DNV·GL

MARITIME INDUSTRY

AQUA RECOVERY

Offshore recycling of wastewater

SAFER, SMARTER, GREENER

Solving the problem of water scarcity has to begin by using water more efficiently, but that alone will not fill the gap. Large-scale reuse of water is essential to a sustainable future for planet Earth.

Paul Reiter former Executive Director International Water Association

04
Global water challenges

08
Offshore recycling of wastewater

12
Applied solutions

DNV GL Extraordinary innovation project. Clean water is in short supply in many areas around the world. Local solutions are needed to provide clean water to people, industry and agriculture. At the same time, large quantities of untreated wastewater are being discharged into the world's oceans and rivers, threatening both the environment and human health. This project explores how local solutions for offshore treatment of wastewater can bring value back to society in terms of clean water.

The project is based on an idea by EnviroNor AS. The objective of DNV GL's Extraordinary Innovation Projects scheme is to investigate potential future technologies and concepts, and present viable solutions for their application.

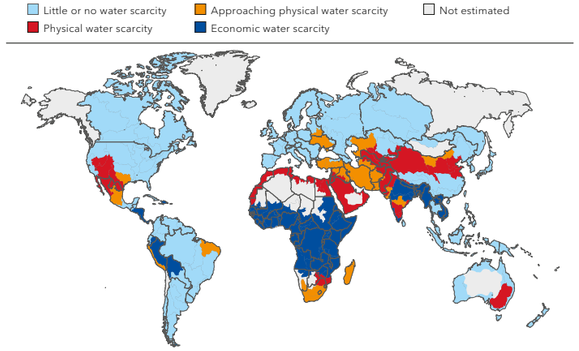
GLOBAL WATER CHALLENGES

© Getty Images

Your life depends on clean water. So does the rest of the world. Not only for hydration, sanitation, cleaning and cooking, but for generating power and producing food, oil, pharmaceuticals and electronics. These are only a few examples. Like many of the world's resources, water is not distributed equally. Some parts of the world have all the clean water they need, while others are fighting a constant water shortage. Globally, there has been a growing focus on water access over the past decade, prompted by statistical extrapolations for world population growth, which indicate that water-related challenges will only continue to increase.

The Earth's water is constantly being recycled: water moves from groundwater reservoirs and rivers to the ocean and the atmosphere through different physical processes, such as runoff, evaporation and precipitation. Since the amount of freshwater remains approximately the same, the growing human population represents a challenge. Being able to supply everyone with clean and safe water depends on our ability to manage our water resources in new and better ways. Utilizing existing water resources as efficiently as possible, and preventing clean water from becoming polluted, are key to creating a healthy, safe and sustainable future for us all.

Areas of physical and economic water scarcity

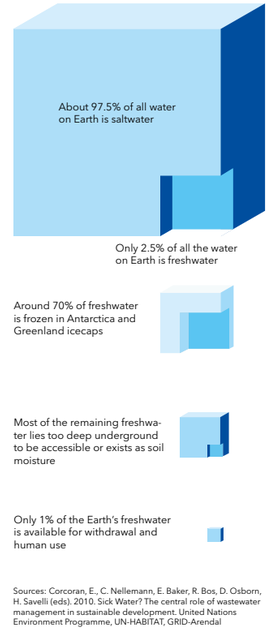


Definitions and indicators

- Little or no water scarcity. Abundant water resources relative to use, with less than 25% of water from rivers withdrawn for human purposes.
- Physical water scarcity (water resources development is approaching or has exceeded sustainable limits). More than 75% of river flows are withdrawn for agriculture, industry and domestic purposes (accounting for recycling of return flows). This definition, relating water availability to water demand, implies that dry areas are not necessarily water scarce.
- Approaching physical water scarcity. More than 60% of river flows are withdrawn. These basins will experience physical water scarcity in the near future.
- Economic water scarcity (human, institutional, and financial capital limit access to water even though water in nature is available locally to meet human demands). Water resources are abundant relative to water use, with less than 25% of water from rivers withdrawn for human purposes, but malnutrition exists.

