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A Feel **for the Flow**

When Albert Sepp shared his idea ten years ago, most people were skeptical: A hydroelectric power plant you can't see because the turbine and generator are hidden in a riverbed shaft? That allows fish to pass safely and freely downstream? Fortunately, Sepp's boss Peter Rutschmann wasn't one of them. "Let's try it," he said and now the idea is becoming reality – on the river Loisach in Bavaria.

Daniela Becker

Herrn Sepps Gespür für Strömung

In der Loisach, nahe der Gemeinde Großweil in Bayern, entsteht das weltweit erste Schachtkraftwerk. Bei diesem ökologischen Wasserkraftwerk befinden sich Turbine und Generator in einem Schacht, der vor einem Wehr im Flussbett eingebaut ist. Auf diese Weise sind nur minimale Eingriffe in die Landschaft erforderlich. Durch die Führung der Strömung über dem Schacht sind Fische in hohem Maße vor Verletzungen geschützt und können über ein „Abstiegsfenster" – eine Aussparung im Wehr – flussabwärts wandern.

Erdacht wurde das Schachtkraftwerk von Dipl.-Ing. Albert Sepp und Prof. Peter Rutschmann vom Lehrstuhl für Wasserbau und Wasserwirtschaft der TUM. Über viele Jahre verfeinerten die Ingenieure gemeinsam mit ihrem Team die Technologie. Die TUM hält daran inzwischen zahlreiche Patente in verschiedenen europäischen Ländern sowie in den USA, in Kanada und Brasilien. „Wir haben etwas Neues entwickelt, das der gesellschaftlichen Forderung nach mehr Naturschutz Rechnung trägt", sagt Rutschmann.

Das einfach zu konstruierende und kompakte Kraftwerk mit geringem Bauvolumen ist für kleine und große Wasserkraftstandorte gleichermaßen geeignet. An größeren Wehren können mehrere Schächte nebeneinander angeordnet werden. „Wir können die Turbine und den Generator aber auch in einem Container vorinstallieren und solch ein Minikraftwerk in Gegenden fernab vom Stromnetz transportieren", sagt Rutschmann.

Wenn das erste Schachtkraftwerk im Frühjahr 2019 in der Loisach in Betrieb geht, sind Sepp und Rutschmann ihrem Ziel einen großen Schritt näher: Die klimafreundliche Wasserkraftnutzung naturschonender zu gestalten. □

