Rotor

generate your own electricity

Markus Heinsdorff

Short product description

This project realizes the idea of a small swimming hydro power plant providing an easy way to generate electricity.
The designed power station generates power by using the stream current of a river. The objective behind it is to supply people in rural areas without connection to an electricity grid, whether temporarily or permanent. It uses low-cost technology and can be constructed by almost everyone in an easy manner. Used materials are variable and available worldwide. A special focus is put on recycling materials. A prototype was already built and proved feasibility and reliability.

Presentation of the product

Access to flowing water is almost ubiquitously available on the whole globe, independent of region and continent. Up to now hydropower stations – in contrast to PV-cells and wind power plants – are unique, site specific and expensive products. The so called 'rotor' covers this niche and provides electricity at almost every geographic surrounding with a decent cost-performance ratio. Even with low flow velocities energy production is possible. The Do-It-Yourself (DIY) construction kit forms the basis for further development.
At the current state a working prototype was already constructed and has been proved under real life conditions. The prototype followed several mock-up models that were tested in a flume of the Hydromechanics Laboratory of the Technische Universität München.

A central challenge for the future in developing countries will be a extensive supply with electricity. According to UN resources there are 1.4 billion people worldwide who do not have access to electricity; with another one billion more having access only to unreliable electricity networks[1]. Lack of electricity heavily affects the chances to development as it forms the basis of education, telecommunication and basic services. Small island grids are in many cases the only possible way to improve the situation. Special focus need to be put on low-cost solutions.

[1] United Nations energy knowledge network, www.un-energy.org

Personal information

Idea and concept

Markus Heinsdorff is a Munich based installation artist. His work is characterized by his artistic exploration of spaces and nature. During his travels around the world, he continually seeks ways to incorporate the potential and possibilities of nature into his design. Trained as a goldsmith and sculptor in southern Germany, Markus Heinsdorff has become an internationally acclaimed artist who has won several awards for his works that link design, art and architecture, together with technical innovations. His current project ‘wasser-werke’ presents objects, installations and photographs using or involving water.

Technical and scientific development and realization

Andreas Zeiselmair (technical realization, development and optimization of the rotor design) studies Environmental Engineering where he specialized in Renewable Energies and Hydraulics at the Technische Universität München (TUM). He worked as a scientific assistant and tutor at the chair for Hydromechanics and was involved in hydro power projects in Ecuador's rainforest and in Cameroon as well as in ‘wasser-werke’ projects in Germany, Brazil and India. Currently he is finishing his master studies.

Christoph Rapp (supervision, realization – former head of the TUM Hydromechanics-Laboratory) studied Civil Engineering at the Technische Universität München (TUM), Germany, worked as a freelancer on hydraulic engineering projects for a year before he became research associate at the Hydromechanics Department of TUM where he did his PhD. He founded the association for the support of international knowledge exchange (www.ez.bv.tum.de), established the art and science project ‘wasser-werke’ and became head of the Hydromechanics-Laboratory. Currently he is responsible for the conception of hydro power plants at a German energy supplier.

Contact information

Markus Heinsdorff Friedrichstr. 27 80801 München phone +49 89 220397 markus@heinsdorff.de www.heinsdorff.de	Andreas Zeiselmair Schraudolphstr. 26 80799 München phone +49 176 23842341 andreas.zeiselmair@web.de	Christoph Rapp Bothmerstraße 5 80634 München phone +49 151 50750408 ch.rapp@ez.bv.tum.de

Technical description of the product

A vertical axis water wheel is mounted in the center of a circular tube. Induced by the flow of a river the wheel turns like a turbine. The rotational energy is transferred by the axis to a wheel where several conventional bicycle dynamos - in the advanced version a specially designed generator - transform the kinetic energy into electricity (Fig. 1). The rotor is fixed to the embankment, a bridge or something similar by mooring ropes.