Source: International Water Management Institute analysis done for the Comprehensive Assessment of Water Management Agriculture using the Watersim model; Chapter 2.

World freshwater supply



Sources: Corcoran, E., C. Nellemann, E. Baker, R. Bos, D. Osborn, H. Savelli (eds). 2010. Sick Water? The central role of wastewater management in sustainable development. United Nations Environment Programme, UN-HABITAT, GRID-Arendal

WATER FACTS

Only **50%** of cities in the developed part of the world have sufficient infrastructure and capacity for treating wastewater[1].

In **industrialized nations**, industries consume more than half of the water available for human use[2].

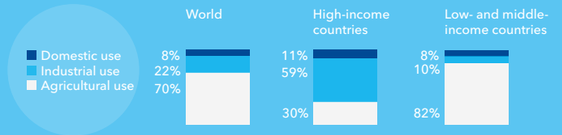
More than **10%** of the world's population consume food irrigated by wastewater that can contain chemicals or disease-causing organisms[4].

More people on Earth have access to a cell phone than to a toilet[3].

Every day **9 million** cubic metres of untreated wastewater is discharged into the Mediterranean ocean. This counts for 53% of the wastewater from the 65 million people living in coastal cities[5].

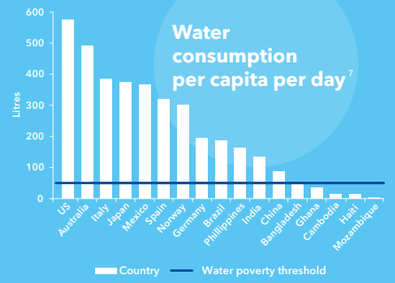
Competing water uses for main income groups of countries[6]

Industrial use of water increases with country income, going from 10% for low- and middle-income countries to 59% for high-income countries.

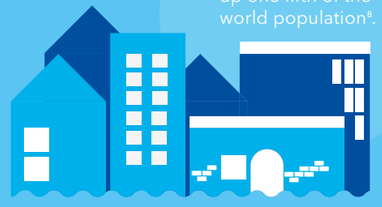


On average, every **US dollar** invested in water and sanitation provides an economic return of eight US dollars[7].

Water consumption per capita per day[7]

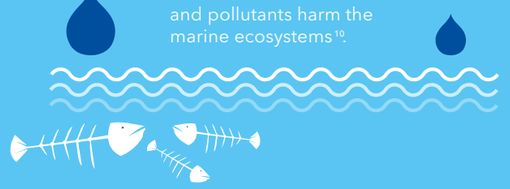


By 2015 the world's **coastal population** is expected to make up one fifth of the world population[8].



2.2 million people die each year from diarrheal disease. Unsafe water is responsible for a majority of these deaths[9].

Untreated wastewater leads to eutrophication of the sea. Toxic chemicals and pollutants harm the marine ecosystems[10].