Graphics: ediundsepp

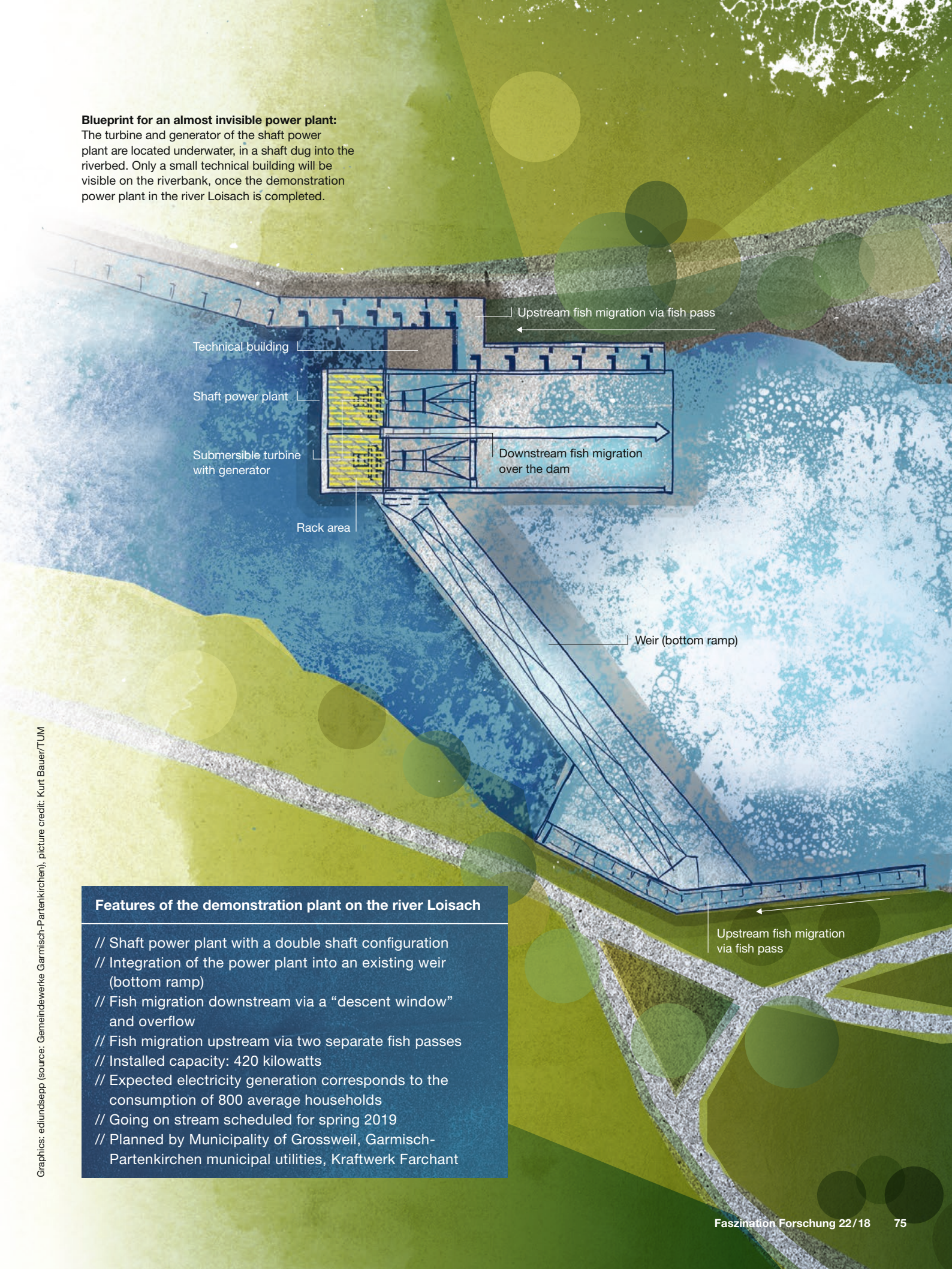
The first shaft power plant is to be built on the Bavarian river Loisach, using an existing weir.

It's a spring morning and the air is chilly. The peaks of the Bavarian Alps towering in the background are still covered in snow. Albert Sepp and Prof. Peter Rutschmann stand on the banks of the Loisach river near the Bavarian village of Grossweil and survey the construction site.

They are looking at a pit the size of a classroom in the riverbed. Since the 1970s, this has been the location of a bottom ramp – layers of stones and boulders between a series of sheet pilings. The ramp maintains the groundwater level and protects the Loisach's riverbed. And now, this is where the municipality of Grossweil – together with the Garmisch-Partenkirchen municipal utilities and a local power plant operator – is busy constructing the hydropower plant Sepp and Rutschmann have spent so many years researching. Implemented here for the very first time, the power plant is concealed in a shaft in the riverbed. The aim is to generate climate-friendly electricity with as little impact as possible on fish and their habitat. The so-called "shaft power plant" is scheduled to go on stream in spring 2019. ▷

Engineers Albert Sepp (right) and Prof. Peter Rutschmann have developed the so-called "shaft power plant". Construction of the demonstration plant at Grossweil could be an important step toward widespread use of this new hydroelectric power concept.

Blueprint for an almost invisible power plant:
The turbine and generator of the shaft power plant are located underwater, in a shaft dug into the riverbed. Only a small technical building will be visible on the riverbank, once the demonstration power plant in the river Loisach is completed.



Graphics: ediundsepp (source: Gemeindewerke Garmisch-Partenkirchen), picture credit: Kurt Bauer/TUM

Features of the demonstration plant on the river Loisach

// Shaft power plant with a double shaft configuration
// Integration of the power plant into an existing weir (bottom ramp)
// Fish migration downstream via a “descent window” and overflow
// Fish migration upstream via two separate fish passes
// Installed capacity: 420 kilowatts
// Expected electricity generation corresponds to the consumption of 800 average households
// Going on stream scheduled for spring 2019
// Planned by Municipality of Grossweil, Garmisch-Partenkirchen municipal utilities, Kraftwerk Farchant

“I think it’s important not to get ahead of ourselves. But when an idea finally takes shape, it certainly does feel good.” *Albert Sepp*

Eco-friendly hydropower

Albert Sepp has spent his entire career working with water. The civil engineer conducts his research at TUM’s Laboratory of Hydraulic and Water Resources Engineering, led by Rutschmann. Sepp, who lives in a passive energy house and drives an electric car, is on a mission to make hydroelectric power more eco-friendly.