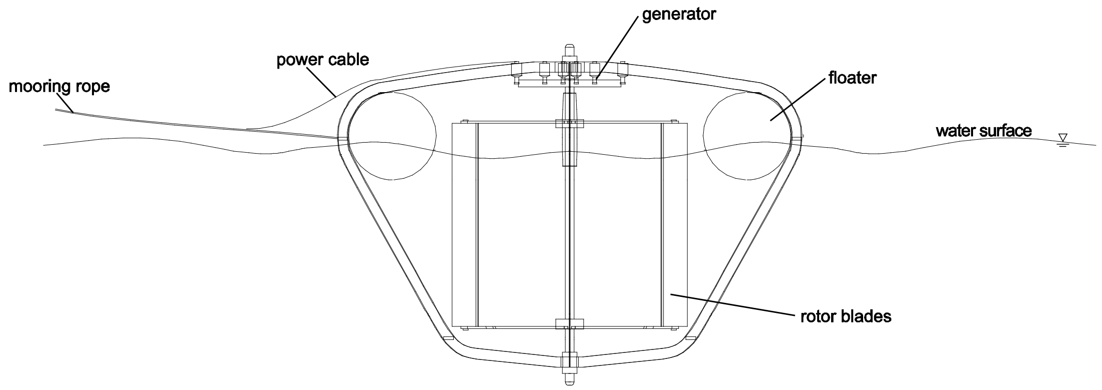


Fig. 1: Working principle of the mini current power plant (sectional view)

The prototype rotor consists of a tractor tire tube, flat bar steel as frame construction, bicycle dynamos and blades made of sheet. All used materials are variable and therefore available worldwide for little money. Further development effort needs to be put on mechanical, electrical and material improvement. A description is shown in Fig. 2.

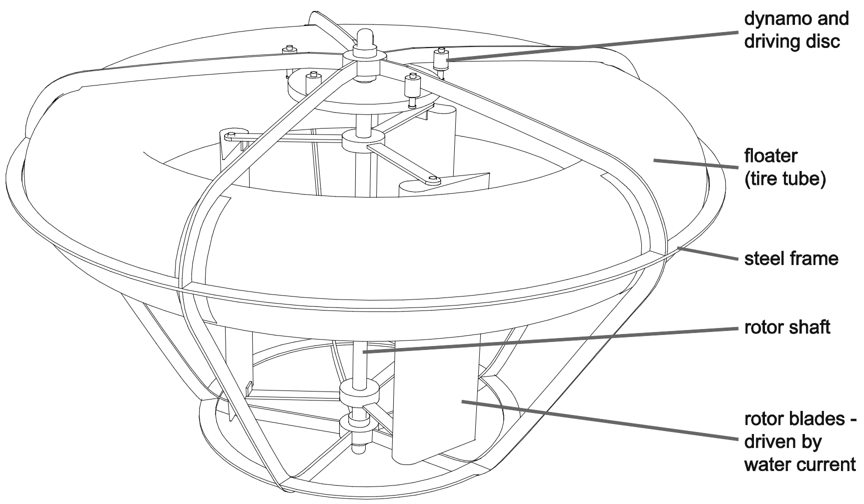


Fig. 2: Description of the prototype rotor parts

A power calculation according to basic fluid dynamics resulted in an approximated output of 150 W for the prototype dimensions at a flow speed of 1.5 m/s. Upscaling to a certain output can be done easily. The basic calculation and functional principle of a Darrieus turbine are described in Fig. 3.

Output power calculation:

$$P_{turbine} = \frac{1}{2} \cdot c_p \cdot A \cdot \rho \cdot v_0^3 \approx 0.125 \cdot A \cdot \rho \cdot v_0^3$$

Flow power:

$$P_{flow} = \frac{1}{2} \cdot A \cdot \rho \cdot v_0^3$$

A: cross-sectional area
ρ: water density (1000 kg/m³)
v_0: flow velocity

Power coefficient:

$$c_p = \frac{P_{turbine}}{P_{flow}} = \frac{P_{turbine}}{\frac{1}{2} \cdot A \cdot \rho \cdot v_0^3}$$

Darrieus water wheel:

