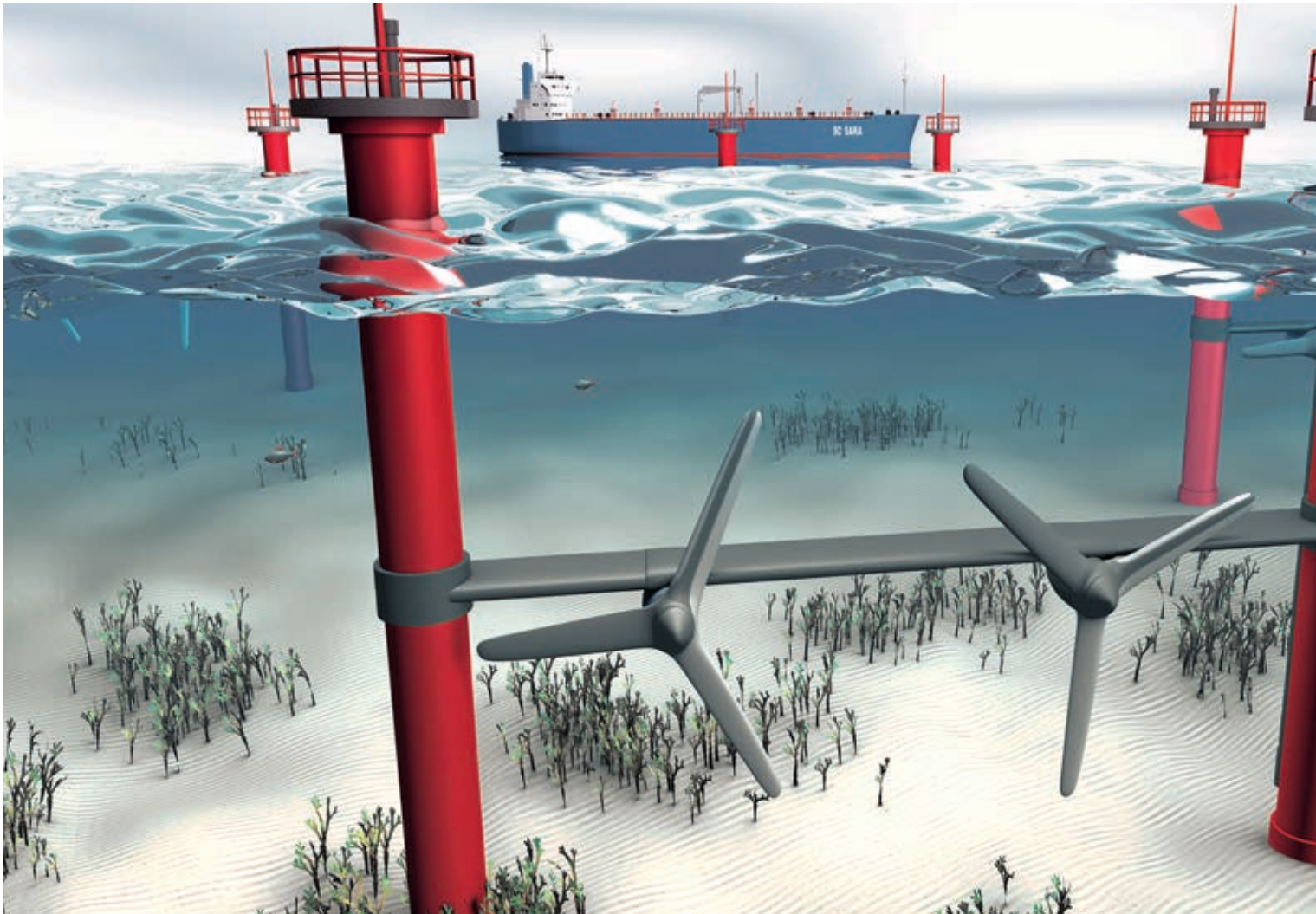


# Ocean Energy Renewable Energy Just Offshore



Anyone who has actually experienced the mighty power of ocean waves and currents will have an idea of the potential energy lying dormant in the seas. Many companies are currently working on a wide range of concepts for large-scale power generation systems from this renewable energy source. We are still right at the start of this development just as was the case a few decades ago with wind energy.