In conventional hydropower plants, water from a dammed river is channeled either directly or via a conduit to a power house, where it flows through the turbines and is then fed back into the river. This is problematic for river wildlife because their natural migration routes are disrupted by the dam and power station structures. Although technical solutions to enable the downstream migration of fish are legally required, their effectiveness is often debatable. If fish swim into the turbine, there is also a risk that they will be injured or killed.

Sepp has investigated many power plant concepts over the years. “I just wasn’t satisfied with the status quo,” he explains. The engineer set about doing some calculations and building physical flow models. In 2008, he put his idea down on paper for the first time: His aim was to dig a shaft – complete with turbine and generator – into the riverbed, removing the need for outlet flow and backflow altogether. This, Sepp believed, would improve flow dynamics while reducing the impact on fish migration and the river ecosystem as far as possible. And so the idea of the shaft power plant was born.

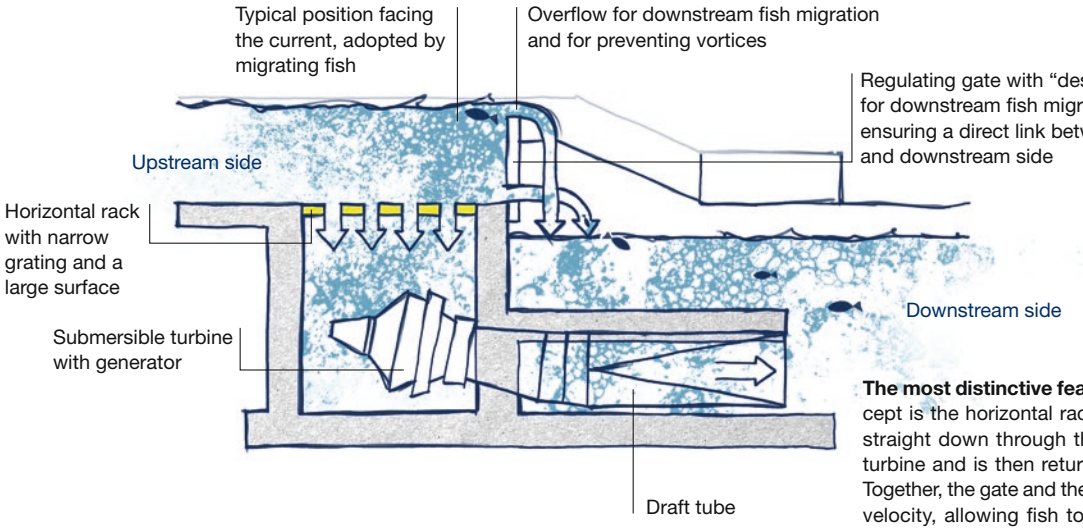
Protecting the river habitat

The standout feature of the shaft power plant is its rack configuration. This metal grate prevents debris such as stones, branches and leaves from getting into the turbine. In Sepp’s concept, it is positioned horizontally across the shaft in the riverbed. The water for the power plant pours straight down through the rack into the shaft, drives the turbine and is then returned to the riverbed downstream. Water also flows over the dam through an adjustable gate above the shaft. This regulating gate can also be opened to divert floating debris and floodwater.

The distances between the bars of the rack are small, but the overall rack area is large, ensuring low flow speeds over the shaft. Together with the overflow, this prevents larger vortices from forming on the water’s surface. In this way, fish can move freely over the shaft and migrate downstream. “My hope was that the fish would swim with the horizontal current to special openings – descent windows – in the regulating gate, rather than following the downward shaft current,” Sepp explains.

