high-end risk prediction and predictive maintenance services. The development of the software platform Metris DiOMera is completely embedded into our industrial internet/Internet of Things (IoT) strategy with Metris at its heart. Metris is the technology brand of ANDRITZ for digital solutions for both new and existing plants. Together with the software platform, a wide range of technology modules, sensor technology and augmented reality coalesce to form an essential solution for new, cost-efficient services for hydropower installation, operations, and maintenance.

ANDRITZ Hydro is well positioned in the growing modernization, refurbishment, and upgrade market for existing hydropower plants. We also have a comprehensive portfolio of services for O&M activities that maximize plant performance and enhance protection for valuable assets.



As the global influence of the IoT expands, new service and maintenance concepts are becoming increasingly necessary. With Metris DiOMera, ANDRITZ Hydro now offers a digital operations and maintenance solution for hydropower plants. Metris DiOMera is a modular and flexible platform that optimally meets specific customer requirements, supports environmental conservation and enhances operations management. Furthermore, the platform provides decision guidance for target-oriented maintenance works. Metris DiOMera tools also consider lifetime management to define the right scope and timing for required maintenance activities in order to maximize plant availability.

### NEED SUPPORT FOR OPERATIONS MANAGEMENT?

Based on the long-term competence and experience of our staff, ANDRITZ Hydro is able to provide operations services on site via our local team or remotely from our Regional Control Centre in Italy. They will ensure optimal plant performance and monitor trends and data in order to maximize availability and reliability, as well as anticipate any potential issues. The need for easy accessibility, interconnection, and communication requires the development and deployment of up-to-date cyber security to protect your assets.

### MAINTENANCE – WHEN AND WHAT?

Thorough maintenance of all electro-mechanical equipment is key to maximizing the lifetime of a hydropower plant and ensuring its longevity. As a result, the profitability and long-term value of a hydropower plant asset is significantly impacted by the quality of the rendered services. To fulfill these requirements, services such as remote assistance, troubleshooting, and preventive and predictive maintenance are necessary. Services can range from continuous monitoring of relevant key performance indicators to adaptive operational optimization of multiple power plants. Our Metris DiOMera digital solution has a modular and flexible design, and provides decision guidance for target-oriented maintenance, reducing outage times, facilitating logistics, and maximizing production.

### HOW DO I REDUCE COSTS AND STAFF?

Manpower concepts for operations and maintenance have to be adapted to meet new market requirements. Even a few years ago, hydro plant O&M was considered one of the core competences of an asset owner and was executed by local staff. Today, the energy market is changing and it is becoming common industry practice to outsource these competencies to a full service provider. Simultaneously, the demand for completely unmanned O&M solutions is growing. Preconditions for unmanned operational concepts are digitalization, a group dispatch center for operations, and powerful digital solutions for predictive maintenance.



### ANDRITZ HYDRO REGIONAL CONTROL CENTER IN SCHIO, ITALY

To meet demanding market requirements, ANDRITZ Hydro built the ANDRITZ Regional Control Center (RCC) in order to establish an advanced remote monitoring and control centre for worldwide operations and maintenance that is available across the full ANDRITZ Hydro Group.

The RCC is a state-of-the-art system for remote hydropower plant monitoring using advanced tools, including our digital platform Metris DiOMera. Sophisticated analysis, machine-learning algorithms, statistical analysis within the ANDRITZ Hydro expertise and knowledge are integrated into this platform to anticipate major failures, to trigger a real predictive analysis for maintenance activities, and to produce optimized operation instructions. Finally yet importantly, full remote operation is also one of the main features and service provided by RCC.

Today, top modern technological tools are deployed within our O&M business models in order to support our clients in reducing their OPEX, preventing critical issues and maximize the annual generation of their assets.

Our RCC delivers 24/7 operations support, offering rapid solution-oriented analysis services and providing technical assistance for any issue customers may have during their daily on-site operation activities.

A dedicated O&M department has also been established to back-up the required services of the RCC and to fulfil the activities we have been contracted in the most professional way both in terms of competence and time reaction.

The RCC is fully ready and running host data, signals and power plants from all regions right across the world. This empowers business opportunities for all our locations throughout the ANDRITZ Group, and includes the latest in cyber security protection.



# ITALY

## SUSTAINABLE GROWTH

With its advanced economy ranking eighth largest in the world and fourth largest in Europe, Italy is one of the world's most developed countries. Although highly industrialized it has a large and competitive agricultural sector – it is the world's largest wine producer, for example. Italy also has high-quality automobile, machinery, food, design and fashion industries. Today, the country plays a prominent role in global economic, military, cultural and diplomatic affairs. Culturally, Italy is home to 54 World Heritage Sites, the most in any country, and is the world's fifth-most visited tourist destination.

The average annual production of electric power in Italy is about 53.5 GWh, ranking it fourth highest in Europe. Electricity production from hydropower accounted for almost 13% of the national total in 2017.

There are a total of 4,274 hydropower plants in operation, of which 460 have an output of more than 30 MW and more than 3,000 less than 1 MW. Most hydroelectric plants are found in the mountainous north of the country, which is blessed with an abundance of water. The bulk of the nation's hydropower capacity was installed before 1975. Since then, while there have been no major new installations, electricity demand has nonetheless increased significantly. Most of this new demand has been met by growth in the use of fossil-fueled generation capacity, which is the main source of electricity production today. However, the share of renewables, such as wind and solar, is growing.

Italy has set an ambitious target to raise the share of total electricity consumption generated from renewable energy sources to 55% by 2030. This goal can only be achieved with additional installed renewable energy capacity estimated at some 40 GW. A national energy strategy aims to see all coal-fired plants decommissioned by 2025 and for renewables to increase to meet the resulting loss of capacity. New initiatives to support renewables, mainly focusing on small and mini hydro, are expected to further boost sustainable growth and improve grid stability.

### ANDRITZ HYDRO IN ITALY

The long success story of ANDRITZ Hydro in Italy began with the foundation of the Silvio Pretto S.A. company in 1884. Since then, more than 2,200 hydropower units with a total capacity of 12 GW have been installed or rehabilitated. Today, the ANDRITZ Hydro operation in Italy is responsible not only for the domestic market, but also for many projects in South America, especially Peru and Chile. Highly skilled ANDRITZ Hydro engineers and staff make the Italian operation a world leader in hydropower service and rehabilitation. Within the last two years, an ANDRITZ Control Center for our operation and maintenance activities has been established in Schio featuring advanced monitoring and control features. It is based on the Metris

The installation of an additional 40 GW capacity is required to achieve the ambitious target to raise the share of renewable energy sources in Italy.





Chievo Dam, Adige River, Verona, five StrafloMatrix units

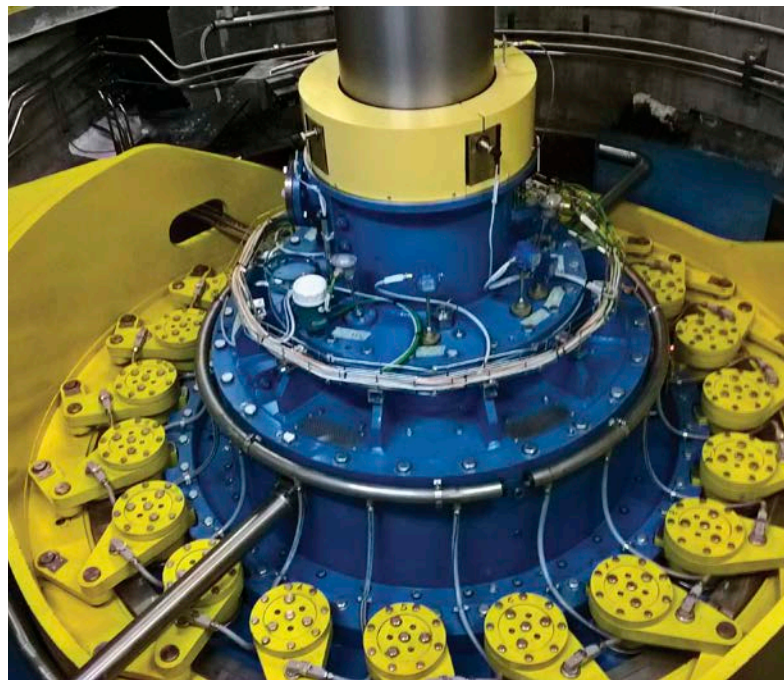
DiOMera platform and is available for the whole ANDRITZ Hydro Group as it can be remotely connected to hydropower installations worldwide. A dedicated O&M team can provide all the required services related to the daily and/or the medium-term operational activities of customer plants. (→ see article page 31)

### SAN PANCRAZIO, SOUTH TYROL

After almost 60 years of operation the turbine at the San Pancrazio hydropower plant was due for rehabilitation. A contract awarded to ANDRITZ comprised a new vertical shaft Francis turbine and a new generator. In addition, the scope of supply included automation and excitation systems, as well as low- and medium-voltage equipment. Due to the excellent design of the new generator, its capacity was increased from 35 MVA to 41 MVA – a total of 17% over the original installation. Design, manufacturing and installation were all executed on time and in May 2018 the hydropower plant was successfully recommissioned.