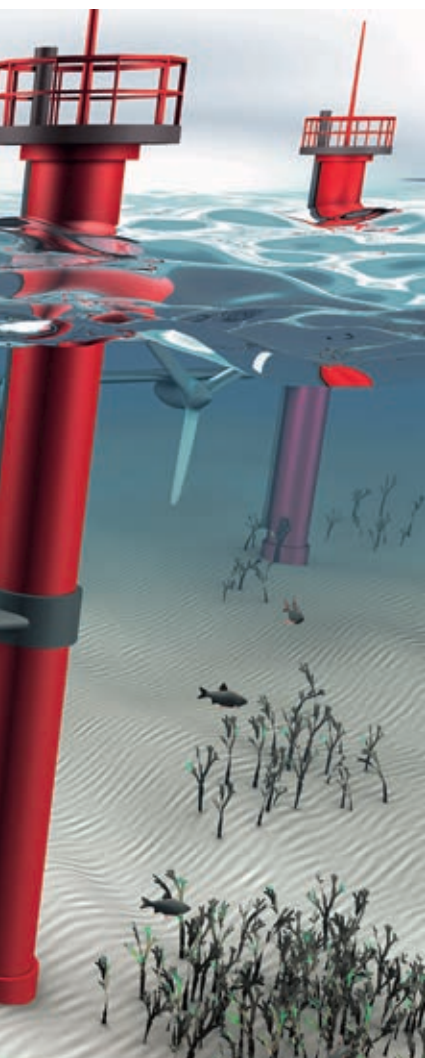
As well as numerous similarities in requirements for harnessing of ocean currents (mainly continuous currents like the Gulf Stream or tidal currents periodically changing over several hours) and wave energy, there are also significant differences. Rexroth offers power take-off solutions for both applications. These are based on Rexroth hydraulic component and system solutions, which are already proving to be exceptionally robust and reliable in a variety of marine applications.



To prevent the unacceptable consequences for humans and the environment, particularly global warming, caused by the growing worldwide energy demand, energy must increasingly be generated from renewable sources. Ecological, efficient and economically sustainable methods of energy generation are required.

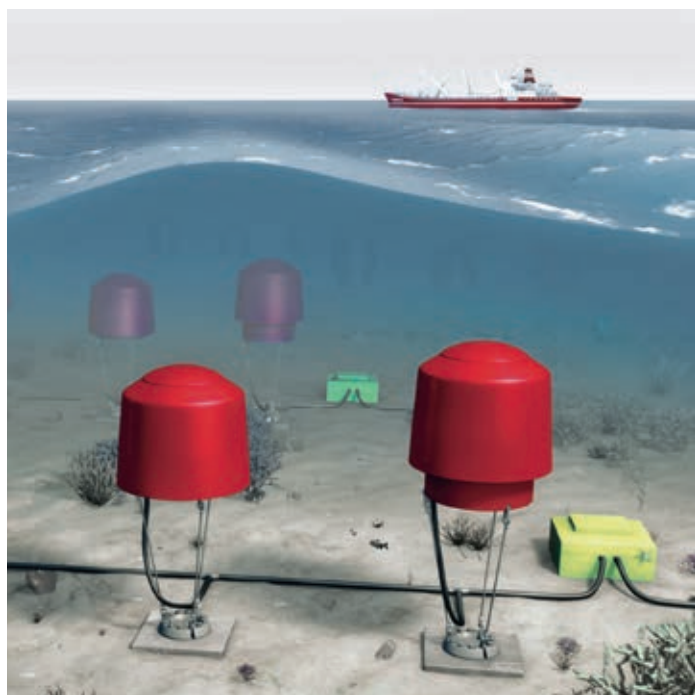
The use of our oceans as an energy source can make a reasonable contribution to the energy mix of the future in many areas worldwide and particularly where sufficient resources can be harnessed near major consumers. As two thirds of the world's population live in coastal regions, electricity can often be generated where it is consumed.