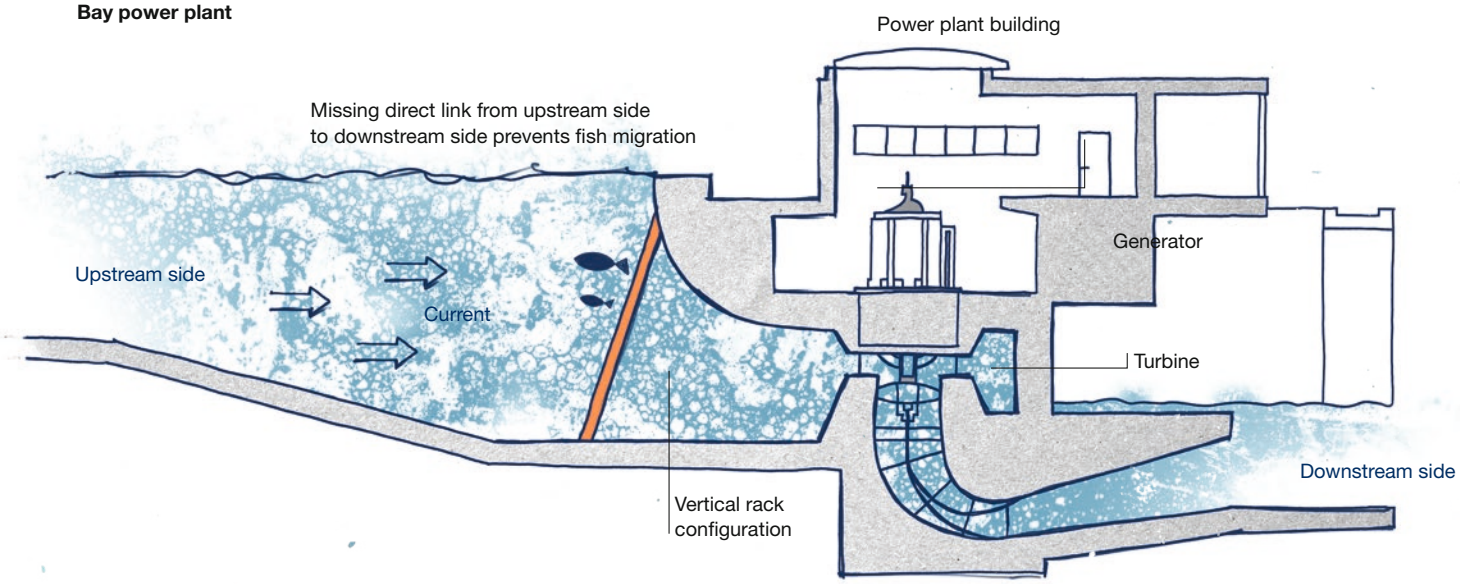
This idea of his caused quite a stir in certain professional circles. Many people in the hydropower industry found it difficult to believe that the horizontal rack idea would actually work, while others were skeptical about the new design because the turbine in a shaft power plant is not accessible around the clock. “But this is not in fact necessary, since the technology used is particularly low-maintenance and stable,” outlines Peter Rutschmann, Chair of Hydraulic and Water Resources Engineering at TUM. ▷

Shaft power plant



The most distinctive feature of the shaft power plant concept is the horizontal rack configuration: The water pours straight down through the rack into the shaft, drives the turbine and is then returned to the riverbed downstream. Together, the gate and the rack ensure a low, controlled flow velocity, allowing fish to swim safely and freely over the shaft and pass downstream.

Bay power plant



In conventional bay power plants, the rack has a vertical position, "barring" the way for fish to pass downstream. At the rack, migrating fish continuously fight against being entrapped. Once exhausted, they are at high risk of passing through the turbine and being injured.