### MORASCO, PIEMONTE

For the Morasco hydropower plant ANDRITZ performed an overhaul of the first unit's 26 MVA generator. The scope of work included a new generator stator core and winding, generator bus ducts, medium-voltage connection, and generator control cubicle – including the partial discharge monitoring system. Additional equipment included the shaft eddy current system, generator and bearing temperature measurement system and, finally, bearing instrumentation. Moreover generator disassembly (including asbestos disposal) and reassembly was included as part of the scope of the contract, as well as installation. Since mid-2018 this refurbished generator unit has been producing renewable electrical energy for the region. Refurbishment of the second unit at Morasco has begun in March 2019.



San Pancrazio, South Tyrol

### NEW TURBINE RUNNER SUPPLY FRAME CONTRACT

ANDRITZ is supplying five Pelton and two Francis runners for various hydropower plants throughout Italy for the country's largest electricity supply utility. Also within the scope of the contract are additional minor rehabilitation programs and site activities.

### PONTE ACQUA, BERGAMO

Since mid-2018 the small Ponte Acqua hydropower plant has been online supplying 1.9 MW to the grid. Under the terms of a refurbishment contract, ANDRITZ supplied a new horizontal shaft Pelton turbine, a new generator, spherical inlet valve, the governor hydraulic power unit (HPU), as well as automation and excitation systems and medium-voltage equipment.

### PUBBLICO CONDOTTO, LUCCA

In 2017, ANDRITZ supplied one Kaplan turbine unit to this mini hydropower plant, which powers an existing paper mill. The Pubblico Condotto plant is an important Mini Compact hydro reference for a double-regulated ADT-type unit installed directly by ANDRITZ Hydro Italy.

#### GENERAL FACTS

Population: **60,551 Mio.**  
 Access to electricity: **100%**  
 Installed hydro capacity: **22,838 MW**  
 Share of generation from hydropower: **12.8%**  
 Hydro generation per year: **38,000 GWh**  
 Technically feasible hydro generation potential: **>65,000 GWh**

#### ANDRITZ HYDRO IN THE COUNTRY

Installed and/or rehabilitated capacity: **12,433 MW**  
 Installed and/or rehabilitated units: **2,266**  
 Locations: **Schio**

TO KNOW

# HIGH HEAD TURBINES

## Meeting new performance needs

**W**ithin the European hydropower sector, much of the current market focus concerns the rehabilitation and upgrade of Pelton turbines. Due to their cyclic loading, Pelton runners have a limited lifespan and there is consequently no alternative but to replace runners when these machines reach the end of their operational life. Given the aging European fleet, this is an important driver for this regional focus on refurbishment. Moreover, refurbishing existing units presents an opportunity to upgrade these machines by adapting or even replacing components to achieve higher performance and improve their suitability to new operating conditions.

The difference between planned and effective operating range can be significant for some plants. Operating conditions can change very quickly depending on the particular services required from a plant. Adapted designs can thus generate a much higher return on investment. Peak output is no longer the sole driver for hydropower performance and today flexibility and good operating conditions over the entire operating range has significant market value.

A new generation of hydraulic runner profiles, the so-called Alpha generation, delivers high performance while being specifically adapted to the operational environment as required. Among other design parameters is the need to integrate the given operating head, with special care required to avoid cavitation in case of very high heads. In addition, in the Alpine region more and more consideration is being given to hydro-abrasive erosion resistance.

Recent projects in Europe and elsewhere with heads above 900 meters are representative of this new generation of designs. With high efficiencies over the entire operational range, wet parts are protected with erosion-resistant coatings that extend life cycles significantly. The La Coche hydropower project in France is an excellent example of this cutting edge approach to Pelton turbine hydropower design. ( → see article page 27)

A number of rehabilitation projects, such as Villarodin and La Bathie in France and Sy-Sima in Norway, are other examples of Pelton units that required new runners and which presented the opportunity to significantly improve overall plant performance.



Technology developments support these evolving market needs, backed with significant investment from ANDRITZ Hydro. Examples include experimental facilities for testing high-performance scale-model Pelton machines or the development of new hydro-abrasion resistant coatings in the ANDRITZ Hydro hydraulic laboratory at Vevey, Switzerland.

This philosophy is very much in line with continuous development in mechanical engineering to improve the maintenance "friendliness" of Pelton components. It also goes together with novel concepts, such as the patented bolted runner technology, that again aim to simplify maintenance and optimize maintenance costs, especially in hydro-abrasive environments.

Managing, assessing and ultimately determining the operational life of aging components is also an important driver for further technology development. Managing the end of the operational life of Pelton runners is a major concern for numerous Pelton unit operators in Europe and

elsewhere. Monitoring, assessing the aging of runners, and establishing adequate maintenance and inspection procedures to provide a continuous assessment of the operational life of aged runners is therefore of strategic importance to many owners and operators.

It calls for the development of new services in the residual life analysis of Pelton runners and, when relevant, specific monitoring and predictive measures. For instance, the Metris DiOMera platform includes features dedicated to the optimization of operations and maintenance regimes of hydro units. (→ see article page 30)

The spectrum of Pelton projects within Europe addresses the entire operational life of Pelton units, calling for excellence in services, technology expertise, and continuous development. ANDRITZ Hydro delivers this excellence on a daily basis and continues to lead the technology advances that meet constantly evolving customer needs.



© Kristofer Ryde

# NORWAY

## FROM MEN AND FJORDS

Norway has a stable economy with the fourth-highest per capita income in the world, ranking it as one of the wealthiest countries in the world. The economy is characterized by a vibrant private sector, a large state sector, and an extensive social safety net. The country is richly endowed with natural resources such as oil and gas, fish, forests, and minerals. Although Norway is one of the world's leading petroleum exporters, domestic electricity production relies almost entirely on hydropower.

Approximately 40% of Norway's land area is above 600 m. This high ground is mostly located towards the west coast where weather from the west/southwest ensures that the reservoirs of hydropower plants are constantly filled. Norway has approximately 50% of Europe's total energy storage capacity in its existing hydropower storage, for example.

Norway has more than 1,500 hydropower plants, which in a normal year produce some 133 TWh or 96% of total Norwegian power production. In 2016, though, a new national record of more than 143 TWh was reached. There are about 3,600 dams registered in the Norwegian Water Resources and Energy Directorate (NVE) database and around 340 of these are large dams with a height above 15m. During 2018, the installed capacity of the Norwegian hydropower supply system passed 32,000 MW.

Most grid companies are wholly- or partly-owned by one or more municipalities. The state owns about 90% of the bulk power transmission grid. Norway already has grid connections to Sweden, the Netherlands and Denmark. With the NordLink cable, Norway will also have a power link to Germany, which is planned to be in operation by 2020. A new interconnector to the UK – North Sea Link – is also under construction and is planned to be in operation by 2021.

In 2012, a joint Norwegian-Swedish electricity certificate scheme was launched to support the growth of renewable power in the Scandinavian market. The scheme is market-based with producers of renewable electricity receiving one certificate per MWh of electricity they produce for a period of up to 15 years. Although the scheme is technology-

Kvilldal, Shut-off valve transportation

**With 1,240 MW, Kvilldal is Norway's largest hydropower plant and has the heaviest valves in the country installed.**





neutral, meaning that all forms of renewable electricity production qualify, in Norway the scheme has been dominated by wind and hydropower. Currently, there are licenses for 526 new power plants in Norway, totaling some 17.4 TWh of annual production (11.8 TWh wind and 5.6 TWh hydropower).

## ANDRITZ HYDRO IN NORWAY

For almost 30 years, ANDRITZ Hydro has been one of the leading companies serving the hydropower fleet in Norway. Located in Jevnaker, ANDRITZ Hydro has a workshop with 50 tons capacity and an area of 5,000 m<sup>2</sup>.

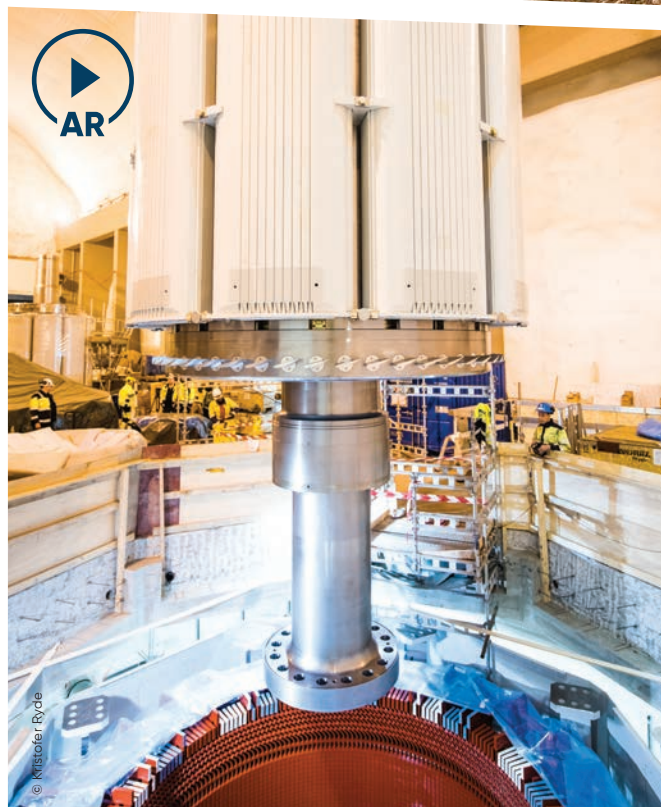
Although most of the country's hydropower plants were built between 1930 and 1990, there are still a number of greenfield power plant projects underway. Contracts for numerous new plants currently under construction, including the Smibelg/Storåvatn, Tolga, Leikanger and, Nedre Otta hydropower plants, as well as several small hydropower projects, are again proof of ANDRITZ Hydro's market leadership.