The decisive criteria for the success of all ocean energy concepts are met by robust and reliable automation components, which are designed specifically to meet the harsh environmental conditions prevailing at sea level and below. Rexroth offers a unique treasure trove of experience for marine automation projects, as well as an extensive portfolio of specially developed components.



**Ocean energy concepts for applications like**

- ◀ Ocean current energy converters
- ▶ Wave energy converters





## The Challenge for Technology: Controlling factor 1,000

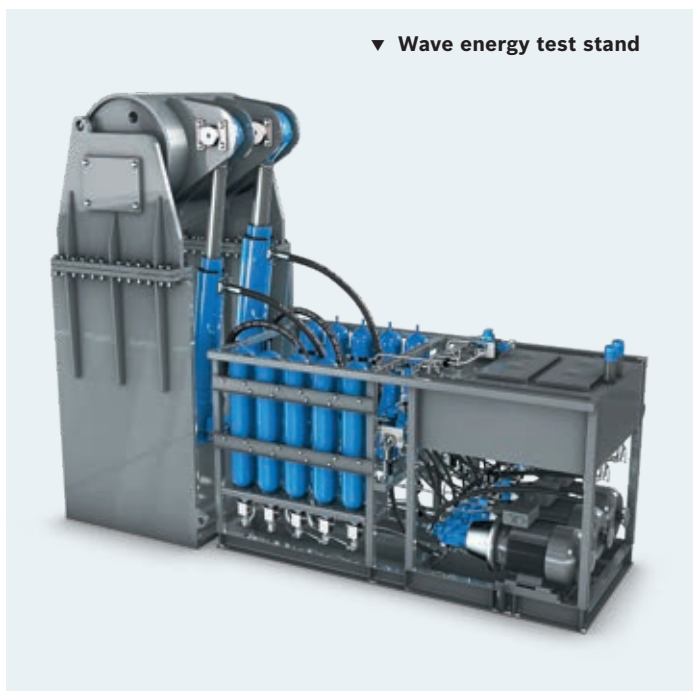
The sea is one of the most challenging environments of all when it comes to energy generation. The corrosive nature of salt water and biofouling demand special materials and coatings. Under extreme conditions, the active forces may exceed the starting threshold of converters by a factor of 1,000. Maintenance often requires intense effort and can only be carried out in specific time windows.

All ocean energy concepts require robust and reliable solutions, which are designed specifically to withstand these harsh environmental conditions.

In the long run, only a few system concepts will meet the decisive factor of success – a competitive levelized cost of energy (LCOE) – and prevail. This LCOE is calculated based on investment and operating costs, service life, efficiency and availability.

From this the following requirements can be derived for ocean energy systems:

- ▶ high availability
- ▶ long maintenance interval of up to five years
- ▶ Service life of up to 30 years
- ▶ high efficiency over a wide load range



### Hydrostatic transmissions for power take-off

For ocean current power systems and wave energy converters, Rexroth bases its power take-off (PTO) solutions on hydrostatic transmissions. These offer numerous advantages:

- ▶ Hydraulically, high transmission ratios can be easily realized by selection of displacements.
- ▶ Stepless variable transmissions can be easily implemented by means of variable displacement hydraulic motors. This way, applications can be realized without any additional power electronics.
- ▶ Among other reasons, the particular robustness of hydraulic transmissions has made them the preferred solution for extreme applications such as construction machinery and mining equipment for decades.
- ▶ Thanks to hydraulics, multiple generator units can be easily realized in parallel. This offers increased availability (redundancy) and improves the efficiency in the often used partial-load range of the systems.
- ▶ Due to the high force density in hydraulics, hydrostatic transmissions are very space-saving while offering high flexibility in structural arrangement of components. This enables realization of easily accessible generator units, e.g. above the water surface.
- ▶ Pressure relief valves ensure that the maximum forces already mentioned are reduced at an early point in the system for small and cost-saving design of downstream components.