Benefits of the shaft power plant concept in comparison with conventional bay power plants

// Only a small technical building above ground required; plant itself completely underwater, avoiding noise emissions and alterations to the landscape
// Effective technology for fish descent
// Flow continuity for bed load and floating debris
// Flood safety
// Can be retrofitted at existing weirs
// Improved river continuity
// Reduced construction work; prefabrication possible

Graphics: ediundsepp (source: Albert Sepp/TUM)

Dipl.-Ing. Albert Sepp

Harmonizing power production with environmental protection

Albert Sepp is a graduate engineer FH from the Munich University of Applied Sciences. He has been part of the team at TUM's Laboratory of Hydraulic and Water Resources Engineering in Obernach since 1980, focusing mainly on physical model testing. He also works as a freelance engineer in the fields of hydropower and energy technology.
As the inventor of the eco-friendly shaft power plant, he was a joint recipient of TUM's Heinz Maier-Leibnitz Medal along with Prof. Peter Rutschmann in 2016. This award was presented by University President Prof. Wolfgang A. Herrmann, "in recognition of pioneering engineering achievements in the design, planning and technical implementation of a new type of hydropower that provides an optimum balance between economic and environmental interests."

A feel for the flow

Sepp picked the quiet time between Christmas and New Year in 2008 to divulge his idea, wanting to know if Rutschmann also saw potential in the shaft power plant. "You bet!" thought the professor. "Few people have as intuitive a sense of how water flows as Albert Sepp," he confirms. So, from then on, the inventor had an experienced expert from the scientific community on board, who helped drive the idea even when they encountered resistance. "To me, being an engineer doesn't just mean continually improving an idea from fifty years ago," emphasizes Rutschmann. "More to the point, it means looking at the challenges that society currently faces. We have developed something new to meet the need for more effective nature conservation."
TUM filed two initial patent applications for the shaft power plant concept with the German Patent and Trade Mark Office (DPMA) in 2009, followed by further applications. Today, the university holds patents in numerous European countries as well as the US, Canada and Brazil.

"To me, being an engineer doesn't just mean continually improving an idea from fifty years ago – it means developing something new."

Peter Rutschmann

A promising prototype

In 2010, the two engineers teamed up with doctoral student Franz Geiger to build a physical model of the shaft power plant at TUM's research laboratory in Obernach. They went on to build a first outdoor prototype, which they fed with water from the river Isar to create realistic operating conditions. This enabled them to investigate the behavior of different types and sizes of fish in relation to the shaft power plant.

Numerous experiments confirmed Sepp's original hope: The narrow grating of the rack does indeed act as a barrier. Thanks to the diverted current and low flow velocity, the fish adopt a slanted position and appear to swim effortlessly over the shaft. Larger fish, highly valuable for reproduction, are completely protected. Although smaller fish, less than 15 centimeters in length, fit physically through the narrow grating, only a small proportion of them actually slip through the rake. And the vast majority of these were able to pass through the turbine unharmed in the experiments led by Rutschmann and Sepp. "There is no power plant concept able to guarantee a hundred percent protection," explains Sepp. "But we do expect the shaft power plant to give the fish a very high level of protection," he adds.

Pilot plant in a challenging location

"When we heard about the idea of an environmentally friendly shaft power plant in 2011, it came at just the right time for us," recalls Günther Rösch from the Garmisch-Partenkirchen municipal utilities. At that time, together with the Mayor of Grossweil, Manfred Sporer, and Markus Pöttinger, a local power plant operator, he was looking for a plant concept that would ensure a high level of protection for fish and be suitable for ecologically sensitive sites. After all, the flora and fauna habitat in the section of the Loisach comprising the bottom ramp is protected under the European Union's Habitats Directive. And, like many other weirs or transverse structures in rivers, the ramp must be made more readily passable by fish in accordance with the requirements of the EU Water Framework Directive.

The shaft power plant was just what Grossweil's hydropower plant operators were looking for. They thus submitted a building application for a shaft power plant in the Loisach, which was approved in December 2014. Initially, several nature conservation and fishing associations filed objections to the planned construction but the various stakeholders involved were able to reach an agreement.

Together with other innovative hydropower plants, the Loisach site is part of a Bavarian-wide monitoring program commissioned by the Bavarian State Ministry of the Environment and Consumer Protection (StMUV) and the Bavarian State Office for the Environment (LfU). A team led by Prof. Jürgen Geist from TUM's Chair of Aquatic Systems Biology will be responsible for monitoring the pilot plant's impact on the local fish population and their habitat. ▷

Graphics: edjundsepp, picture credit: Kurt Bauer/TUM

Solutions of all sizes for worldwide deployment

The team has since received numerous inquiries about shaft power plants – both from within Germany and abroad. The engineers are able to adapt the concept to different requirements. In a case study for a power plant in the Mekong River, for instance, Rutschmann outlines how the shaft principle can also be applied to larger dams by constructing several shafts next to one another. Such a multishaft power plant would incorporate a channel between blocks of adjoining shafts, providing a near-natural habitat for fish and allowing them to swim downstream. “There are plans for countless hydropower plants in Asia and Africa, as well as in Southeast Europe,” Rutschmann reports. “These projects should be implemented in an ecologically sustainable way.”

