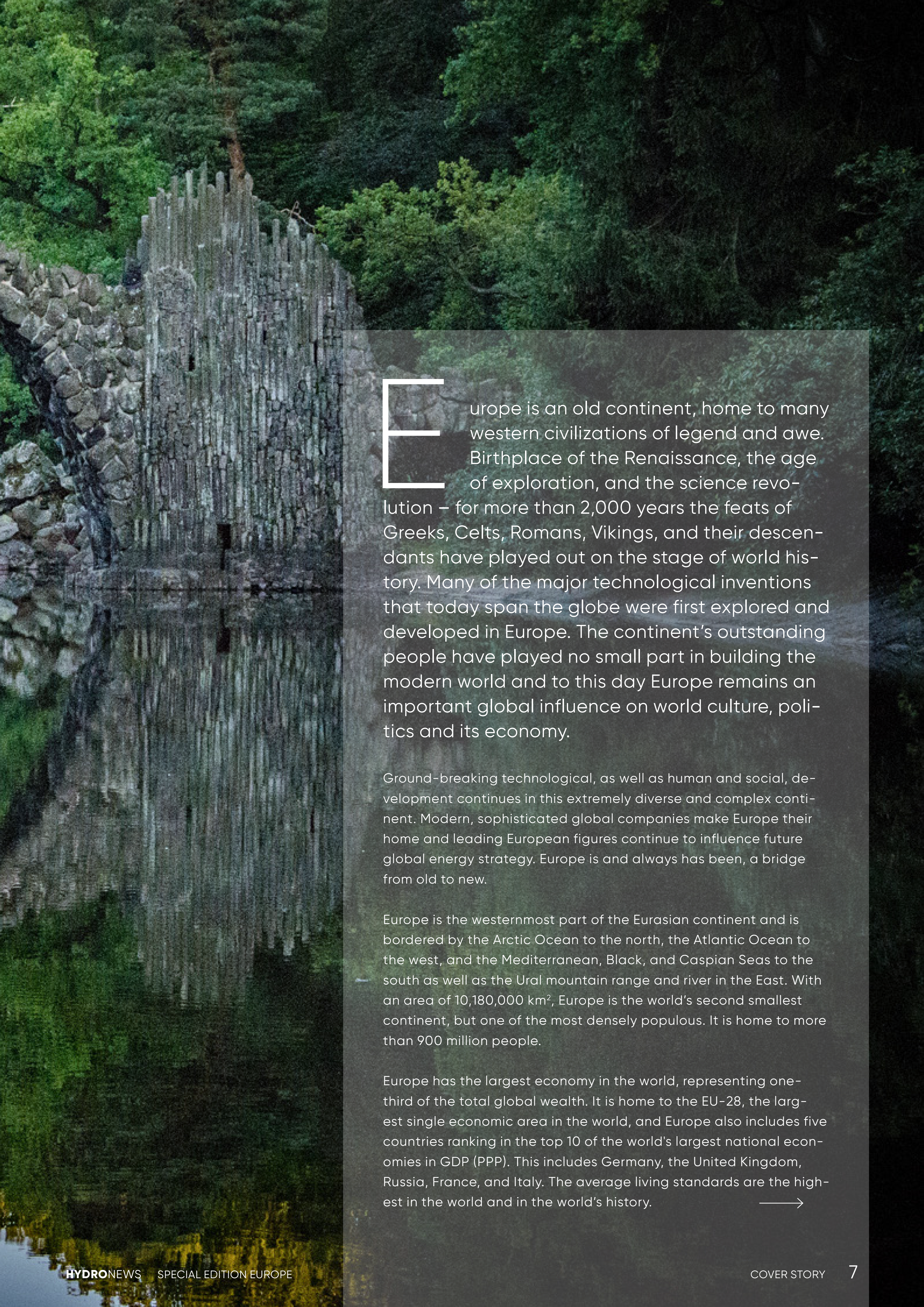
A NEW OLD CONTINENT EUROPE

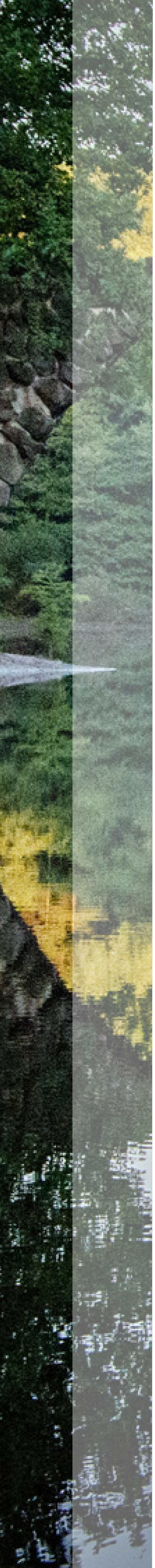


Europe is an old continent, home to many western civilizations of legend and awe. Birthplace of the Renaissance, the age of exploration, and the science revolution – for more than 2,000 years the feats of Greeks, Celts, Romans, Vikings, and their descendants have played out on the stage of world history. 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.