# Tidal and Ocean Current Energy Converters: Going with the Flow

Whether with tide or a natural ocean current: As with wind energy it is the flow that drives the rotors. Water, however, is 1,000 times denser than air and generates extremely high forces, even at low flow rates. This requires novel concepts.

Underwater rotors are able to pick up energy effectively with a diameter that is considerably smaller than that of wind turbines. Even at low speeds, high forces act on the complete system. At Rexroth, we focus on the use of hydrostatic transmission.

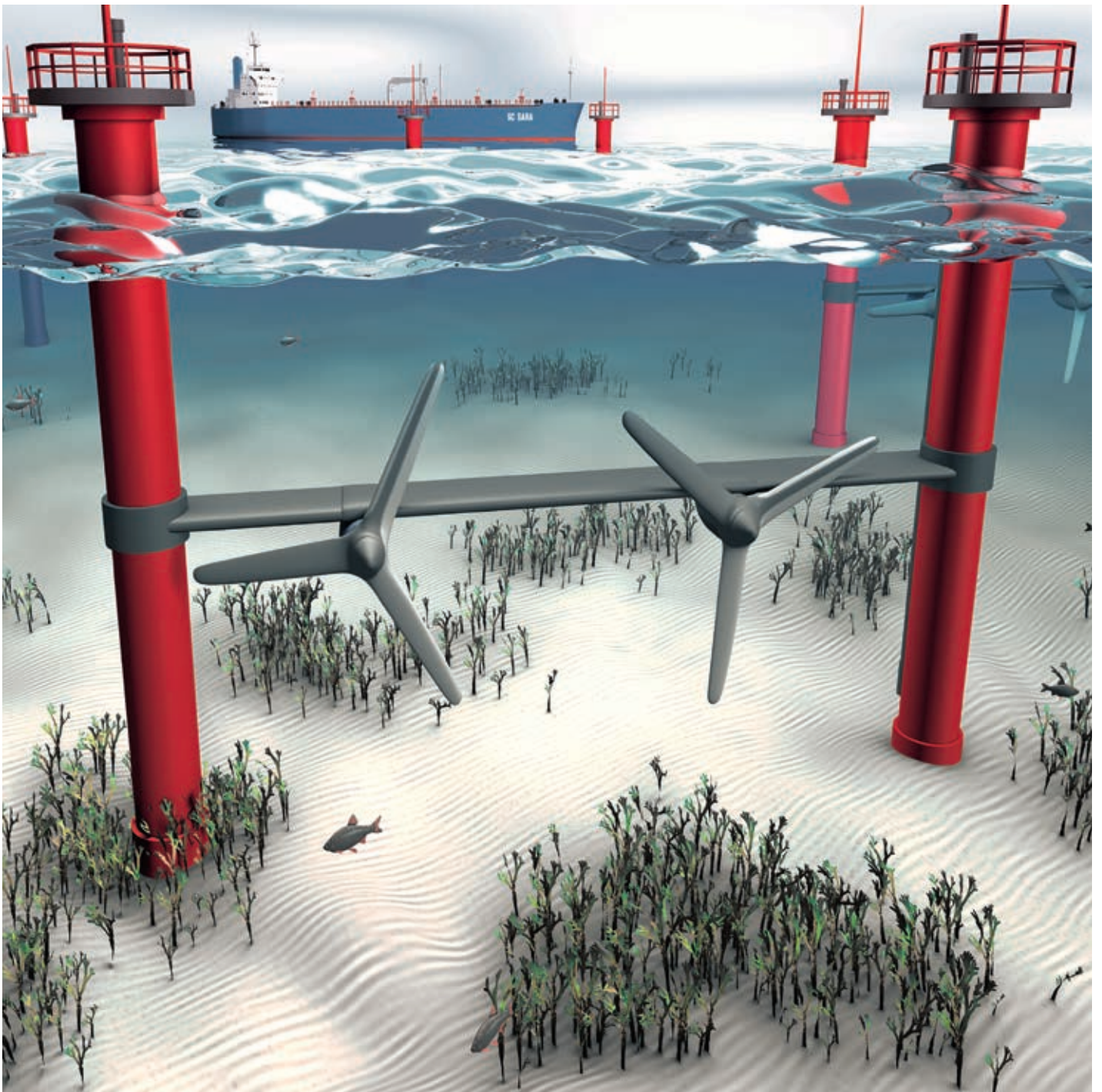
This straightforward and extremely robust concept converts rotational movement into a hydraulic flow, which drives a closed-loop controlled hydraulic motor coupled to a genera-