Upgrading and extension of existing plants is also a growing trend in the market. For example, ANDRITZ is to upgrade and deliver new runners to the Kvilldal hydropower plant (4×310 MW Francis machines). End of 2018, a contract to supply electro-mechanical equipment for the new Nedre Fiskumfoss hydropower plant – a replacement of the old plant – was awarded to ANDRITZ. It will be producing about 380 GWh of electricity per year.

Over recent years, ANDRITZ Hydro has increased its focus on service of smaller units both mechanical and electrical as quick and capable support of the hydroelectric fleet is important for us and our customers.

### LYSEBOTN II, ROGALAND

In 2018, ANDRITZ successfully put into operation the hydropower plant on the Lysefjorden River as a replacement for Lysebotn I. Under the contract terms, two identical 185 MW high-pressure Francis turbines working on a gross head varying from 686 m to 618 m were supplied as part of the



Lysebotn II, Rogaland

electro-mechanical equipment. The contract also covered the supply of the penstock and gates for the new power plant. Post-refurbishment the estimated average annual electricity production of 1.5 TWh implies an increased annual energy production of approximately 180 GWh or around 14%.

#### GENERAL FACTS

Population: **5,282 Mio.**  
 Access to electricity: **100%**  
 Installed hydro capacity: **31,837 MW**  
 Hydro capacity under construction: **800 MW**  
 Share of generation from hydropower: **95.8%**  
 Hydro generation per year: **142,996 GWh**  
 Technically feasible hydro generation potential: **300,000 GWh**

#### ANDRITZ HYDRO IN THE COUNTRY

Installed and/or rehabilitated capacity: **29,071 MW**  
 Installed and/or rehabilitated units: **946**  
 Locations: **Jevnaker**

TO KNOW

# ANDRITZ' FOOT PRINT

## In the European Pumped Storage Market

**F**ollowing the European pumped storage boom between 1970 and 1990, a long development drought finally broke around 2010 when a second boom in pumped storage projects began across Europe.

As one of the global leaders for hydraulic power generation, ANDRITZ made its mark, in particular with its expertise in low-head pump turbines. For example, with the contract award to supply the pump turbines for the Baixo Sabor Cascade on the Sabor River in northern Portugal, ANDRITZ began a new era of pumped storage development on the Iberian Peninsula. The upstream power station of the Baixo Sabor Cascade is equipped with two pump turbines of 77 MW each. It operates across a very wide head range of between 69 and 105 m. The two pump turbines at the downstream power station operate at a very low head of between 26 and 35 m. In the downstream station each of the units provides a rated capacity of 18 MW. Both grid-connected power stations were built to both generate electricity and create a strategic reserve of water in the region.

A couple of years later, in late 2011, ANDRITZ received an order to supply equipment for another pumped storage plant in Portugal – the 234 MW Fóz Tua pumped storage power station. The dam, with two pump turbines, is located on the lower branch of the Tua River. It forms part of a national effort to increase power generation from renewable sources.

Beyond the Iberian Peninsula, ANDRITZ experience in pumped storage technology has allowed other nations to benefit from pumped storage hydropower capacity. For instance, two of the largest pumped storage power plants in Europe use equipment from ANDRITZ.

The Goldisthal plant in Germany was the first variable speed pumped storage power plant outside Japan. The pump turbines at Goldisthal are able to regulate energy not only in turbine mode, but also during pump operation. Additionally, the plant supplies advanced grid services, improving reliability and stability across the national transmission system.

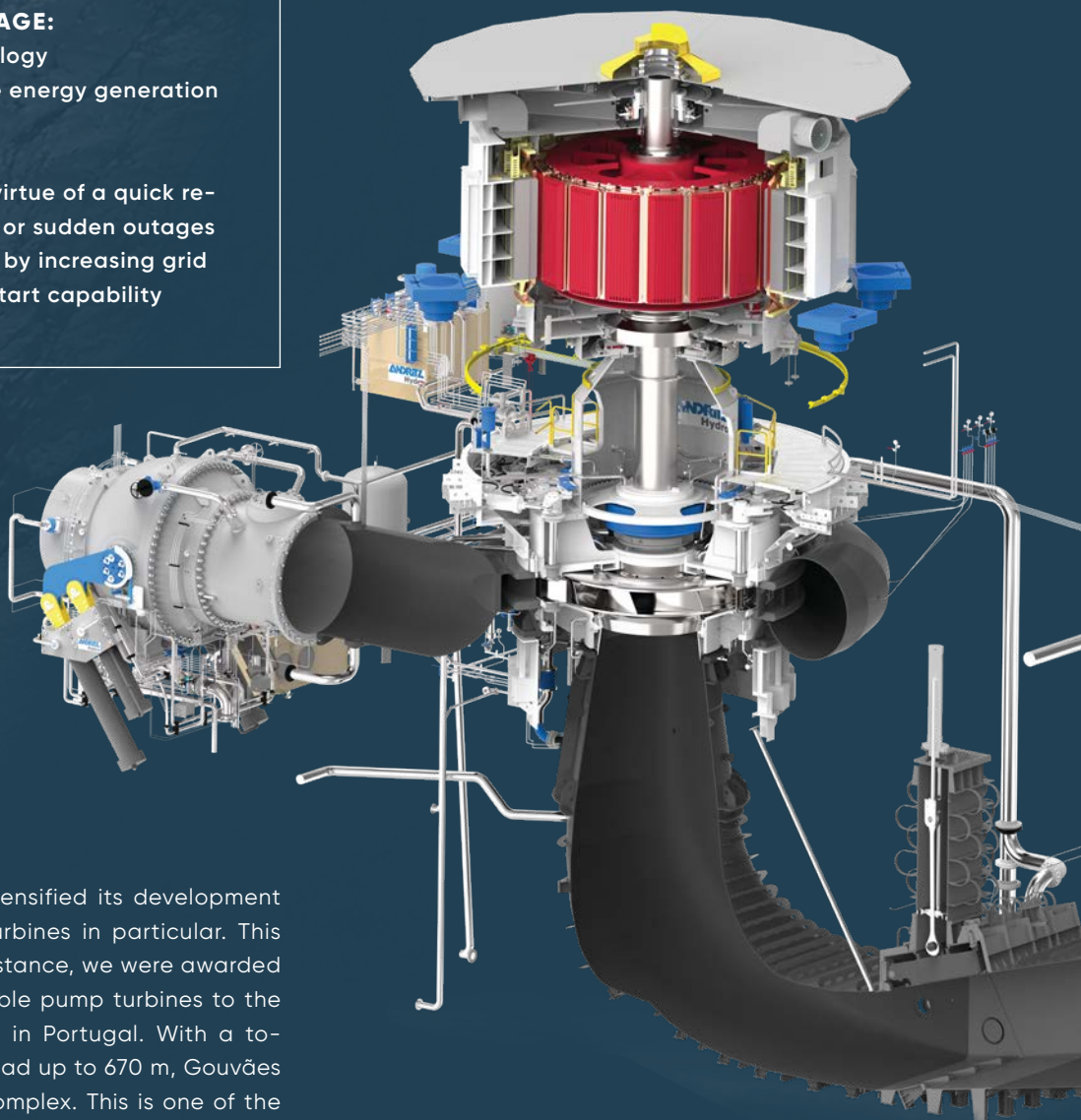
In 2015, the second largest pumped storage plant in Europe, the Vianden power station in Luxembourg, was extended with an 11<sup>th</sup> pump turbine unit supplied by ANDRITZ. The addition of this new unit, with a rated capacity of 200 MW, boosted the total capacity of the power station to almost 1,300 MW.

Ternary sets and multi-stage units are also an important part of ANDRITZ' extensive pumped storage technology portfolio. The ternary set of Kops II, Austria, as well as the four-stage pump turbine of Nestil, Switzerland, are operated with ANDRITZ equipment, for example.

In 2017, the six-stage storage pump Oschenik 1 at the Innerfragant hydropower station in Austria was successfully commissioned. With a rated capacity of 30 MW the storage pump is able to pump water up to 950 m from the lower to the upper reservoir.

#### BENEFITS OF PUMPED STORAGE:

- Best-proven, low-risk technology
- Balancing volatile renewable energy generation with demand
- Managing grid bottlenecks
- Supporting grid stability by virtue of a quick response to changing demand or sudden outages
- Contributing to grid stability by increasing grid inertia and providing black start capability
- Very long facility lifetime



In recent years, ANDRITZ has intensified its development program for high-head pump turbines in particular. This effort is paying off. In 2016, for instance, we were awarded a contract to supply four reversible pump turbines to the Gouvães pumped storage plant in Portugal. With a total capacity of 880 MW and a head up to 670 m, Gouvães is at the heart of the Tâmega Complex. This is one of the largest hydropower projects in Europe currently and produces about 1,500 GWh of electrical energy annually. (→ see article page 41)

The first power stations developed during the European pumped storage boom in the 1970s are now aging. One after another, rehabilitation of these older units is becoming an increasing necessity in order to ensure reliable operation and to meet prevailing legal and regulatory requirements.