Water use

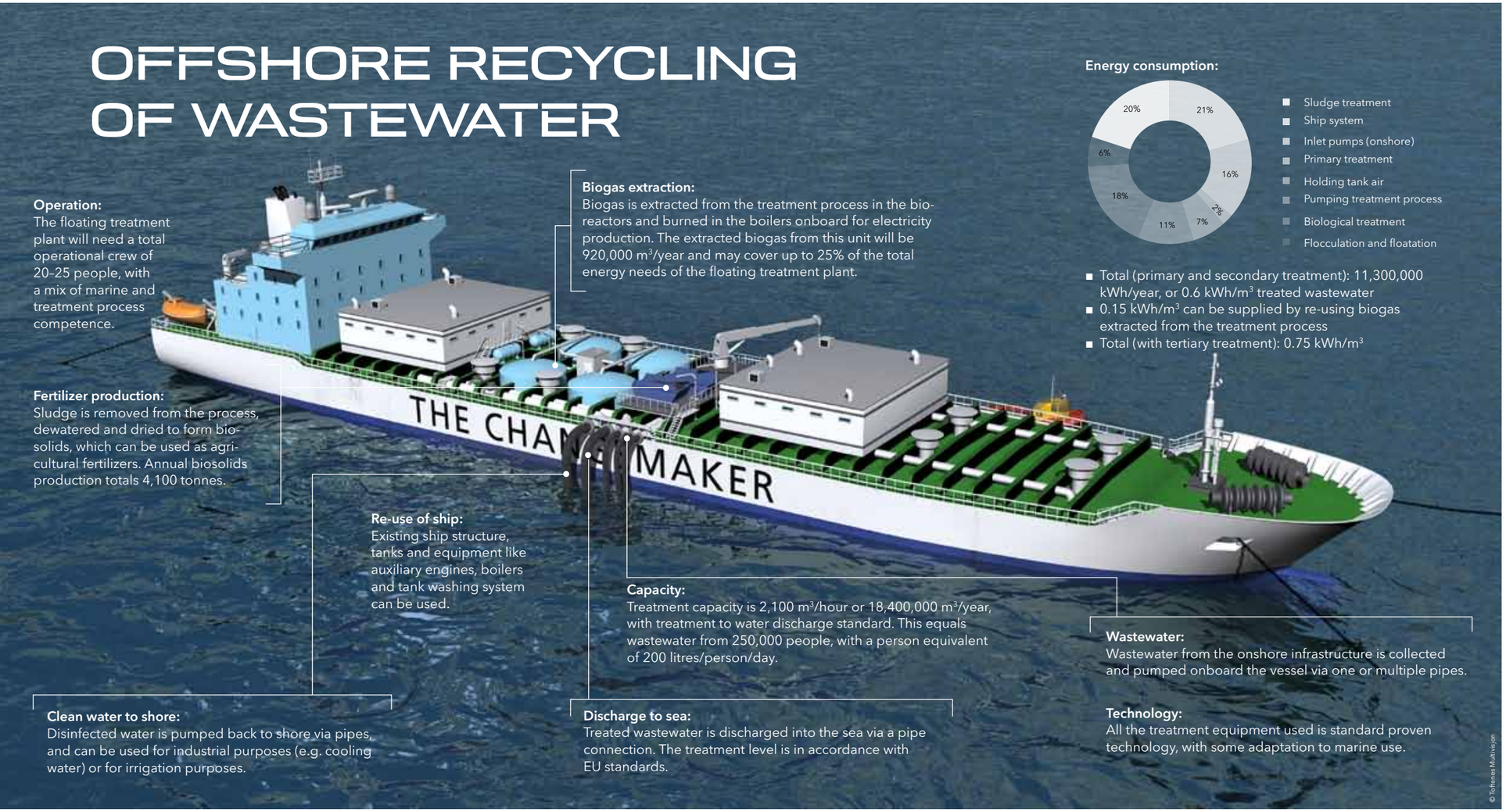
On a global basis, most freshwater resources are used for agricultural irrigation, almost one quarter is used for industrial purposes, and less than one tenth is used by domestic households. However, there are large differences between countries. In the United Kingdom less than 5% is used for irrigation, while in India more than 90% is used for the same purpose. Typically, in high-income countries most water is used for industry and less for agricultural use, while in low- to middle-income countries most water is used for agricultural purposes. The industries that make extensive use of water are many and diverse. Some of the most water-intensive industries are oil and gas, power generation, food and beverage, pharmaceuticals and microelectronics. There are also large differences when it comes to domestic use. For instance, Australians use 500 litres of water per capita per day, while Germans use 200 litres.