tor with a high degree of efficiency. On the pump side, a slow-running hydraulic motor picks up the rotor speed, generating a volumetric flow. This energy feeds a high speed variable displacement axial piston motor directly driving the grid connected generator. This way the hydraulic converter can dispense with the need for costly closed-loop control electronics and frequency converters.

One particular benefit is as follows: Thanks to the variable displacement options offered by the axial piston motor, the steplessly smooth adjustment of the transmission ratio not only absorbs peak demand, it also adjusts the rotor speed to different current speeds. The system is thus able to achieve an optimum degree of efficiency across the complete tide cycle.

Above all, this solution simplifies the overall design, as the variable displacement motors directly detect the reversal of rotation at ebb and flow with fixed orientation systems. The decentralised construction method of hydraulics furthermore reduces the number of components under water: Only the robust rotor pump generating the hydraulic flow is positioned directly inside the installation. The system operator can install the hydraulic motor-generator assembly above water to reduce maintenance and increase availability at the same time.





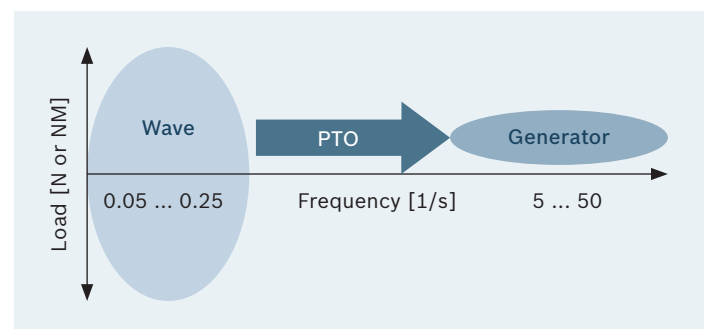
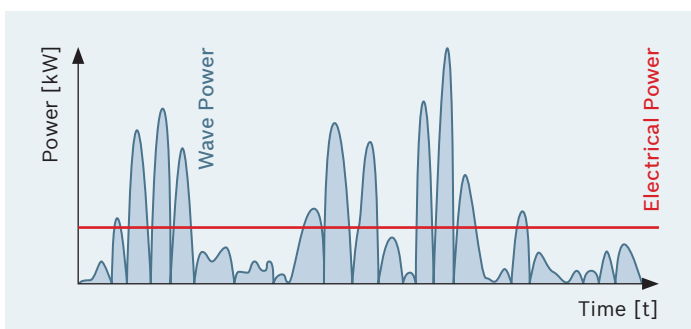
# Wave energy converters: From the Wave to Kilowatts

The continuous up-and-down motion of waves is the most visible sign of the immense power there is in the sea. Wave energy converters have to be able to cover an extremely wide application window: Gentle waves in calm weather just as well as winter storms in Europe, hurricanes, typhoons or cyclones.