$$c_{p,max} = 0.25 \rightarrow 0.40$$

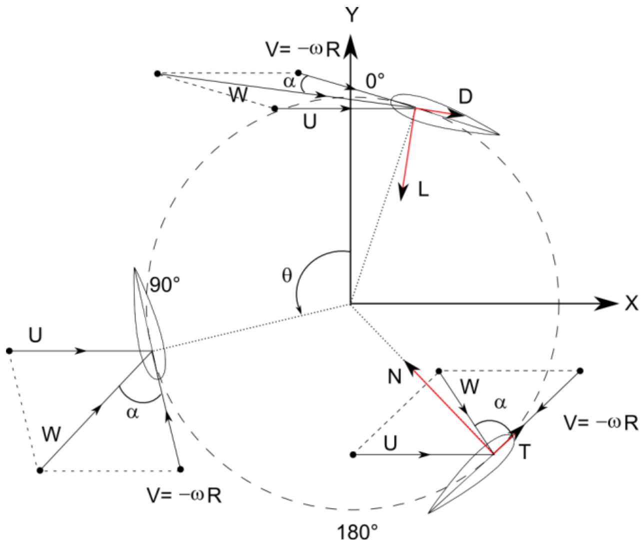


Fig. 3: Power calculation and functional principle of a Darrieus turbine
(picture source: http://en.wikipedia.org/wiki/Vertical_axis_wind_turbine)

As the power output is dependent on the Betz' law defining an ideal power coefficient of

$$c_{P,ideal} = \frac{16}{27} \approx 0.59$$

the maximum overall efficiency is strictly limited. Real mechanical efficiency can reach 0.45 to 0.49 [2]. Nevertheless for the intended use special focus is put on universal application more than on highest efficiency. The following table shows calculation examples for the following boundary conditions:

- Rotor height: 0.6 m
- Rotor width: 0.6 m
- Power coefficient (including mechanical or electrical efficiency)
  c_p: 0.25 (conservatively chosen)
- Water density ρ: 1000 kg/m³

flow velocity v_0 [m/s]	$P_{turbine}$ [W]
0.3	1
0.5	6
0.7	15
1.0	45
1.2	78
1.5	152
1.7	221
2.0	360
2.5	703

[2] German Federal Ministry for the Environment, 'Potentialermittlung für den Ausbau der Wasserkraftnutzung'

Technology issues and advantages of this rotor type contain:

- Intended low-tech solution
- Generator located above water level
- Low rotational speed → does not harm fish
- Technical principle already applied in vertical axis wind turbines
- Proven reliability
- Easy maintenance
- Lift force driven turbine (higher efficiency compared to drag force turbines)
- Simple design
- Little vibrations
- Easy fixation
- 24 - 7 electricity production

The shape of the blade profiles is a standardized NACA airfoil design (Fig. 4). Nevertheless there is still potential for further optimization.

