WAVE POWERED DESALINATION
Providing safe water for a sustainable future
Water availability is a concern for people all over the world, impacting industry, agriculture and healthy living conditions. We are outpacing our natural water resources, not only in arid regions, but in countries worldwide. Unless addressed, by 2050 more than half of the world’s population is predicted to live in water scarce areas.

Every summer DNV GL brings together a group of committed students with a wide variety of academic backgrounds, to find innovative solutions to important real world challenges.

In 2014, the Summer Project has taken a closer look at how wave power and desalination technology can contribute to the effort of supplying clean and sustainable water to the Earth’s growing population.

"If the wars of the 20th century were fought over oil, the wars of this century will be fought over water"  
- World Bank
The importance of water

We are in the process of altering the Earth's climate. Half of the world's wetlands have disappeared over the last century, groundwater levels are sinking and widespread pollution is making fresh water resources unsafe for human consumption.

Sufficient water supply of good quality is imperative to the health and well-being of life on Earth, as well as for socio-economic development. Water-borne diseases prevent education and productive activity, and maintain the levels of poverty in developing countries.

Food security and adequate nutrition is reliant on water and agriculture accounts for the majority of all water consumption. According to the Food and Agriculture Organisation, demand for food is predicted to increase by 60% by 2050 as a result of the growing population and changing diets.

Today, one in three people are affected by water scarcity. This situation is expected to escalate due to population growth, urbanisation, climate change and industrial development. According to estimates by the Water Resource Group, global demand for water is likely to exceed supply by 40% within the two next decades.

Sustainable production of fresh water

A potential solution for addressing water scarcity and future water needs can be found through the desalination of sea water. This is the process of removing salts and other minerals in order to produce fresh water. Most prevailing desalination technologies rely on the use of fossil fuels, which results in significant CO₂-emissions, thus further contributing to global warming. Nevertheless, desalination is gaining recognition worldwide as an important means of increasing water supply.

Sources for illustration:
INTRODUCING THE OCEAN OASIS

The Ocean Oasis is a combined Wave Energy Converter (WEC) and desalination plant floating offshore and delivering clean water to the mainland.

Waves represent a large and global energy resource, and numerous concepts for harvesting this energy have been developed. Unfortunately, through the process of producing electricity, their efficiency levels remain below that of competing renewable energy resources. For this reason, the Ocean Oasis pressurises sea water directly. Furthermore, using wave energy for desalination does not put additional strain on the existing electricity grid, and fresh water can be produced without leaving any carbon footprint. As a result, the Ocean Oasis offers a more sustainable approach to producing potable water.

Anyone who can solve the problems of water will be worthy of two Nobel prizes - one for peace and one for science
– John F. Kennedy
The Ocean Oasis is a two-body axisymmetric floating Wave Energy Converter (WEC). It consists of a cylindrical body with an internal floating disc.

The outside hull has an optimised shape for wave generation, and is therefore a good wave energy absorber. Both bodies are carefully designed to have complementary natural periods, which ensures large relative motions over a wide range of wave frequencies. The relative motions are absorbed by three symmetrically placed pistons. The pistons then pressurise sea water, which is directly used for the desalination process.

**Construction, installation and operation**

The hull of the Ocean Oasis is shaped as a nonagon in order to ease construction, and is designed to be towed from the construction site to its final location offshore. In deep water, the hull will be ballasted to reach the operating draft. The mooring system will consist of three anchor lines. Each line is segmented in synthetic fibre and chain to ensure sufficient freedom for energy extracting motions while keeping it in place.

**Survival mode**

In storm conditions the power production will seize and the Ocean Oasis will go into survival mode. This involves shifting the ballast down to the lower tanks in order to minimise pitch and roll motions. Furthermore, winches will elevate the internal disc and pull it up against a rubber covered steel skirt. The sealed moon-pool will create an air-pillow, protecting the power take-off system.

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**KEY FIGURES THE OCEAN OASIS**

- Displacement: 8357 t
- Steel weight: 1350 t
- Equipment: 68 t
- Sea water ballast: 6926 t
- Draft: 34 m
- Outer diameter at top: 28 m
- Outer diameter at keel: 19 m
- Inner diameter: 16 m
- Power rating: 560 kW

The Ocean Oasis can generate power in a wide range of wave frequencies.
The desalination plant, placed inside the hull of the WEC, works in the following manner:

**A. Water intake:** An average of 10 million litres of water is pumped in every day.

**B. Pumps:** The low pressure pumps, powered by the main pistons, regulate the pre-filtration pressure and drive the transportation of fresh water to shore. These pumps follow the same principles as the energy recovery unit.

**C. Pre-treatment:** The feed-water is pre-treated using the ultrafiltration (UF) method. Larger particles are removed by a screening filter, after which a biocide is added to prevent biological growth in the system. The UF unit then removes particles down to the size of 0.01 µm, including viruses and smaller bacteria. Finally, a scale inhibitor is added to prevent scaling of the reverse osmosis membranes.

**D. Main pistons:** Wave energy forces three pistons to oscillate vertically, thereby pressurising the sea water held inside. These pistons are made of material able to withstand both high pressure and corrosion.