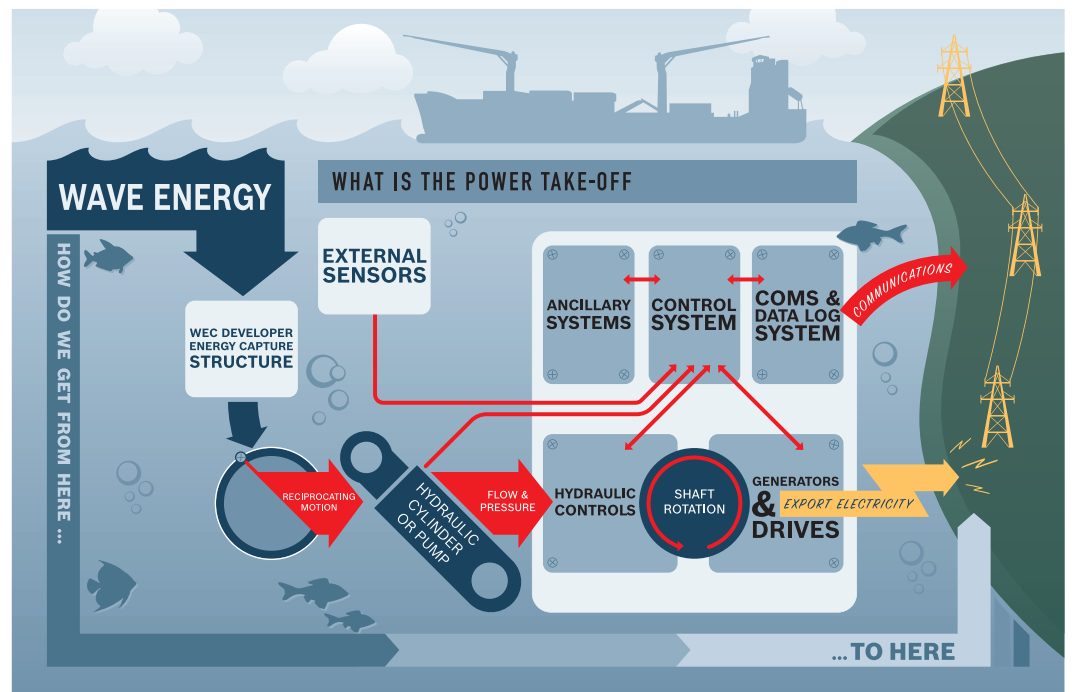


Fluid technology is particularly suited to the use of wave energy for power generation. It can convert linear oscillation into a closed-loop controlled rotational movement with a high degree of efficiency and a minimum of mechanics. At the same time, high transmission ratios can be economically realized, i. e. high input forces or slow movements at the wave energy converter are converted to much lower torques and high speed at the generator shaft.

The known high force density of hydraulics enables very compact design. Low forces of inertia and favorable attenuation properties offered by this technology facilitate the handling of widely fluctuating power inputs. Optional power smoothing can also be realized easily by means of hydraulic accumulators. Under extreme conditions sensitive system components are protected from over-pressure using hydraulic methods like pressure relief valves or switching to allowing free-wheeling mode.



- Conversion of wave energy into electricity
- ▼ Rexroth Enduroq procedure for coating of piston rods



### Enduroq for corrosion protection

Direct contact between the hydraulic cylinder acting as pump and sea water often cannot be prevented. A perfect surface condition of the cylinder rod is decisive for the proper long-term functioning of the cylinder and the entire hydraulic system.

Based on the already extensively tried-and-tested Enduroq 2000 and Enduroq 3000 coatings, Rexroth engineers have developed a new procedure. It ensures additional corrosion protection to further support long-term functional operation in salt water. Particularly in the often oxygen-rich water layer near the surface or in areas in contact with spray water, this is of special importance. Seals specially constructed for marine applications round off the seaworthiness of this system.