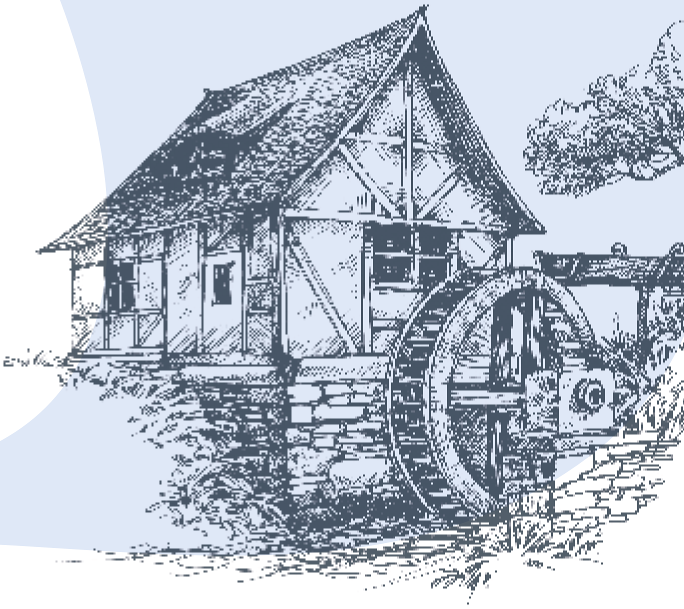
Ground-breaking technological, as well as human and social, development continues in this extremely diverse and complex continent. Modern, sophisticated global companies make Europe their home and leading European figures continue to influence future global energy strategy. Europe is and always has been,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

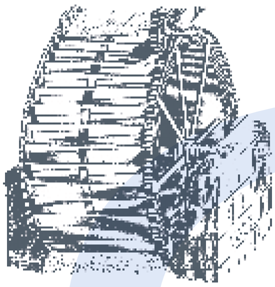
Europe is the westernmost part of the Eurasian continent and is bordered by the Arctic Ocean to the north, the Atlantic Ocean to the west, and the Mediterranean, Black, and Caspian Seas to the south as well as the Ural mountain range and river in the East. With an area of 10,180,000 km^2, Europe is the 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. →

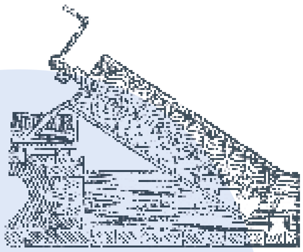


Europe – the cradle of hydropower

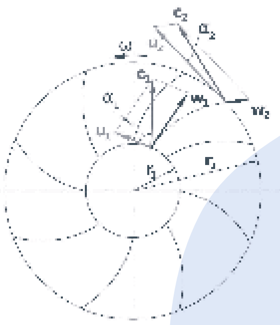




Using the flow and fall of water to facilitate labor is as old as civilization. The first documented **water wheels** date back more than **2,500 years** and water has been used for agriculture, irrigation, and grist-, saw- and textile mills since ancient times. The ability to take advantage of water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



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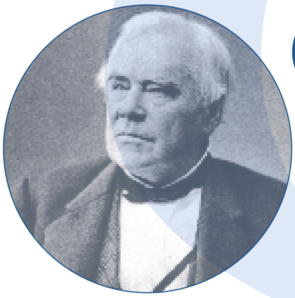
It was during the course of the science revolution in the **17th and 18th Centuries** that the evolution from the water wheel to the turbine took place. European academics set the course. German doctor and physicist **Johann Andreas von Segner** invented the **Segner water wheel,** a kind of reaction turbine. Ancestor to the modern turbine, the Segner wheel is still used for sprinkler systems today. Swiss mathematician and physicist **Leonhard Euler** come 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-19th 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.