Alongside increased efficiency, improved part load operation is also required to meet the needs of the future energy market. ANDRITZ, for example, recently supplied four new runners to the Bolarque II power station in Spain. This project will make the more than 40-year-old pump turbines ready for the energy market challenges of the coming decades. (→ see article page 43)

From the low head of the Baixo Sabor power plant to the high head of the Oschenik 1 multi-stage pump, to the refurbished runners of the Bolarque II power station and the state-of-the-art pump turbines of Gouvães, ANDRITZ supplies the full range of pumped storage technology. As a leading player in global pumped storage development, ANDRITZ is ready to contribute to the improvement and modernization of the European energy market and to meet the changing needs of the future.

**PUMPED STORAGE HYDROPOWER PLANTS** are well proven as the most cost-effective form of energy storage to date. They offer state-of-the-art technology with low risks, low operating costs and balance grid fluctuations through their high operational flexibility, allowing the successful integration of intermittent renewable power. Thus, they significantly contribute to a clean energy future.



# PORTUGAL

## ON THE WIND OF INNOVATION

One of the oldest states in Europe, Portugal is a developed and a high-income country but with the lowest per capita GDP in Western Europe. The economy is mainly based on agriculture, fishing – following its long tradition as a sea fairing power – and mining. A diversified industry is ranging from automotive, aerospace, electronics and textiles, to food, chemicals, cement and wood pulp. Portugal is further an innovative modern country with intensive scientific and technological research activities. Portugal-based innovation is in 15<sup>th</sup> position in international rankings.

Until recently, the country's primary energy source was hydropower. There is considerable hydropower potential, with most hydropower plants located in the mountainous northern region. About a third of the total installed hydropower capacity of 7,193 MW is pumped storage.

Wind is also emerging as an important energy source. In 2006, the world's largest solar power plant at that time, the Moura photovoltaic Power Station, began operating near Moura in the south of the country. In 2017, renewable energy generation supplied almost 39% of the total generation. The government has implemented measurements to promote renewable energy. To balance variable energy sources like wind and solar, pumped storage power plants will play an increasingly important role. However, the "National Plan for Dams with High Hydroelectric Potential" is currently being reevaluated in the context not only of economic and energy production factors, but also the quality of water flows and water bodies. As a result, the government has placed all planned hydropower construction projects on hold whilst this review takes place.

### ANDRITZ HYDRO IN PORTUGAL

ANDRITZ has been delivering hydropower equipment to Portugal since 1914 and has equipped numerous plants. These include the Ermida, Ribeiradio, and Bemposta plants, Bemposta being one of the largest pumped storage hydropower plants in Western Europe. On the

occasion of the execution of the works for the pumped storage hydropower plant Baixo Sabor, ANDRITZ Hydro established a local company based in Porto. The objective in establishing this company was not only to cover the work for a specific project, but also to base skilled and

**"The Tâmega Hydroelectric Complex represents the largest hydropower project in the history of Portugal and is designed to generate up to 1,760 GWh annually guaranteeing the supply of energy for almost three million people."**



experienced personnel in Portugal for global site installations. The Porto company supports ANDRITZ Hydro manufacturing capabilities in locations such as Ravensburg in Germany or Weiz in Austria, for example.

Meanwhile, installation and commissioning teams from Portugal are in action not only in Portugal itself, but also around the world in Austria, Norway, Iceland, Angola, Malawi, Lao, Vietnam, Peru and elsewhere. An impressive list of references shows the efficiency and high quality performance of the installation teams operating out of Porto.

Close corporation with universities and agencies also allows ANDRITZ to offer specialists for site management and supervision with multi-disciplined personnel who can work on multiple products – such as turbines, generators, gate installation, EPS installation and commissioning – as and when this is required.

### BAIXO SABOR, SABOR RIVER

ANDRITZ supplied the electro-mechanical equipment for two powerhouses (Montante and Jusante) for the Baixo Sabor complex. The scope of supply included two reversible pump turbines with auxiliary systems, generators, power bus bars, transformers, switchgear, the complete automation and control system, and auxiliary equipment for the turbine house. Particular challenges associated with this project included the extremely wide operational spectrum in regard to the water head and load at

On site installation work Gouvães, Tâmega River



Bemposta Dam, Douro River

the Montante powerhouse, as well as the use of reversible pump turbines for the unusually low water heads found at Jusante. The Baixo Sabor hydropower complex began operations in 2016.

### GOUVAES, TÂMEGA RIVER

In 2017, ANDRITZ received a contract to supply the electro-mechanical equipment and the penstock for the new Gouvães pumped storage power plant, the heart of the Alto Tâmega hydropower scheme. The scope of supply comprises design, manufacturing, delivery, and installation supervision for the reversible pump turbines, motor generators, and electrical power systems. Also part of the contract are design, manufacturing, supply, and complete installation of a penstock, including three bifurcators with a total weight of about 12,000 tons, an average diameter of about 5,400 mm and a length of 2.5 km.

#### GENERAL FACTS

- Population: **10,3 Mio.**
- Access to electricity: **100%**
- Installed hydro capacity: **7,193 MW**
- Hydro capacity under construction: **1,158 MW**
- Share of generation from hydropower: **10%**
- Hydro generation per year: **5,536 GWh**
- Technically feasible hydro generation potential: **24,500 GWh**

#### ANDRITZ HYDRO IN THE COUNTRY

- Installed and/or rehabilitated capacity: **5,619 MW**
- Installed and/or rehabilitated units: **231**
- Locations: **Porto**

TO KNOW





## SUN, WIND AND HYDROPOWER

Once at the heart of the world's first global empire, today Spain is a modern and developed country with the world's 14th largest economy. Spain's enduring cultural legacy includes half a billion Spanish-speaking people worldwide, making it the second most widely spoken language.

Spain has a strong commitment to the development of renewable energy. By 2017 renewables represented 46% of the total installed power generation capacity in Spain. With 23,132 MW of wind power capacity installed, the country is one of the world leaders. A further 4,687 MW of solar PV puts the country into the top 10 countries in terms of installed solar PV capacity too. Spain also led the world as the first country to develop concentrated solar power (CSP). However, although Spain already has a very high share of renewables, there is still a long way to go to achieve its ambitious renewable energy targets of 70% of total electricity production by 2030 or the goal of zero emissions by 2050. To reach these goals much more investment into renewables and deployment of smart-grids will be needed, alongside

government support in the form of development programs, as well as the closure of existing thermal power plants.

Most of the installed hydropower base of 20,360 MW is conventional hydropower with some 3,329 MW of pumped storage within this total. Pumped storage plays a major role in balancing the intermittent resources of renewable electricity generation, helping to stabilize the grid and provide peak power load. As a result, throughout Spain there are a number of pumped storage hydropower projects in the planning and permission phase. In addition, an interesting market for service and rehabilitation of hydropower plants exists as the average age of the country's hydropower fleet is more than 40 years.

Bolarque, Tagus River



San Pedro, Sil River, Galizia





Aldeávila, Douro River

**"Spain is home to the world's largest renewable energy operator."**

## ANDRITZ HYDRO IN SPAIN

ANDRITZ Hydro has contributed to the development of hydropower in Spain since its beginnings at the end of the 19<sup>th</sup> century. The company has played an active role in Spain ever since and some 60 years ago established a Spanish company and workshops in Algete/Madrid. This organization provides customized solutions and products not only to the Spanish market and neighboring Portugal, but also to numerous projects in Central and South American markets.

### RIBARROJA, EBRO RIVER, TARRAGONA

In 2018, ANDRITZ received a contract for the refurbishment and environmental improvement of Kaplan turbine units #1, #3, and #4 at the Ribarroja hydropower plant. Rated at 79 MW each, the scope of supply includes conversion into oil-free units. With a diameter of 5,800 mm, these will be the biggest Kaplan runners in Spain using oil-free

technology. Commissioning of the first unit took place at the end of 2018. The second and third units are scheduled for commissioning in 2019 and 2020 respectively.

### SAN PEDRO, SIL RIVER, GALIZIA

To meet current environmental standards, a contract for the conversion of two 16 MW Kaplan turbines into oil-free units was awarded to ANDRITZ in 2018. These will be the biggest Kaplan runners refurbished to date in our Madrid facilities. Commissioning of the second unit is expected to take place in December 2019.

### BOLARQUE, TAGUS RIVER

Repowering of four pump-turbine units together with the main inlet valve was the objective of a contract awarded to ANDRITZ in 2015 for the Bolarque pumped storage plant. The units each have a capacity of 55 MW. High efficiency levels in both turbine and pump mode will be achieved after the rehabilitation is complete. The commissioning of the last unit is scheduled for 2019.

### ALDEÁVILA, DOURO RIVER

ANDRITZ received a contract for new runners in order to extend the lifetime of the largest hydropower plant in Spain, the Aldeávila hydropower plant. As a fundamental element in the regulation of the Spanish national grid, the units run over a very wide operational range, alternating from very low partial load to full load frequently. This regime exposes the units to severe operational conditions. The successful recommissioning of the units was completed in 2017.

### EL HIERRO, CANARY ISLANDS

ANDRITZ supplied the electro-mechanical equipment for a small pumped storage power plant on El Hierro, the smallest and most southerly of the Canary Islands. This hydropower facility is replacing a diesel-fueled generation plant and is stabilizing variable energy production from a wind farm on the island. This not only ensures energy self-sufficiency for the island, but also allows energy exports to neighboring islands.

