# Small is beautiful in hydroelectric power plant design, and good for the environment

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In the shaft power plant design developed at the Oskar von Miller Institute of the Technische Universitaet Muenchen, water drops vertically into a concrete housing dug into the river bed, turns the turbine of a submersible generator, and returns to the river below the dam. This photo shows an experimental model of a shaft power plant -- without the water. Credit: TU Muenchen

Hydroelectric power is the oldest and the "greenest" source of renewable energy. In Germany, the potential would appear to be completely exploited, while large-scale projects in developing countries are eliciting strong criticism due to their major impact on the environment. Researchers at Technische Universitaet Muenchen (TUM) have developed a small-scale hydroelectric power plant that solves a number of problems at the same time: The construction is so simple, and thereby cost-efficient, that the power generation system is capable of operating

profitably in connection with even modest dam heights. Moreover, the system is concealed in a shaft, minimizing the impact on the landscape and waterways. There are thousands of locations in Europe where such power plants would be viable, in addition to regions throughout the world where hydroelectric power remains an untapped resource.

In Germany, hydroelectric power accounts for some three percent of the electricity consumed – a long-standing figure that was not expected to change in any significant way. After all, the good locations for hydroelectric power plants have long since been developed. In a number of newly industrialized nations, huge dams are being discussed that would flood settled landscapes and destroy ecosystems. In many underdeveloped countries, the funds and engineering know-how that would be necessary to bring hydroelectric power on line are not available.

Smaller power stations entail considerable financial input and are also not without negative environmental impact. Until now, the use of hydroelectric power in connection with a relatively low dam height meant that part of the water had to be guided past the dam by way of a so-called bay-type power plant – a design with inherent disadvantages:

- The large size of the plant, which includes concrete construction for the diversion of water and a power house, involves high construction costs and destruction of natural riverside landscapes.

- Each plant is a custom-designed, one-off project. In order to achieve the optimal flow conditions at the power plant, the construction must be planned individually according to the dam height and the surrounding topography. How can an even flow of water to the turbines be achieved? How will the water be guided away from the turbines in its further course?

- Fish-passage facilities need to be provided to help fish bypass the power station. In many instances, their downstream passage does not succeed as the current forces them in the direction of the power plant. Larger fish are pressed against the rakes protecting the intake of the power plant, while smaller fish can be injured by the turbine.

A solution to all of these problems has now been demonstrated, in the small-scale hydroelectric power plant developed as a model by a team headed by Prof. Peter Rutschmann and Dipl.-Ing. Albert Sepp at the Oskar von Miller-Institut, the TUM research institution for hydraulic and water resources engineering. Their approach incurs very little impact on the landscape. Only a small transformer station is visible on the banks of the river. In place of a large power station building on the riverside, a shaft dug into the riverbed in front of the dam conceals most of the power generation system. The water flows into a box-shaped construction, drives the turbine, and is guided back into the river underneath the dam. This solution has become practical due to the fact that several manufacturers have developed generators that are capable of underwater operation – thereby dispensing with the need for a riverbank power house.

TU Muenchen civil engineer Albert Sepp (left) and Professor Peter Rutschmann are co-developers of the shaft power plant design. The power plant, most of

which lies concealed below the riverbed, is designed to let fish pass along with the water. Credit: TU Muenchen, all rights reserved

The TUM researchers still had additional problems to solve: how to prevent undesirable vortex formation where water suddenly flows downward; and how to best protect the fish. Rutschmann and Sepp solved two problems with a single solution – by providing a gate in the dam above the power plant shaft. In this way, enough water flows through to enable fish to pass. At the same time, the flow inhibits vortex formation that would reduce the plant's efficiency and increase wear and tear on the turbine.

The core of the concept is not optimizing efficiency, however, but optimizing cost: Standardized pre-fabricated modules should make it possible to order a "power plant kit" just like ordering from a catalog. "We assume that the costs are between 30 and 50 percent lower by comparison with a bay-type hydropower plant," Peter Rutschmann says. The shaft power plant is capable of operating economically given a low "head" of water of only one to two meters, while a bay-type power plant requires at least twice this head of water. Series production could offer an additional advantage: In the case of wider bodies of water, several shafts could be dug next to each other – also at different points in time, as determined by demand and available financing.

Investors can now consider locations for the utilization of hydropower that had hardly been interesting before. This potential has gained special significance in light of the EU Water Framework Directive. The directive stipulates that fish obstacles are to be removed even in smaller rivers. In Bavaria alone, there are several thousand existing transverse structures, such as weirs, that will have to be converted, many of which also meet the prerequisites for shaft power plants. Construction of

thousands of fish ladders would not only cost billions but would also load the atmosphere with tons of climate-altering greenhouse gas emissions. If in the process shaft power plants with fish gates and additional upstream fish ladders were installed, investors could shoulder the costs and ensure the generation of climate-friendly energy over the long term – providing enough power for smaller communities from small, neighborhood hydroelectric plants.

Shaft power plants could also play a significant role in developing countries. "Major portions of the world's population have no access to electricity at all," Rutschmann notes. "Distributed, local power generation by lower-cost, easy-to-operate, low-maintenance power plants is the only solution. For cases in which turbines are not financially feasible, Rutschmann has already come up with an alternative: "It would be possible to use a cheap submersible pump and run it in reverse – something that also works in our power plant."

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