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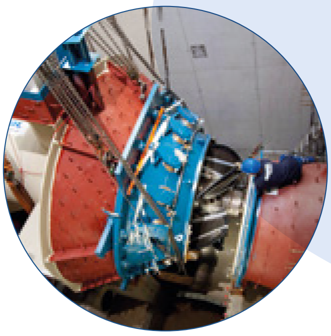
One of the founding fathers of the ANDRITZ Hydro family tree was not European but the American engineer **Lester Pelton.** Nonetheless, since their first construction in **1879 Pelton turbines** have been continuously developed in European laboratories ever since – first and foremost at ANDRITZ Hydro. 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.

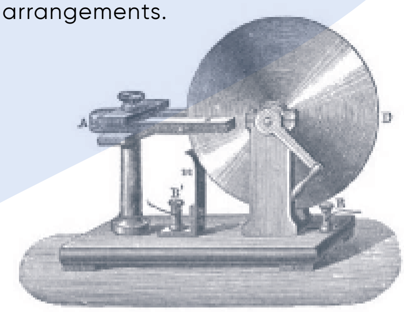
In the late **1840s, Ferdinand Redtenbacher** and **Julius Weisbach** both wrote essential books about scientific mechanical engineering and formulated mathematical turbine theories. Their work enabled the precise calculation of **energy conversion** and output when water strikes turbine blades – a crucial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

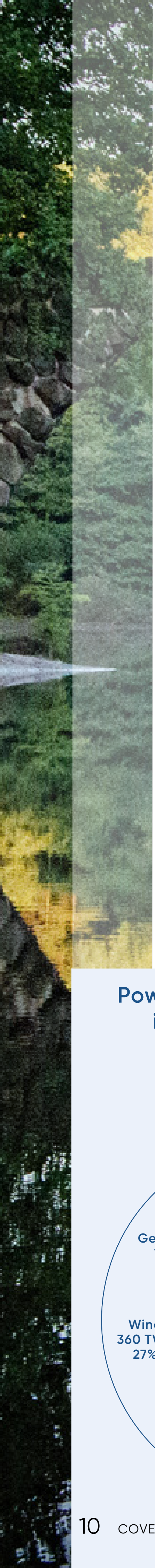
One of the most important milestones in hydropower history was the invention of **the first electric generator** by **Michael Faraday** in **1831.** This made it possible to generate electricity from hydropower. In **1837,** German technician **Carl Anton Henschel** built his axial high-pressure turbine, 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 20th 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.

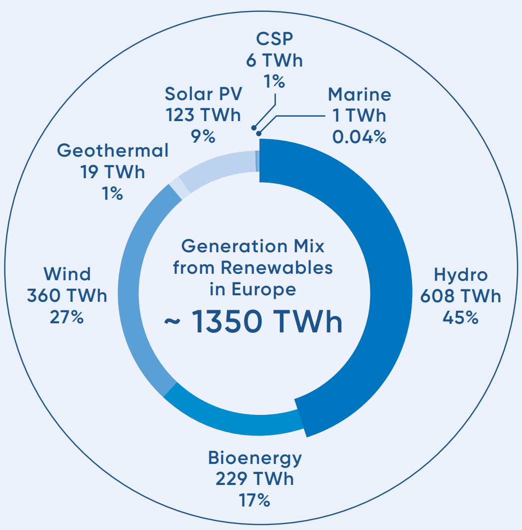
Despite unfavorable weather conditions with drought and low rainfall, hydropower generated more than 770 TWh (incl. Georgia, Kazakhstan, Russia, and Turkey) of clean electricity in 2017. While wind, solar and other renewable energy sources are increasing throughout Europe, these intermittent energy systems 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.

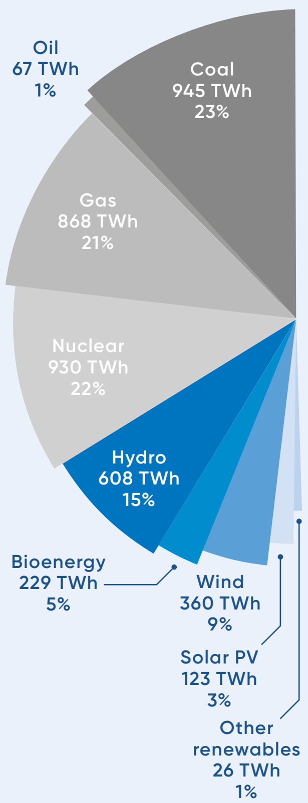
With resource efficiency, flexibility, competitive costs, and low-carbon electricity for both peak and base loads, hydropower remains more than fit to meet the future challenges of the energy transition.