#### GENERAL FACTS

Population: **46,572 Mio.**  
 Access to electricity: **100%**  
 Installed hydro capacity: **20,360 MW**  
 Share of generation from hydropower: **7%**  
 Hydro generation per year: **18,364 GWh**  
 Technically feasible hydro generation potential: **61,000 GWh**

#### ANDRITZ HYDRO IN THE COUNTRY

Installed and/or rehabilitated capacity: **9,323 MW**  
 Installed and/or rehabilitated units: **630**  
 Locations: **Algete/Madrid**

TO KNOW

# SOUTHEAST EUROPE

## GROWING PERSPECTIVES

All the states in South East Europe have open market economies, most are in the upper-middle income range. Croatia, Romania, Greece and Slovenia are regarded as having high-income economies. Recent projections for economic growth in the region have generally been surpassed with a high volume of private investment boosting economic progress. Numerous countries in this region are already in the European Union (EU) or are in Member State accession negotiations. The EU has a strong interest here and is promoting and supporting economic development of the region.

Komani, Albania



South East Europe – also known as the Balkans – comprises the countries Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Greece, Kosovo, North Macedonia, Moldova, Montenegro, Romania, Serbia, and Slovenia.

Collectively, South East Europe still represents a significant proportion of untapped European hydropower potential as its river catchments have remained largely undeveloped. Up to 30% of the region's rivers remain in near natural or pristine states and have a very high conservation value. The region has an estimated 80,000 GWh of technical potential, which is concentrated in the mountainous regions of Montenegro and Albania as well as in Bosnia and Herzegovina.

In 2016, the European Union commissioned a regional hydropower masterplan for the region, aiming to define how to develop the hydropower potential in a way that balances energy generation, flood protection and ecological concerns. This plan also strengthens regional cooperation between the European Union and especially the Western Balkan countries.

Albania already derives 95% of its domestically produced electricity from hydropower, Bosnia and Herzegovina 31.3%, Serbia 27.5% and Montenegro 31%, respectively.

Serbia has some 3,018 MW of currently operational hydropower plant capacity. Over two-thirds of this capacity is concentrated near to the border with Romania. The country boasts an undeveloped potential of 17,600 GWh, focused on the Drina and Danube rivers. Romania has the

highest installed hydropower capacity of all the countries within the region, as well as the biggest economically feasible hydropower potential.

Bosnia and Herzegovina has a hydropower potential of more than 24,000 MW, of which only 2,196 MW has been exploited to date. North Macedonia has a technical annual hydropower production potential of 5,500 GWh. Only about 30% of this is currently being utilized, representing a total installed capacity of 676 MW.

Montenegro has abundant water resources, despite its relatively small size. Two large hydropower plants provide approximately three-quarters of the total domestic power supply, but account for only 18% of total hydropower potential.

Although relatively small, the hydropower market is in an upswing across the whole region. For example, governments are supporting the development of small hydro with feed-in-tariffs and other incentives. Several hundred megawatts of small hydropower potential is waiting to be exploited.

South East Europe is also a major market for service and rehabilitation. Numerous plants were constructed in the 1960s–1980s. However, since the Balkan war of the 1990s, low energy prices and low levels of investment have curtailed much needed major rehabilitation works on hydro plants. The hydropower fleet is now in urgent need of modernization and uprating to adjust to new requirements and standards. Ongoing market liberalization, as well as binding environmental targets to reduce the use of fossil-fueled energy sources and develop a low carbon economy, are driving many of the rehabilitation programs throughout the region.

## ANDRITZ HYDRO

ANDRITZ Hydro has a long history of equipment delivery throughout South East Europe. Beginning as far back as 1909 with the first delivery in Greece. Just a year later, Bulgaria. The more than 220 units and a total capacity of more than 7,400 MW delivered across the region are ample proof of the strong and long-term presence of ANDRITZ Hydro in South East Europe.

An excellent network of local partners has made ANDRITZ Hydro one of the leading equipment suppliers, which has been involved in important projects in the region such as Ashta and Komani in Albania, Tzankov Kamak and Belmeken in Bulgaria, Kastraki and pumped storage plant Thissavros in Greece, Salakovac in Bosnia and Herzegovina, and Bajina Basta in Serbia.

## BOCAC II, BOSNIA AND HERZEGOVINA

At the end of 2018, ANDRITZ successfully commissioned the Bocac II hydropower plant, located on the Vrbas River. The contract for the supply of the complete electro-mechanical equipment and services included two horizontal EcoBulb turbines, electrical power systems, control system, and automation. To the complete satisfaction of the client, the turbine efficiency is better than that guaranteed under the terms of the contract – further proof of the expertise and exceptional performance of ANDRITZ.



Bocac II, Bosnia-Herzegovina

## KOMANI, ALBANIA

At 600 MW, Komani is the largest hydropower plant in Albania. ANDRITZ received a contract for full-scale rehabilitation of the plant including turbines, generators, main transformers, and automation, as well as mechanical and electrical auxiliary systems. In February 2019, the last of the four units was put into commercial operation. Today, the plant is again producing about 1,800 GWh of electrical energy per year, some 30% of Albania's total electricity consumption.

### GENERAL FACTS

Population: **64,104 Mio.**  
 Access to electricity: **100%**  
 Installed hydro capacity: **24,700 MW**  
 Technically feasible hydro generation potential: **226,100 GWh**

### ANDRITZ HYDRO IN THE COUNTRY

Installed and/or rehabilitated capacity: **7,438 MW**  
 Installed and/or rehabilitated units: **228**

TO KNOW





# SWEDEN

## TOWARDS 100% RENEWABLE ENERGY

Sweden is an open, competitive and export-oriented economy with a high standard of living and extensive welfare benefits. It is the seventh-richest country in the world in terms of GDP. Timber, hydropower, and iron ore are the base of industry in Sweden, where exports account for more than 44% of GDP. Currently, Sweden's economy is growing at about 5% annually, one of the highest rates in Europe.

The country's demand for electrical energy is mostly covered by hydropower and nuclear power. There are about 16,301 MW of total hydropower capacity installed, producing some 63.9 TWh/year or around 40% of the national output. The bulk of the more than 2,000 hydropower plants in Sweden are located on the four main rivers – the Luleälv, Indalsälv, Umeälv and Ängermanälv.

In order to become independent of fossil fuels in all sectors the government has announced a strong commitment to the development of sustainable energy resources. Under these plans, by 2040 Sweden's entire energy supply is to be 100% based on renewable energies. A major focus will be onshore wind but this intermittent energy will be balanced by existing hydroelectric power plants, as well as stronger networking with neighboring countries. In 2017, the country also established a goal of being fully greenhouse gas-neutral by 2045 as set out in its Climate Protection Act.

As the average age of the hydropower plants in Sweden is 45 years, there is an extensive market for service and rehabilitation to make them fit for the new operational regimes and grid demands associated with large volumes of variable output renewables.

Mörsil, Jämtlands Län



**"Today, almost 90% of the country's hydropower capacity is generated with equipment supplied by ANDRITZ."**

## ANDRITZ HYDRO IN SWEDEN

For almost 40 years ANDRITZ Hydro has had an established office and manufacturing facility in Näliden, but the association with Sweden stretches back far longer. The first equipment deliveries date to the early 1920s. Today, almost 90% of the country's hydropower capacity is generated with equipment supplied by ANDRITZ and its predecessor companies. Projects like Harsprånget, Stornorrfors, Porjus, Kilforsen, and Porsi are only some prominent names on our reference list.

### MÖRSIL, JÄMTLANDS LÄN

This contract comprises the rehabilitation and upgrading of two generators at the plant. After the completion of the work, the two units will see a power increase of 30%, from 22 MVA to 28.7 MVA each. Commissioning of the new generators is scheduled for the end of 2019 and 2020, respectively.

### RENGÅRD, SKELLEFTEÄLVEN

In March 2019, ANDRITZ signed a contract for the rehabilitation of the turbine and generator of unit #1 of the Rengård hydropower station. The scope of supply includes a new five-bladed oil-free Kaplan runner, new turbine and generator parts as well as hydraulic engineering, model test, erection and commission. The main objective of the rehabilitation is an extended lifetime of 50 years and the output increase of the generator from 40 MVA to 50 MVA. Commissioning is scheduled for end of 2021.



Rengård, Skellefteälven

#### GENERAL FACTS

Population: **10,1 Mio.**  
Access to electricity: **100%**  
Installed hydro capacity: **16,301 MW**  
Share of generation from hydropower: **40.4%**  
Hydro generation per year: **61,000 GWh**  
Technically feasible hydro generation potential: **130,000 GWh**

#### ANDRITZ HYDRO IN THE COUNTRY

Installed and/or rehabilitated capacity: **16,000 MW**  
Installed and/or rehabilitated units: **1,800**  
Locations: **Näliden**

TO KNOW

Bjurfors Övre, Västerbottens län





# TURKEY

## CONNECTING TWO CONTINENTS

Characterized by its growing industry and service sectors, Turkey is an emerging market with a large traditional agricultural sector. With its strategic location as a transcontinental country proving advantageous throughout history, GDP since 2016 nonetheless reflects the recent developments that have left the economy struggling with unfavorable international conditions.