Discharge of untreated wastewater to the marine environment can lead to eutrophication. The high concentration of nutrients in water leads to a bloom of algae, causing reduced water quality and oxygen depletion during decomposition. Since the marine life depends on oxygen, the areas may become dead zones. Untreated wastewater can also contain harmful chemicals, hormones, heavy metals, pharmaceuticals and other toxic pollutants. More than 80 % of wastewater flows untreated into lakes, rivers and oceans. This has a severe impact on ecosystems, fisheries and the livelihoods of local populations. However, when wastewater is treated it can become a significant resource. Treated water can be used for irrigation or industrial use. Sludge can be used as fertilizer, and biogas can be extracted and used to produce electricity. It is also a low-cost alternative compared to desalination of seawater.

[1] DNV market research, [2] www.worldometers.info/water/, [3] *Deputy UN chief calls for urgent action to tackle global sanitation crisis,* United Nations News Centre, 4 World Health Organization, [5] *Municipal wastewater treatment plants in the Mediterranean coastal cities,* United Nations Environment Programme, [6] *Progress on Sanitation and Drinking Water*, WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation 2012. [7] *Human Development Report 2006. Beyond Scarcity: Power, poverty and the global water crisis,* United Nations Development Programme,

[8] Corcoran, E., C. Nellemann, E. Baker, R. Bos, D. Osborn, H. Savelli (eds). 2010. *Sick Water? The central role of wastewater management in sustainable development,* United Nations Environment Programme,UN-HABITAT, GRID-Arendal, [9] Estimated with data from Diarrhea: *Why children are still dying and what can be done,* UNICEF/WHO 2009, [10] www.mfe.govt.nz/publications/waste/wastewater-mgmt-jun03/html/table2-2.html.

OFFSHORE RECYCLING OF WASTEWATER



Operation:
The floating treatment plant will need a total operational crew of 20–25 people, with a mix of marine and treatment process competence.

Biogas extraction:
Biogas is extracted from the treatment process in the bio-reactors and burned in the boilers onboard for electricity production. The extracted biogas from this unit will be 920,000 m^3/year and may cover up to 25% of the total energy needs of the floating treatment plant.

Fertilizer production:
Sludge is removed from the process, dewatered and dried to form bio-solids, which can be used as agri-cultural fertilizers. Annual biosolids production totals 4,100 tonnes.

Re-use of ship:
Existing ship structure, tanks and equipment like auxiliary engines, boilers and tank washing system can be used.

Capacity:
Treatment capacity is 2,100 m^3/hour or 18,400,000 m^3/year, with treatment to water discharge standard. This equals wastewater from 250,000 people, with a person equivalent of 200 litres/person/day.

Clean water to shore:
Disinfected water is pumped back to shore via pipes, and can be used for industrial purposes (e.g. cooling water) or for irrigation purposes.

Discharge to sea:
Treated wastewater is discharged into the sea via a pipe connection. The treatment level is in accordance with EU standards.

Wastewater:
Wastewater from the onshore infrastructure is collected and pumped onboard the vessel via one or multiple pipes.

Technology:
All the treatment equipment used is standard proven technology, with some adaptation to marine use.

Energy consumption:

- Total (primary and secondary treatment): 11,300,000 kWh/year, or 0.6 kWh/m^3 treated wastewater
- 0.15 kWh/m^3 can be supplied by re-using biogas extracted from the treatment process
- Total (with tertiary treatment): 0.75 kWh/m^3

THE FLEXIBLE SOLUTION

The flexible solution for recycling wastewater offshore is based on proven technology, but applied onboard a ship or a floating unit. The solution is flexible in terms of size and can be designed according to requirements at the location. While this example utilizes a phased-out product tanker as a platform, several other types of ships as well as barges and dedicated floating units may fit the purpose.

Vessel:
Product tanker 40,000 DWT, 15 years old. Converted into a treatment plant by fitting necessary equipment, filters and piping, together with some structural modifications to tank spaces.