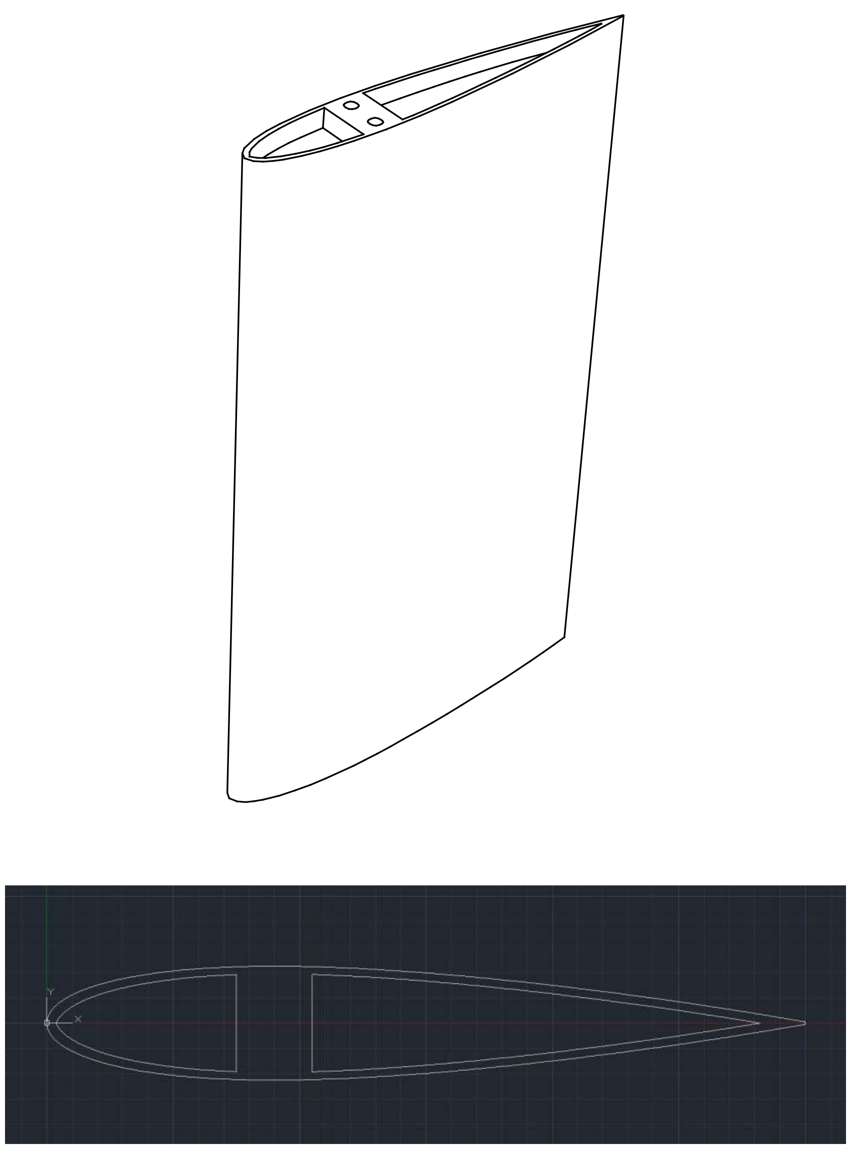


Fig. 4: Rotor blade design and NACA profile

Realization

Two different approaches are planned to reach the realization:

1. **Complete self construction**
   A Do-It-Yourself manual will be provided online and offers a variety of possible materials to be used. This can be all different types of materials with a special focus on sustainable recycling. The information will be accessible on a website that contains detailed instruction manuals. These internationally comprehensive instructions include also DIY video presentations.

➔ Goal is to develop and construct rotors that can supply basic accommodation with light or charge batteries and mobile phones.

2. **Pre-fabricated construction kit**
   The kit includes the most important parts, i.e. tire tube, blade profiles, canvas cover and a specific generator. Its features are advanced and highly reliable parts at low prices that in case can be replaced easily (Fig. 5). The distribution will be organized via the website and are planned to offer opportunities for local businesses in the future.

➔ Goal is to provide a fair and stable power output of approx. 100 W to supply several huts with lights, small cooling devices, a temporary medical centre or for similar purposes.