The shaft power plant can also be deployed on a smaller scale. “We could pre-install the turbine and generator in a container and transport this ‘plant-in-a-box’ to remote areas where people have no access to the power grid,” reveals Rutschmann. The World Bank is already showing an interest in this project.

In collaboration with technology consultant Dr. Christian Hackl, Rutschmann and Sepp founded the company HYDROSHAFT GmbH to advise plant operators and investors on the construction of shaft power plants. A licensing agreement gives the company the necessary rights to use TUM’s patents and allows it to pass on the appropriate rights of use to future plant operators.

“We could pre-install the turbine and generator in a container and transport this ‘plant-in-a-box’ to remote areas.”

Peter Rutschmann

Prof. Peter Rutschmann

Devising win-win solutions

Born in Switzerland, Peter Rutschmann pursued his studies and received his doctorate at ETH Zurich, where he worked in applied research for over twenty years. He was then appointed to the University of Innsbruck (Austria) in 2002. Since 2007, he has held the Chair of Hydraulic and Water Resources Engineering at TUM.

Rutschmann’s research focuses on environmentally sustainable hydropower, flood protection, river morphology and ecohydraulics. Since 2016, he has coordinated the European research project Fishfriendly Innovative Technologies for Hydropower (FIThydro). The project brings together 26 partner organizations from 10 different countries. “We aim to create an online tool that can be used to plan and evaluate hydroelectric power plants,” explains Rutschmann. “This will enable us to find solutions that are scientifically sound while factoring in all interests – both economic and environmental,” he continues.

Together with Albert Sepp, Rutschmann was awarded the Heinz Maier-Leibnitz Medal by TUM. Rutschmann has also been commended by the Bavarian State Ministry of the Environment and Consumer Protection (StMUV) for his services to the environment.

Constructing the first shaft power plant

In November 2017, the time had finally come for the project to officially launch. Almost ten years on from the initial idea, Sepp and Rutschmann joined Grossweil's Mayor Manfred Sporer, Günther Rösch from the Garmisch-Partenkirchen municipal utilities, and the then Bavarian State Minister for Economic Affairs, Ilse Aigner, for the official groundbreaking ceremony for the first shaft power plant at Grossweil. The Free State of Bavaria is contributing around 1.9 million euros in prototype funding to the demonstration project that is scheduled to go on stream in spring 2019. It should then generate roughly the amount of electricity that 800 average households consume. Yet Grossweil's citizens will see and hear very little of the power plant hidden in the riverbed. "This is why we are planning a viewing platform so people can look at the shaft," reports Mayor Sporer.

On that spring morning in May 2018, Sepp and Rutschmann look quite content as they gaze into the sunlight. The shaft for their power plant will soon be installed in the construction pit at the bottom of the Loisach river. But Sepp still has his feet firmly on the ground: "Water levels on the Loisach river can rise dramatically, carrying a lot of driftwood. We are demoing our new technology under extreme conditions," he explains. "So I think it's important not to get ahead of ourselves. But when an idea finally takes shape, it certainly does feel good."

Daniela Becker

Peter Rutschmann (left) and Albert Sepp aim at reconciling hydropower and environmental protection. For the purpose of advising plant operators and investors on the construction of shaft power plants, they have founded the venture HYDROSHAFT GmbH.

In spring 2018, there is still only the construction pit of the future shaft power plant to be seen. It is scheduled to go on stream at the beginning of 2019.

Graphics: ediundsepp, picture credit: Kurt Bauer/TUM

Peter Rutschmann (left) and Albert Sepp standing above their first prototype of the shaft power plant, installed at TUM's Laboratory of Hydraulic and Water Resources Engineering in Obernach.

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