# From Concept to Operation: Experience Counts

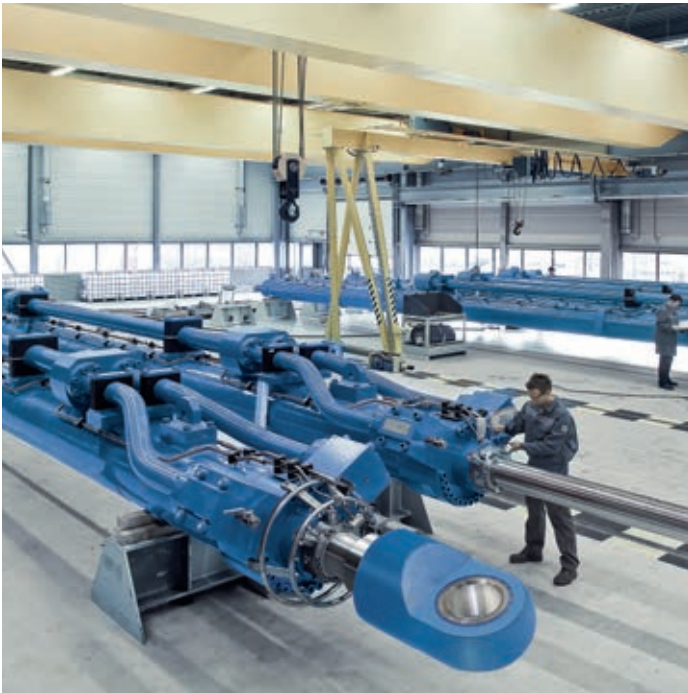
Ideal automation partners for ocean energy systems will know the prerequisites for renewable energies and will have the experience in marine applications and components specifically designed for such. They will also be able to work with their own development personnel in the long term, as well as collaborating closely with system manufacturers. Who, other than Rexroth, can offer this combination?



When the industrial development of wind energy systems began more than thirty years ago, Rexroth put itself forward as a technology partner right from the start, with solutions for transmissions, drives and controls. Together with all major OEMs, Rexroth increased the level of reliability and efficiency of these core components. From this, automation manufacturers developed a deep understanding of the very stringent reliability requirements in power generation systems.

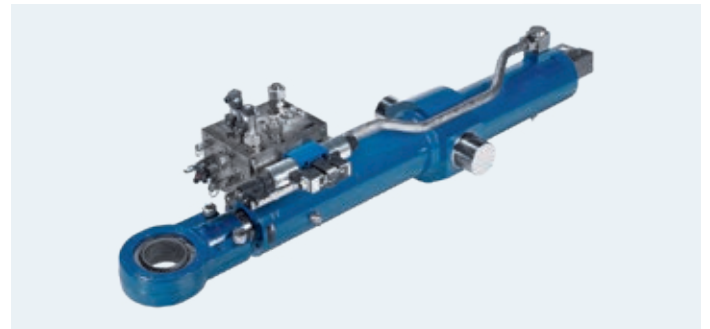
Marine applications have always been a part of Rexroth's core activities. Whether on board ships, typhoon-proof ferry terminals, tidal barrages or offshore technology: Rexroth hydraulic components and systems are proving themselves in every ocean and under the toughest of conditions. Here, too, users are expecting lifetimes of decades when it comes to the design of their systems.

In the industrial field of "renewable energies", Rexroth is combining all this experience and focusing on the development of automation solutions for ocean energy converters. The efficiency and high availability of the power take-off are the key to low power generation costs. Only if the investment costs are optimized as a whole, taking into account a long service life and comparatively low operational and maintenance costs, will ocean energy systems be able to reveal their true potential.



This is the challenge currently faced by many a system manufacturer. Experience from wind energy and other major projects demonstrates again and again the necessity and relevance of close co-operation between system component supplier and system builder. As power take-off system supplier, Rexroth supports system manufacturers right from the start with “Wave-to-Wire” computer simulations. Rexroth specialists are in an interactive process optimizing power take-off for the relevant system, as well as designing and supplying ready-to-install subassemblies.

We are your competent partner backed by the strength of a global player: Rexroth, your partner for the development and realization of ocean energy converters.



Examples of hydraulic solutions developed by Rexroth – exceptionally robust and reliable:

- ◀ LHC - Large hydraulic cylinder
- ▲ Electrohydraulic pitch adjustment for tidal energy converters
- ▶ Hydraulic cylinder for application as linear pump for wave energy converters
- ▶ MLC hydraulic control system
- ▶ A4VSO or A4VSG for generator drive
- ▼ Radial piston units Haegglunds CBM and CA for PTO and secondary drives



**Bosch Rexroth AG**

Zum Eisengießer 1  
97816 Lohr, Germany  
[www.boschrexroth.com](http://www.boschrexroth.com)

**For more information please contact:**

[oceanenergy@bosch.com](mailto:oceanenergy@bosch.com)