**E. Pressure controller:** The pressurised water is transported into a header. From the header, water is directed to the reverse osmosis membranes and to the low pressure pumps. The header is connected to an accumulator stabilising the pressure. If this pressure exceeds the acceptable limit, it is released by a pressure release valve to prevent destruction.

**F. Reverse Osmosis:** Six membranes are placed in line inside a total of 56 pressure vessels. The small dimensions of the holes in the semipermeable membranes allow for nothing but water particles to pass through. Salt and minerals remain in the feed-water, which now becomes highly concentrated brine. Almost 50% of the water entering the vessels is desalinated. A control system continuously regulates the amount of pressure vessels in operation depending on the wave conditions.

**G. Energy Recovery:** After the reverse osmosis process the brine retains almost all of the original feed-water pressure. An energy recovery device reuses 98% of this energy. Assisted by two pressure exchange vessels the energy is transferred to pre-treated water, leaving the brine with low pressure. There is still a tiny lack of energy in the pre-treated water. This deficiency is corrected in the main pistons before entering the membranes.

**H. Brine disposal:** After the brine has been depleted of most of its energy, it is led into a flexible hose. This hose, connected to the fresh water hose, releases the brine at 50m depth. In order to minimise potential environmental impact, it will be dispersed through a multiport system. The dense brine will automatically form a negatively buoyant plume thereby not affecting the salinity of the sea water around the intake area.

**I. Water transport:** The fresh water exiting the reverse osmosis process has atmospheric pressure and must therefore be sent through a pump, where it receives enough energy to be carried to shore. Leaving the Ocean Oasis, the water will travel through a flexible hose placed in a lazy wave configuration until it reaches the sea floor. Along the sea floor the fresh water is transported through a 5 km long polyethylene pipe to shore. This transportation arrangement is designed for minimal disturbance to the energy producing oscillating movements.

**J. Post treatment:** Onshore the water is made potable. To regulate pH and hardness, limestone and carbon dioxide is introduced to the water flow, after which sodium chloride is added for disinfection and prevention of bacterial growth.
Enshrined in the South African constitution is the right to clean water. Although the water situation has undergone enormous improvement since the fall of the Apartheid regime, safe water is still not accessible to everyone. Being a semi-arid country, its fresh water resources are almost fully utilised and under severe stress. The World Wildlife Fund (WWF) notes that water availability is “one of the most decisive factors that will affect the economic, social and environmental well-being of South Africa over the next decade.”

Water scarcity

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Economics

Through vast mining activity South Africa has become the world's largest producer of gold, platinum and chromium, making its export-based economy the most developed in Africa. Furthermore, the country’s stock-exchange now ranks 16th in the world. South Africa is therefore considered to be one of the world’s most prominent emerging markets, attracting significant amounts of foreign investment every year. Its well-functioning financial, legal, energy and transportation sectors provide a good foundation for innovative projects requiring reliable and stable conditions.

As more seawater desalination plants produce water at an affordable price, it is bound to generate extended socio-economic benefits through increased access to clean water. Increased productivity of the labour force, more time devoted to productive activity, less disease, as well as reduced mortality rate will result in at least 2% increase in GDP.
FINANCIAL FEASIBILITY

Our cost analysis includes capital expenditures (CAPEX) associated with the construction and installation of the plant as well as operational expenditures (OPEX) associated with the operation and maintenance of the plant. Revenues are calculated assuming that water is sold to and distributed by the public sector.

A large portion of the CAPEX stems from the large amount of steel necessary for the construction of the WEC structure. Other costs include pistons, storm winches, mooring and installation, and transportation. In addition to the WEC, CAPEX include the initial purchase and installation of the components needed for the RO process and transportation of fresh water to shore. Lastly, there are CAPEX associated with the construction of an onshore structure consisting of a control and remineralisation facility. The additional costs from the construction of the WEC result in CAPEX exceeding that of a standard desalination plant.

The OPEX are dominated by the maintenance of the RO system and labour costs associated with the supervision and maintenance of the Ocean Oasis. In order to prevent periods of standstill production, we have assumed 24 hour supervision of the plant resulting in labour costs significantly higher than those generally associated with desalination. However, due to the fact that the Ocean Oasis is driven purely by wave power a major cost saving in production is electricity costs, as visualised by the figures on the next page. As a result, despite high CAPEX, the estimated Net Present Value (NPV) is positive at approximately USD 13.7 million. The NPV is calculated based on a 25-year horizon and using a discount rate of 8.4%.
MAIN BENEFITS OF THE OCEAN OASIS

- No electricity results in cost savings
- Renewable energy results in reduced carbon footprint
- No energy losses from electrical conversion
- Development of innovative and powerful wave energy technology
- New solutions in desalination technology
- No visual contamination of the coastal scenery
- Brine disposal far from sensitive coastal ecosystem
- Increased water supply
- Jobs created through the construction and operation of the Ocean Oasis
- Improved health conditions
DNV GL SUMMER PROJECT 2014 TEAM

We would like to thank DNV GL for giving us the chance to be a part of the DNV GL Summer Project 2014. This has been a great opportunity for us to expand our horizons and gain unique experiences. We are grateful for all the help we have received from committed co-workers, which has been essential to our result. The positivity, support and availability we have encountered has been inspirational.

Thank you!

Bibliography

DNV GL. A Safe and Sustainable Future: Enabling the Transition. DNV GL; 2014.
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