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."

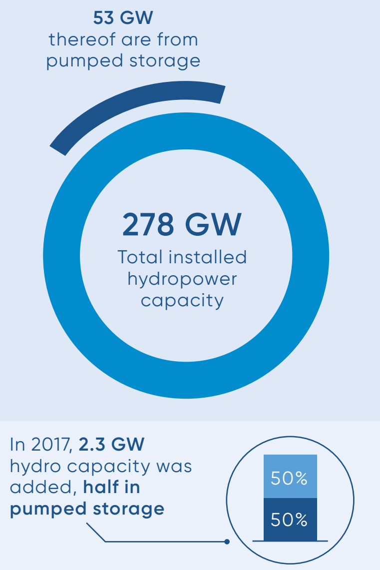
Power Generation Mix in Europe (TWh)





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

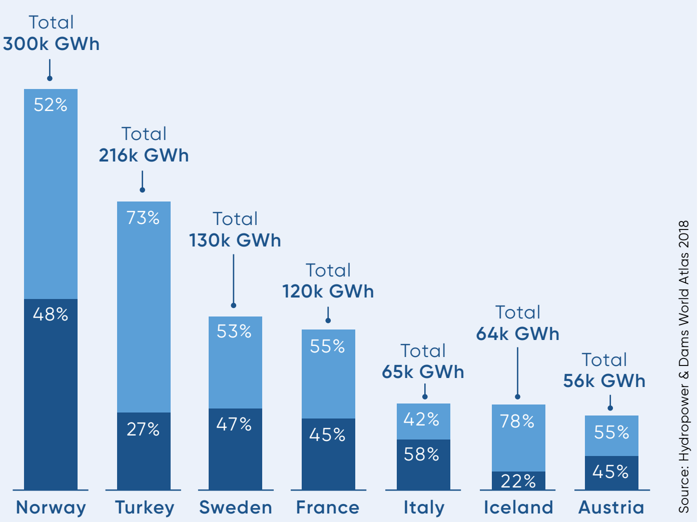


Source: Hydropower & Dams World Atlas 2018 especially true in Europe, where in many places geological and topographical conditions are ideal. Today, the commercial aspects of harnessing the power of the oceans are not satisfactorily advanced and thus require more political support. Nonetheless, the scale 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

Unexploited versus developed hydropower potential



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 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. →

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.

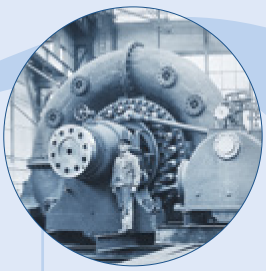
ANDRITZ Hydro, part of the ANDRITZ GROUP, is one of those pioneers of hydropower and can justifiably and proudly boast of a continuous line of advancement, expertise and competence spanning over three centuries. Prominent names such as Escher Wyss, Sulzer, Elin, Bouvier, Ateliers de Charmilles, Atelier 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 adaptions. 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



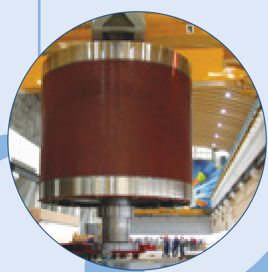
NIEDERWARTHA Germany, the **first pumped storage plant in the world** in **1929**

1950

Jochenstein on the German-Austrian border the **first run-of-river plant on the Danube** in **1955–56**

Edolo Italy, **one of the world’s first multi-stage pumped turbine units** (130 MW) in **1979**

Goldisthal Germany, the **first asynchronous variable speed pumped storage unit** (330 MVA) outside Japan in **1997**



2000

Lower Olt Romania, **the largest low-head Bulb-type pumped generating units** (14.5 MVA) in the world in **2004**

Tsankov Kamak Bulgaria (80 MW), commissioning of the **first joint implementation project under the Kyoto protocol** in **2004**

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."

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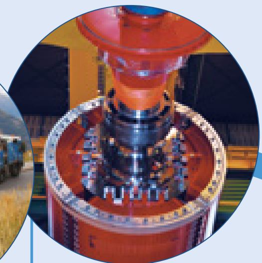
Ashta I (24 MW) and **II** (45 MW), Albania, 90 modules for the **world's largest Hydromatrix power plant** were put into operation in **2008**

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**

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



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

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

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

2019