Treatment process:
- Primary treatment through filtration
- Biological treatment for removal of organic substrate and nitrification by moving bed biofilm reactors (MBBR) in two parallel lines
- Coagulation and floatation treatment
- Sludge treatment and biogas extraction

If wastewater is to be reused for industrial purposes or irrigation, further treatment will include:
- Fine filtration
- Disinfection by UV

Other treatment technologies and processes may also be applicable.

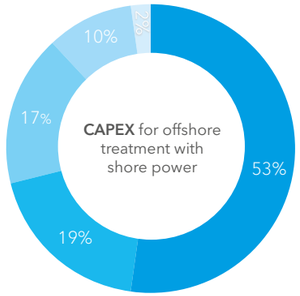
Infrastructure:
The offshore wastewater recycling unit requires an existing onshore wastewater infrastructure to which it can be connected. There must be sufficient sea depth at the given location, and the vessel should be anchored in a sheltered area to ensure an optimal treatment process.

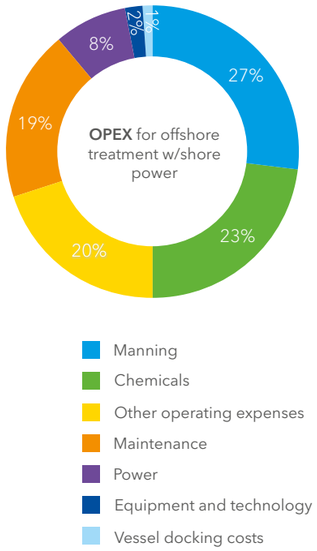
Costs

Offshore wastewater treatment can be profitable. The estimated net present cost of investing in and operating an offshore treatment facility is ~13 million USD* lower than for an onshore alternative, over a 20 year lifetime. The offshore solution has only 70% of the capital expenses (CAPEX) compared to the land-based solution. The lower CAPEX is mainly due to a reduction in construction costs by building in a low cost country, by removing the property cost and by re-using existing structure, tanks and equipment on board the vessel. Lower CAPEX can make an offshore solution affordable for communities that have limited access to capital.

Main operating expenses (OPEX) drivers are the costs of manning, maintenance, chemicals and other operational costs related to the treatment process. The costs of energy constitutes only 10–13% of the total operational costs, depending on whether electric power from shore or marine gas oil consumed on board is applied. The fact that only a small fraction of the OPEX is related to fuel makes the investment less vulnerable for future uncertainties in energy prices.

*) The estimated net present cost is based on using a 15-year-old product tanker of 40,000 DWT as basis. A time horizon of 20 years and a discount rate of 8% is applied.





Main benefits of offshore wastewater recycling

There are three main benefits of using a floating solution compared to an onshore solution:

Independent of property:

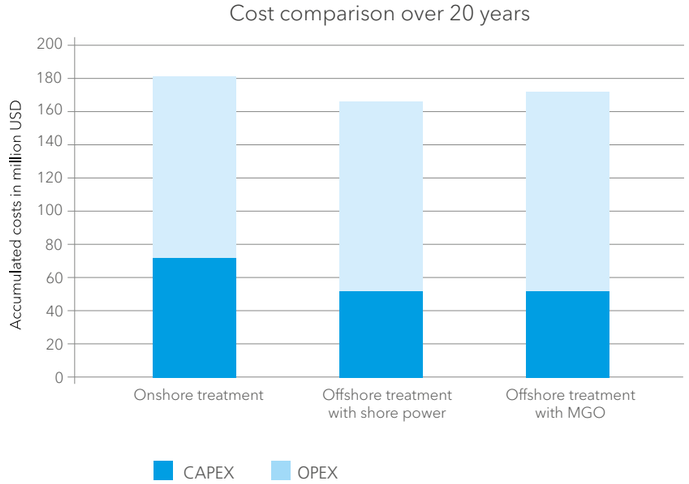
- Potential major cost advantage in areas with high property prices.
- Major advantage in areas where the terrain makes it very difficult (or costly) to build an onshore treatment plant.