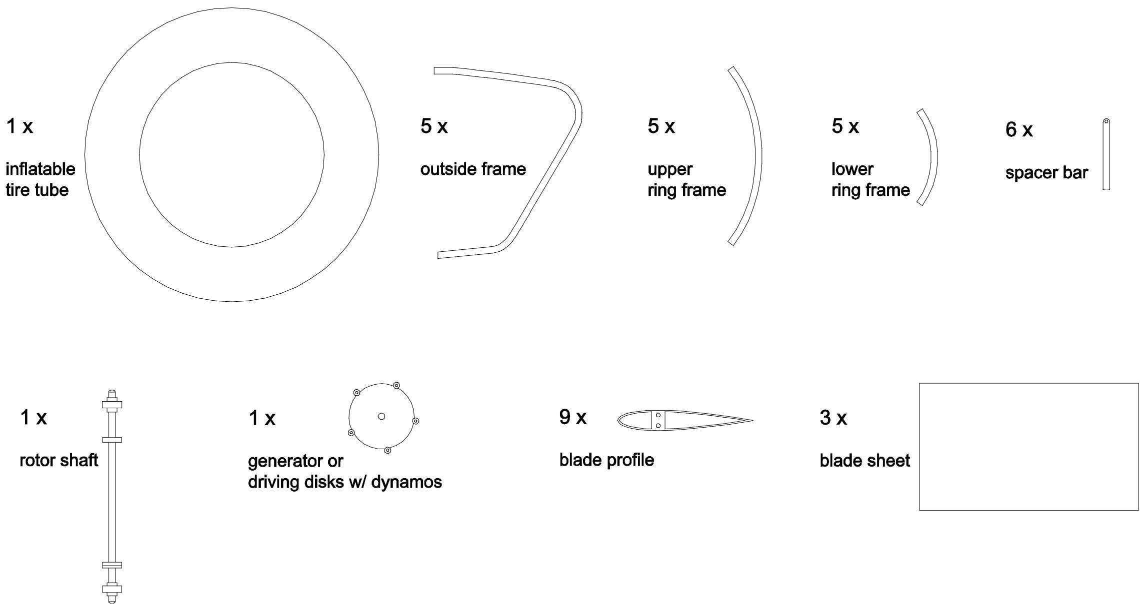
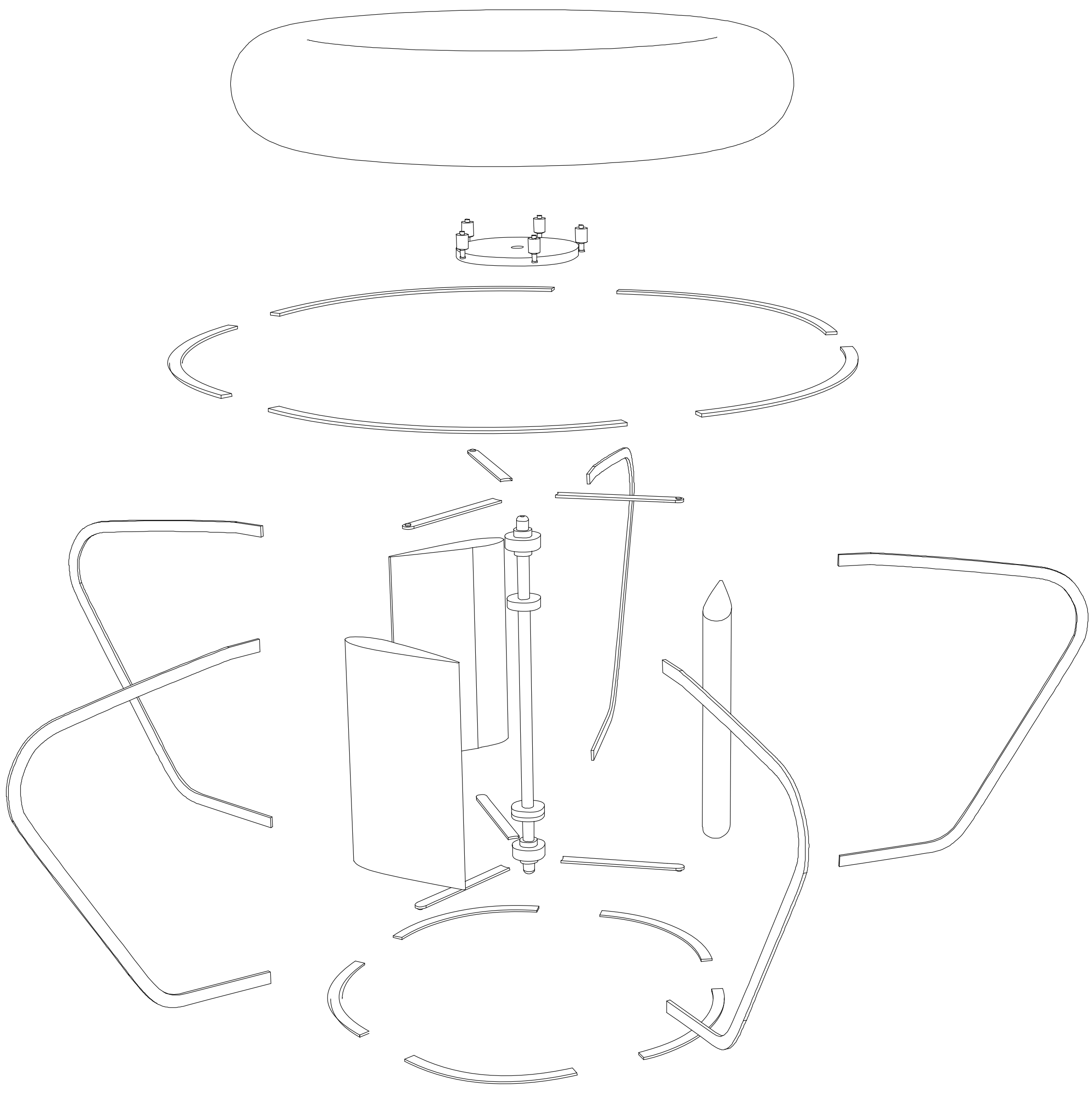
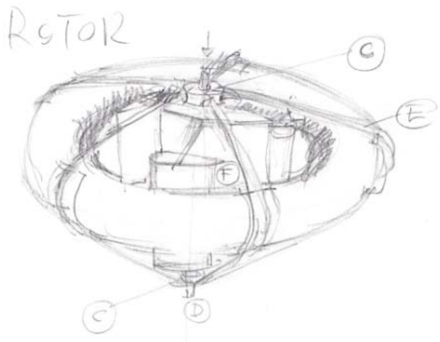