Although Turkey is largely dependent on oil and gas imports, it is blessed with significant hydropower resources. Hydropower generation represents a share of more than 30% of the total installed capacity that, as of 2018, has reached 85,200 MW. Of this total, thermal capacity of 46,927 MW represents 53% and renewables including hydro of 40,513 MW accounting for 47%. Hydro itself has an installed base of about 27,273 MW, a share of 68% of all renewable energy sources and 32% of the national installed capacity.

The increase in energy consumption in Turkey is picking up pace and in addition to conventional power generation, renewable sources such as wind and solar power plants are intended to be built on a large scale. Due to Turkey's high import dependency for its primary energy, the Government has been encouraging the use of renewable resources.

With more variable renewable capacity anticipated over the coming years, the need for flexible generation capacity will also increase. Technologies able to balance and store energy – like pumped storage hydropower stations – will become far more important. No pumped storage projects have been executed in Turkey to date, but their capabilities will definitely be necessary to solve these growing energy supply and demand issues.

The coming decade (2020–2030) is crucial for the development of flexible generation, given the expected strong growth in electricity prices – driven by a tighter supply/demand-balance, increasing gas prices and additional contributions from carbon emission costs.

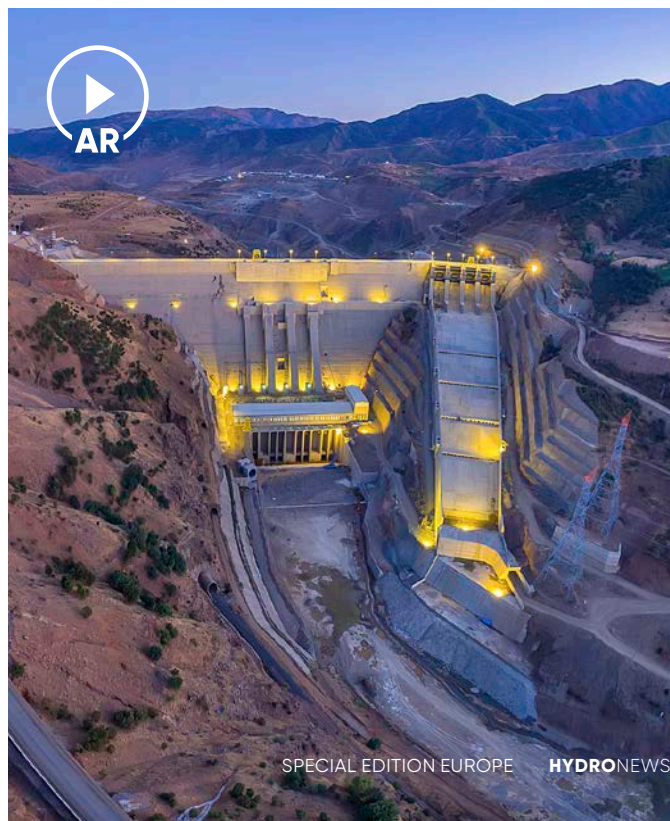
Turkish generation capacity is expected to almost double between now and 2040, with solar PV experiencing the fastest growth rates and onshore wind the biggest

absolute increases. Together they are set to cover about one third of total national capacity in 2040. Meanwhile, hydropower capacity is going to grow by about 30% over the same period to add about 8,000 MW, excluding pumped storage.

### ANDRITZ HYDRO IN TURKEY

ANDRITZ Hydro has been active in Turkey for many decades, reaching as far back as the 1920s when the first turbine deliveries took place. Over the years, the company has become the established market leader for electro-mechanical equipment with 15,733 MW of supplied or rehabilitated turbines and 8,180 MVA of generator equipment delivered, representing market shares of 57% and

Upper Kaleköy Dam, Murat River







© Faraways / iStockphoto.com

30%, respectively. Currently, ANDRITZ Hydro projects under execution total some 2,700 MW of large hydropower projects and 12 small hydropower plants, which will collectively add about 137 MW of capacity in total.

Our local service center in Izmir is close to our clients and is part of an on-going long-term relationship with the Turkish market. Besides state-of-the-art technological solutions, the center offers immediate response times and experienced project implementation and execution, as well as efficient spare parts management.

Some of the highlights from the ANDRITZ Hydro portfolio in Turkey include hydropower plants such as Upper Kaleköy, Beyhan-1, Cetin, Boyabat, the Kandil Cascade, Ermenek, Borcka Muratli, Deriner and Birecik. This is in addition to major projects like Karakaya, Keban, Ilisu and Atatürk – still the largest hydropower plant in Turkey.

### ILISU, TIGRIS RIVER

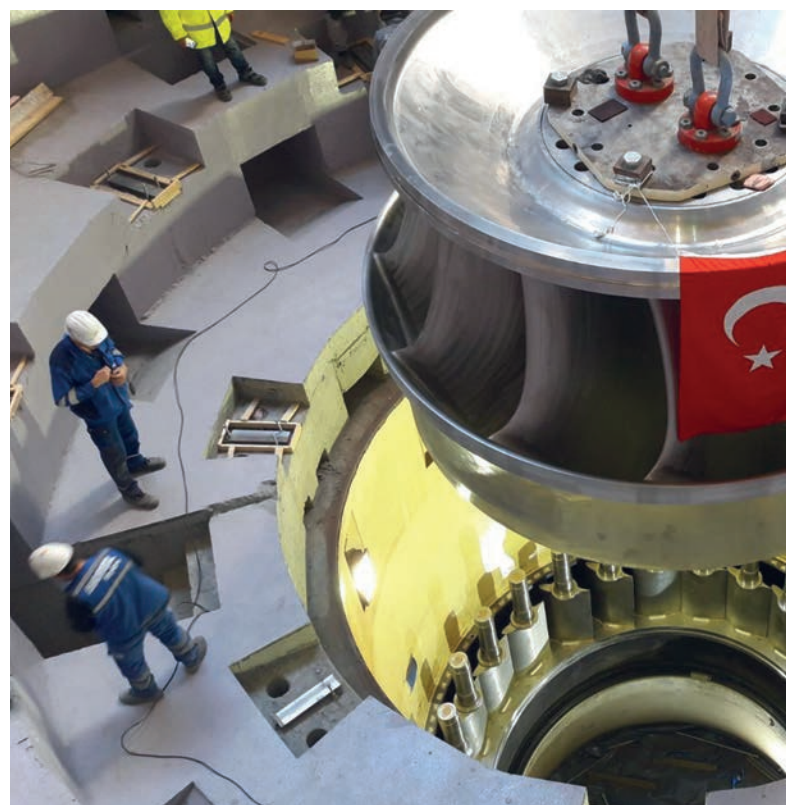
At one of ANDRITZ largest current projects, the Ilisu hydropower plant on the Tigris, the scope of supply comprises both hydro-mechanical equipment and the entire electro-mechanical equipment. The delivery includes six 204 MW Francis turbines. Ilisu will provide about 3,833 GWh of sustainable renewable energy for about two million local households, contributing significantly to the stabilization of the grid in southeastern Turkey. Commissioning is scheduled for mid-2019.

### LOWER KALEKÖY, MURAT RIVER

ANDRITZ has received an order for the supply, installation, and commissioning of three 186 MVA generators here. The hydropower plant is part of the Beyhan-Kaleköy hydropower complex. It will supply some 1,200 GWh of electricity annually, providing important support to the Turkish energy network. Commissioning is scheduled for early 2020.

### YUSUFELI, ÇORUH RIVER

This new hydropower plant will have a total installed capacity of 558 MW. At 270 m, this double-curvature dam will be Turkey's highest and the third highest of its kind worldwide.



Installation work at Ilisu, Tigris River

Our contractual scope of supply comprises design, supply, installation, and commissioning of three 186 MW generating units with all auxiliary equipment and automation systems, as well as hydro-mechanical equipment. The start of commercial operation is scheduled for the third quarter of 2019.

#### GENERAL FACTS

Population: **80,745 Mio.**  
 Access to electricity: **100%**  
 Installed hydro capacity: **27,273 MW**  
 Hydro capacity under construction: **5,000 MW**  
 Share of generation from hydropower: **19,6%**  
 Hydro generation per year: **58,219 GWh**  
 Technically feasible hydro generation potential: **216,000 GWh**

#### ANDRITZ HYDRO IN THE COUNTRY

Installed and/or rehabilitated capacity: **15,796 MW**  
 Installed and/or rehabilitated units: **336**  
 Locations: **Izmir**

TO KNOW

Source Facts: The World Bank, IHA, CIA Factbook, Hydropower & Dams World Atlas 2018

# LOW HEAD TURBINES

Fit for the  
Future

**W**hen Austrian professor Viktor Kaplan (1876–1934) filed his essential patents for the eponymous turbine in 1912 and 1913, he opened the way for a new technology able to use low hydrostatic heads for power generation in an economically feasible way. Now, considering low-head applications automatically leads to discussion of Kaplan turbines, either horizontal or vertical.





Although there are not that many large-scale green field projects featuring Kaplan machines currently underway in Europe, there is nonetheless a huge potential for this turbine type in small hydro applications. With new requirements for grid control, increasing demands for ecological performance and minimizing fish injury rates in particular, the operators of existing low-head power plants are being driven toward equipment upgrades. Consequently it is vital this technology is continually developed to be fit for the needs of the 21<sup>st</sup> century and beyond. ANDRITZ – the worldwide leader in low head turbines – focused its research and development efforts on meeting these new demands at an early stage and thus has appropriate solutions in place.

#### **CHANGING CONTROL REQUIREMENTS**

Switching turbine regulation from level control to primary control introduces a significant change in the frequency of regulation movements by the runner and guide vane mechanisms. More regulation movements result in more load cycles for the affected parts and inevitably make fatigue a greater consideration.

ANDRITZ has developed tools to accurately assess the impact of changing operational requirements on fatigue and can therefore support energy producers in the diagnosis and assessment of the residual service life of turbine equipment.

#### **DEMANDING ENVIRONMENTAL PERFORMANCE**

The impact hydropower stations have on aquatic life has become a major issue for new hydropower plants and the refurbishment of existing hydraulic turbines. Increasing demands for environmental performance have prompted changes in the use of problematic substances such as lubricating oils, for example.

Development of oil-free solutions for Kaplan turbine runners was initiated many years ago and within the last 25 years ANDRITZ has recorded more than 200 references. These examples include oil-free Kaplan runners up to largest diameters, outputs and heads for these types of machines. Each one is the best possible solution for the given application. Instead of oil, the hub is filled with water together with corrosion inhibitors which are non-toxic and not hazardous to aquatic life.

#### **FISH-FRIENDLY SOLUTIONS**

From the first phases of considering plant design and layout or a refurbishment program, important parameters are set that have a major influence on both energetic and environmental performance. In particular, the hydraulic as well as the mechanical design of the turbines offers many opportunities to significantly and positively influence fish survival rates. In order to accurately assess different designs in terms of their fish mortality-related performance, comprehensive knowledge of injury mechanisms and their corresponding mitigation measures is necessary.

Since the 1990s, ANDRITZ has followed a combined design strategy to ensure high rates of fish survival. Different design features are possible, associated with the various injury mechanisms caused by the different stressors (measurable, physical qualities that can be linked to each injury mechanism). It is worth noting that the optimal choice of design parameters for fish survival might be slightly different from those design considerations in which maximizing energy production or minimizing costs are the only targets. Nonetheless, efficient operations and good fish survival rates are possible if the appropriate design considerations are made.

ANDRITZ uses a biological assessment tool supported by CFD to record the various stressors on a fish along its trajectory through an operating turbine. Based on in-depth knowledge of the stressor limits for injuries to various fish species, survival rates can be calculated with this assessment tool.

Viktor Kaplan's idea for a low head and efficient turbine emerged more than a century ago but, in light of changing environmental, economic and operational needs, this ingenious basic idea must evolve and change too. ANDRITZ strives to ensure that Kaplan's idea continues to advance and fulfill today's demanding requirements, making his legacy FIT FOR THE FUTURE.



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# UKRAINE

## BIG PLANS FOR HYDRO

The largest country with its borders entirely within Europe, Ukraine is a developing country whose economy relies largely on agriculture. With very fertile farmlands, Ukraine is one of the world's largest grain exporters but other important industry sectors are heavy industry, vehicle manufacturing, and information technology. Over the last two years, the economy has shown considerable growth as it increasingly opens to the EU and other western industry states.

Most energy supplies, especially oil and gas, have to be imported. Total annual electricity generation amounts to 155,414 GWh. Of this, nuclear power contributes some 55%, fossil-fueled thermal and CHP 32% and hydropower around 6.8%. Aside from hydropower, other renewable energy sources represent only about 1.2% to date.

Total installed hydropower capacity is 6,229 MW, including 1,528 MW of pumped storage. About 60% of the installed hydropower base, corresponding to some 3,400 MW, was built in the 1960s and is now in need of modernization and rehabilitation. A large-scale and on-going rehabilitation program to improve generation capacity, reliability and safety of most of the existing hydropower plants should be completed during 2022. Rehabilitation and modernization could add more than 4,000 MW of hydropower capacity to the country's total.

In order to reduce the need for expensive imported fossil fuels, Ukraine has also established a goal to more than double installed hydropower capacity to reach 15.5% of the total supply over the next decade. Several new projects are currently in the planning or feasibility study phase. The technically feasible national hydropower potential is about 21,500 GWh per year, of which half has already been developed.



Ukraine intends also to increase the share of other renewable energy sources such as wind, solar, and small hydro in the future. Currently, renewables show the highest growth rates but their share of national generation total is still small. Interesting incentives and new tariffs are being launched in order to attract investors to the country's energy sector.

## ANDRITZ HYDRO IN UKRAINE

ANDRITZ Hydro established a representative office in the Ukrainian capital Kiev back in 1992. This office covers the entire product and service portfolio including large new installations with entire "from water-to-wire" packages. In addition, rehabilitation and modernization services, equipment for small and mini hydropower units, automation solutions, pumps for all applications and turbo generators are all also available locally.

### DNIPRO 1, DNIEPER RIVER

The Dnipro 1 hydropower plant was originally built in 1939 and, together with the Dnipro 2 expansion of the plant, is the largest hydropower scheme in Ukraine at 1,500 MW capacity. After almost 70 years of operation, to improve performance, efficiency, and reliability the units now need to be

Dnipro 1, Dnieper River



**"ANDRITZ is the first West European contractor for a large hydro rehabilitation project in Ukraine."**

replaced. ANDRITZ is the first West European contractor for a large hydro rehabilitation project in Ukraine and will supply three 75 MW Francis turbines and generators including dismantling of the existing equipment and supply, installation, and commissioning of the new units. According to the terms of the contract, the last unit should be finished and commissioned in late 2021.

### KRUTOGORNAJA, KIEV

ANDRITZ was awarded a contract to supply the complete electro-mechanical equipment for the new mini hydropower plant Krutogornaja. Due to the small size of the installation and the need to maintain the necessary pressure in the utility water supply line, the three turbine units are pumps operating as turbines. Completion of the entire project is scheduled for 2019.

### AUTOMATION SYSTEMS

In recent years ANDRITZ has supplied 15 turbine governor systems for some of the largest hydropower stations and pumped storage plants in Ukraine. These governors operate in plants with a total installed capacity of about 2,500 MW and demonstrate the high quality of ANDRITZ technology and our expertise, as well as the confidence this installs in our customers.

#### GENERAL FACTS

Population: **44,831 Mio.**  
 Access to electricity: **100%**  
 Installed hydro capacity: **6,229 MW**  
 Share of generation from hydropower: **6.8%**  
 Hydro generation per year: **10,568 GWh**  
 Technically feasible hydro generation potential: **21,500 GWh**

#### ANDRITZ HYDRO IN THE COUNTRY

Installed and/or rehabilitated capacity: **225 MW**  
 Installed and/or rehabilitated units: **3**  
 Locations: **Kiev**

# BIG AND BIGGER

## ANDRITZ Engineered Pumps

**W**ater is the source of all life, but also an indispensable resource for business, industry, agriculture, and energy supply. However, water is becoming scarcer; soon the demand for fresh water will exceed the supply by nearly 50%.

At face value, this does not appear to be an issue for European countries. There is a reliable supply system and water resources are used sustainably with a view to the long term. This appearance, however, is deceptive. Seasonal shortages, little precipitation, high population density, and intensive business and industrial use are affecting existing water resources and are creating sustainability and supply problems in some areas.

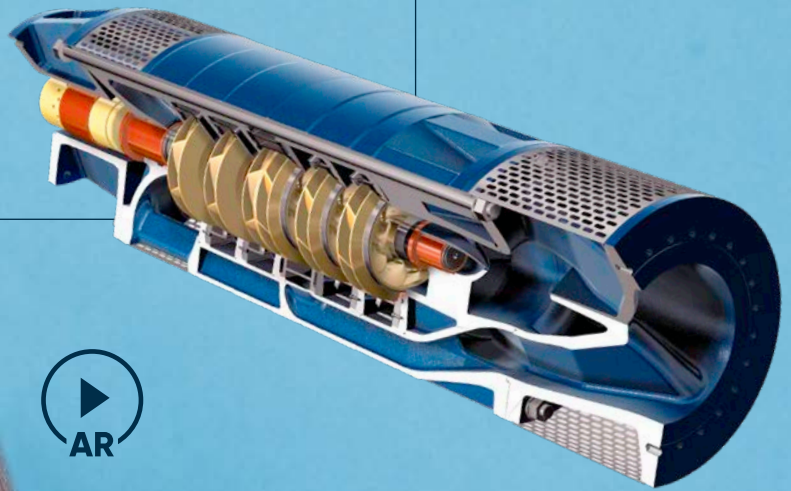
In order to mitigate these issues and address the associated requirement for reliable and sustainable water management in Europe, it is necessary to equip and retrofit existing systems with appropriately efficient technology.

As one of the world's leading technology companies, ANDRITZ not only looks back on more than a century of expertise in the manufacturing and supply of electro-mechanical equipment for hydropower plants. The company wields decades' of experience in the construction and supply of project- and customer-specific large engineered pumps. Starting in the 1960s, ANDRITZ put various pump stations for irrigation and drinking water supply into service across the Middle East and Africa, for example.

Today, we offer a broad product portfolio, which, in addition to vertical line shaft pumps and double-suction and multi-stage split case pumps, also includes vertical and concrete volute pumps, as well as submersible motor pumps. With a multitude of pump project references covering irrigation, large pumps for drinking and industrial water supply, flood protection for cities, dewatering mines, desalination, cooling thermal power plants, and large infrastructure projects, there is ample proof of ANDRITZ's technical expertise.