Fig. 5: Content of the construction kit



Development scheme:

1. **Idea**



2. **Development of different types and technical details**

3. **Mock-up – working models**

4. **Flow channel tests**
   Hydromechanics Laboratory (TUM)

5. **Improved real size prototype**

6. **Real-life test (river Loisach)**

   Video online:
   http://vimeo.com/47503158

7. **International presentation**

   During the exhibition series ‘wasser-werke’ the object was shown worldwide at international exhibitions, i.e. São Paulo, Brazil and Pune, India where the rotor gained very positive feedback.

8. **Outlook**

   further improvement and deployment

Evidence of functionality

Idea

- Possibility of installation in isolated remote areas
- Contribution to future development
- Realizable with standard craftsmen skills

Current state

- Technical feasibility proven
- Successful prototype tests
- First international recognition during presentations at worldwide platforms

Advantages

- Low-cost solution
- Flexible application
- Easy construction (“no rocket science”)
- Mobile – temporary usage possible
- Energy available 24-7
- Decentralized deployable
- Renewable energy source
- Ecologically harmless (even according to European Water Framework Directive)
- No river impact, no shoring
- Sustains river continuity

Description of usage in a real project

During several tests at the TUM Hydromechanics Lab different blade shape forms and flow velocities were tested and functionality was proved (Fig. 6).

Fig. 6: Mock-up blade tests at low flow velocities (v ≈ 0.4 m/s)

Next step was to test the prototype. Therefore it was installed at the river Loisach close to Munich, Germany. Fig. 7 shows a photo series of the temporarily fixed rotor at only low flow velocities (approx. 0.8 m/s).

Fig. 7: Test installation in river Loisach near Munich

A visualization of prototype usage including an installation scheme is presented in a video documentation to be found here:

http://vimeo.com/47503158

Description of application scenario and target groups

The rotor can cover a broad range of possible usage settings. It is specially designed to serve at multiple levels and scales and is easily adjusted to locally available resources.
The following application scenarios are conceivable:

1. **Isolated use at rural areas without grid connection**

   In regions without any other opportunities of electricity supply through a working grid local generation is the only possible way to get access to power. The rotor could be one solution. In comparison to small PV cells and wind turbines the presented stream turbine has the advantages of producing energy 24-7 without the need of expensive big battery storage. Furthermore it is specially designed for self construction and can easily be maintained by local mechanics.
   So imagine a small village in the African back country, a little community in the Amazonian rainforest or a hut in the remoteness of the Russian Taiga. In a few steps, with a little bit of constructional work and at minimum cost all of them can be supplied with energy.

2. **Emergency aid, i.e. temporary use in case of natural disasters**

   In case of natural catastrophes the reconstruction of a working energy supply often may take many weeks or even months. Delivered in easy to construct DIY-packages the rotor offers a fast and simple way to provide a basic supply; also in substitution of battery driven devices. Its advantages are obvious:

   > Easy delivery
   > Simple and universal set-up
   > Cost-efficient application

   Especially in developing countries the national grid is often prone to long term blackouts as there are often no sufficient backup facilities. The rotor can serve there as a minimum backup solution.

3. **Mobile use**

   A mobile version of the rotor is designed for easy transportation, set-up and installation. Low weight, small packing size and easy handling make it perfect for frequently changing locations. Possible users would be non-stationary people like shepherds, nomadic people or similar.

Besides the intended application further areas of application can be:

- fixed hydropower plant in rivers and tidal power plants (increased size)
- outdoor, camping use (fast installation – little weight – small packing size)
- boat energy supply during anchoring in rivers

Outstanding tasks

Main important tasks and goals to be achieved are as follows:

- Improvement of design of already available prototype, i.e. further technical development regarding all different possible fields of application
    - > Generator improvement
    - > Optimization of blade design and shape (blade profile shape, Gorlov turbine)
    - > Solution for single-embankment fixation, i.e. tailplane construction
    - > Efficiency increase
    - > Weight reduction
    - > Cost reduction

- Development of a Do-It-Yourself toolkit

- First small series and deployment of flagship and showcase projects worldwide

- Reduction of manufacturing effort

- Set-up of local production workshops and facilities

- Online presentation incl. website and video documentation