As part of a suite of sophisticated condition monitoring solutions, special pump sensors provide constant operating and condition data, which is accessible to customers from the ANDRITZ Metris system. This not only delivers a 24/7 service for the customer, but also continuous optimization of the entire plant.

**ANDRITZ HYDRO PROVIDES PUMPS** that meet the demand for ever larger, higher-performance units, whether for low flow rates or wear-resistant applications. Depending on the application case, ANDRITZ Hydro develops, produces, tests, and supplies both standard pumps and custom-tailored large pumps. ANDRITZ engineered pumps operate worldwide in large infrastructure projects for irrigation, drainage, desalination, flood control and for drinking and industrial water supplies.



#### **TOBOLSK, RUSSIA**

At 2 million t/year, ZapSibNeftekhim, located near the Siberian city of Tobolsk, is the largest polymer production plant in Russia. ANDRITZ provided the large pumps for cooling water supply. Seven high-tech vertical line shaft pumps in total were developed and manufactured according to customer- and project-specific requirements. Each 2.7 MW pump demonstrates an efficiency of up to 90% and transports 9,216 m<sup>3</sup>/h of water. The pumps were delivered to Tobolsk in December 2017. The completion of the plant is due at the end of 2019.

#### **RAG WALSUM, GERMANY**

After closure of the last remaining coalmines in the Ruhr Pot, the necessity for intense maintenance and water management has resulted in a plan to transform the former hard coal mining locations into drinking water wells. For this project, ANDRITZ manufactured and delivered three double-suction, submersible motor pumps of 13 tons a piece. With a speed of 1,470 rpm, they achieve an efficiency of 81% and convey 530 m<sup>3</sup>/h water from a depth of more than 800 m. These pumps can fully compensate for axial thrust loads of up to 30 tons and have 50% less flow speed. Every pump with ANDRITZ heavy-duty mining (HDM) technology is specifically customized, has maximum operating reliability, minimum wear, and an extremely long lifetime of more than 20 years.





# UNITED KINGDOM

## ON THE ROAD TO RENEWABLES

The United Kingdom of Great Britain and Northern Ireland is a leading international power with the world's fifth-largest economy by nominal GDP and Europe's second largest economy. One of the world's first industrialized countries, nowadays the capital London is one of the three most important financial centers of the world. Currently, negotiations over the UK's exit from the European Union are ongoing.

The UK's total installed energy generation capacity is about 106 GW, mainly dominated by combined cycle gas and coal-fired thermal power. Renewable energy sources account for about 29.3% producing some 99,330 GWh per year of electricity. With most ideal natural conditions, wind is the largest contributor to renewable energy production

with around 50 TWh annually. The government is set to increase the share of renewables further to meet international climate goals and has, for instance, been setting out various incentives to develop additional small hydropower in the UK.

Llys Y Fran, Wales



The UK is one of the world's leaders in marine energy and wave power research and development. Estimates assume a combined feasible potential of around 20% of the UK's current electricity needs, which corresponds to around 30–50 GW. There are numerous initiatives and feasibility studies supporting the deployment of this technology. Tidal lagoons could play an important role as part of the UK energy mix and renewable achievement, but discussions are on-going for this type of development.

### ANDRITZ HYDRO IN THE UK

The first orders delivered to the UK date back to the beginning of the 1900s. Since then ANDRITZ has been involved in most of the large- and medium-sized hydropower stations in the UK. Major projects such as Dinorwig, Ffestiniog, Foyers, Glendoe, Lochaber, Cruachan, Kilmorack and Aigas feature in the ANDRITZ reference list. Service and rehabilitation as well as small hydro development are key focus areas in support of the country's ambitions for the development of clean and sustainable energy.



In 2010, ANDRITZ incorporated one of the market leaders in tidal current technology to enhance their marine energy activities. Now operating as ANDRITZ Hydro Hammerfest UK, we have driven forward the development of this technology and have successfully deployed not only the first test turbines, but also machines for the largest commercial tidal array worldwide to date.

### MEYGEN, SCOTLAND

ANDRITZ supplied three tidal stream turbines to this project, the largest commercial tidal energy project worldwide to date. Following successful grid synchronization, energy production has exceeded expectations. The anticipated average generation of each turbine is some 4.1 GWh per year. Realization of this project is an important step towards the production of renewable energy from ocean resources and a major contribution to future power generation.

### CIA AIG, SCOTLAND

The run-of-river power plant of Cia Aig was built with an intake weir and a 3.2 km-long buried pipeline. ANDRITZ' scope of supply comprised two vertical five-nozzle Pelton turbines, generators, hydraulic pressure units, and main inlet valves, as well as electrical equipment. In March and August 2016, respectively, the first and second units went into operation after two years of construction. They have been contributing sustainable energy to the national grid ever since.

### LLYS Y FRAN, WALES

With order execution successfully finalized in the record time of less than eight months, Llys Y Fran was completed by the end of 2017. The ANDRITZ scope of supply comprised one horizontal Mini Compact Francis turbine, one



MeyGen Tidal Turbines before deployment, Scotland

hydraulic power unit, one synchronous generator and one inlet butterfly valve. The turbine was integrated into the local drinking water supply system in Pembrokeshire and is now operated using the raw untreated water from the supply reservoir, which also carries the name Llys Y Fran.

#### GENERAL FACTS

Population: **66 Mio.**  
 Access to electricity: **100%**  
 Installed hydro capacity: **4,775 MW**  
 Share of generation from hydropower: **1.6%**  
 Hydro generation per year: **5,928 GWh**  
 Technically feasible hydro generation potential: **5,311 GWh**

#### ANDRITZ HYDRO IN THE COUNTRY

Installed and/or rehabilitated capacity: **4,449 MW**  
 Installed and/or rehabilitated units: **141**  
 Locations: **Glasgow**

TO KNOW

Dinorwig Pumped Storage Plant, Wales





## Installed Hydropower Capacity

(all countries in alphabetical order)

<b>Albania</b>	2,048 MW
<b>Austria</b>	14,130 MW*
<b>Belarus</b>	96 MW
<b>Belgium</b>	109 MW
<b>Bosnia &amp; Herzegovina</b>	2,196 MW
<b>Bulgaria</b>	3,204 MW*
<b>Croatia</b>	2,117 MW
<b>Czech Republic</b>	1,093 MW
<b>Denmark</b>	9 MW
<b>Estonia</b>	4 MW
<b>Faroe Islands</b>	39,7 MW
<b>Finland</b>	3,241 MW
<b>France</b>	25,517 MW*
<b>Georgia</b>	3,164 MW
<b>Germany</b>	14,782 MW
<b>Greece</b>	3,152 MW
<b>Greenland</b>	91,3 MW
<b>Hungary</b>	61 MW
<b>Iceland</b>	1,984 MW
<b>Ireland</b>	534 MW*
<b>Italy</b>	22,838 MW*
<b>Kazakhstan</b>	2,456 MW
<b>Latvia</b>	1,564 MW
<b>Lithuania</b>	1,028 MW*
<b>Luxembourg</b>	34 MW
<b>Moldova</b>	64 MW
<b>Montenegro</b>	679 MW
<b>Netherlands</b>	38 MW
<b>North Macedonia</b>	676 MW
<b>Norway</b>	31,837 MW
<b>Poland</b>	2,328 MW*
<b>Portugal</b>	7,193 MW*
<b>Romania</b>	6,761 MW
<b>Russia</b>	50,955 MW
<b>Serbia</b>	2,398 MW
<b>Slovakia</b>	2,537 MW
<b>Slovenia</b>	1,329 MW*
<b>Spain</b>	20,360 MW*
<b>Sweden</b>	16,301 MW
<b>Switzerland</b>	15,295 MW*
<b>Turkey</b>	27,273 MW*
<b>Ukraine</b>	6,229 MW*
<b>United Kingdom</b>	4,775 MW*

\*figure includes pumped storage or all capacity of mixed pumped storage plants  
Source: IHA, Hydropower & Dams World Atlas 2018

**278 GW**

Total installed hydro-  
power capacity  
in Europe

incl.

**53 GW**

Pumped stor-  
age capacity  
installed in  
Europe



**770 TWh**

Hydro generation  
per year

renewable  
and sustainable  
energy for



**915 mio.  
people**



**190 GW**

Total capacity  
installed and/or  
rehabilitated  
by ANDRITZ

**12,500 units**

Installed and/  
or rehabilitated by  
ANDRITZ

## Hydropower in Europe

Today, hydropower is the best-proven and most-developed form of electricity generation in Europe. Across the continent some 278 GW of installed hydropower capacity stands ready to supply energy to Europe's more than 900 million people, its towns and industries.

Europe's generally well-developed potential for hydropower schemes suggests limited scope for the introduction of new projects. There are exceptions however. In some regions, for economic or other reasons, new pumped storage and small hydro projects are witnessing sustained growth. Nonetheless, right across Europe the bulk of hydropower industry activity is focused on rehabilitation and uprating of the existing fleet. Changing operational requirements, more stringent environmental standards, and the need for prolonged operational life times for a still better return-on-investment are key points of emphasis today.

Hydropower will continue to be the solid backbone of renewable energy development in Europe – key to the clean energy transition. Flexible, cost-effective, and secure, hydropower is uniquely able to sustainably stabilize the grid and balance variable renewable energy sources like wind and solar. Modern hydropower is building a bridge from the conservative, fossil-driven energy system of the old world and on, to the new carbon-free, zero-emission world of the future – from old to new.



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