Mobility:

- Can be used at different locations during its lifetime. A mobile unit can be an advantage where the site demands treatment capacity for a limited time period, for example during repair and upgrading of existing treatment plants.

Construction flexibility:

- Planning, engineering and construction can be done in a low-cost country. The cost advantage depends on the difference in labour and material costs, between site of construction and site of operation. A shorter construction time may also be expected.



APPLIED SOLUTIONS

© Contra Costa Water District/Tofteres Multivision

© Tofteres Multivision

© Tofteres Multivision

© Tofteres Multivision

The Reliever
Relieving shore-based treatment facilities during upgrading and repair.

Features:
- Treats wastewater from shore and discharges treated water into the sea (primary and secondary treatment).

Who is it for:
- Area where a land-based wastewater treatment plant needs upgrading, is mal–functioning or has insufficient capacity.

Value:
- Limiting negative impact to the marine environment by avoiding discharge of polluted wastewater in areas or in periods with insufficient wastewater treatment capacity ashore.

Conditions:
- Must be a need for treatment of wastewater.

Location:
- Semi-industrialized countries with insufficient wastewater treatment facilities.

KEY BENEFITS:
- **Mobility:** can serve a community for a limited period of time and leave again when its mission is completed.
- **Construction flexibility:** can be at location and in operation within a short time span.

The Changemaker
Bringing value back to society by recycling wastewater into clean water.

Features:
- Treats wastewater from shore and delivers disinfected water back to shore, which can be used for irrigation or for industrial purposes.
- Produces fertilizer which can be used in agriculture.

Who is it for:
- Area in need of clean water for irrigation.
- Area in need of clean water for industry (e.g. cooling water for power plants).

Value:
- Better utilization of an area's current water resources by recycling wastewater into valuable clean water.
- Limiting negative impact to the marine environment by avoiding discharge of polluted wastewater.

Conditions:
- Must be a need onshore for irrigation water and/or industrial water.
- Land area for construction of shore-based treatment plants is limited or not available

Location:
- Mediterranean countries with a high demand for irrigation water and a dry climate without rain for large parts of the year. Many Mediterranean countries have limited facilities for treatment of wastewater.

KEY BENEFITS:
- Independent of property cost: in areas where land space is limited and expensive.
- Construction flexibility: can be at location and in operation within a short time span.

The Water Factory
Producing clean drinking water.

Features:
- Converts river water into clean drinking water.

Who is it for:
- Area where clean drinking water is a scarce resource.

Value:
- Better utilization of the current water resources in an area by recycling river water into clean drinking water.
- Giving more people access to clean drinking water, which has positive health impacts.

Conditions:
- Must be a need onshore for clean drinking water.
- Land area for construction of shore-based water-treatment plants is limited or not available.

Location:
- River in China, where clean drinking water is a scarce commodity in many parts of the country.

KEY BENEFITS:
- **Flexibility:** Quick access to clean drinking water without costly up-front investment through reclamation of land and construction of land-based treatment plant.
- **Mobility:** Can be used at a location for a limited time period, for example during planning and construction of a land-based water treatment plant. Can also serve different locations in an area.

We have since long looked for an opportunity to create something in the environmental space around water. We have been invited by EnviroNor to join up on Floating Wastewater Treatment Plants. With this project we want to bring more knowledge to the market on how this can be done in practice.

Henrik Madsen DNV GL Group CEO

We have to think differently if we shall solve some of the global challenges related to water supply and pollution from discharge of untreated wastewater. By combining known technologies in a new way, a floating wastewater treatment plant can be tailor-made to the specific location. My wish is that this can bring prosperity to people and communities.

Sigmund Larsen Founder and entrepreneur EnviroNor

DNV GL AS
NO-1322 Høvik, Norway
Tel: +47 67 57 99 00
www.dnvgl.com

DNV GL
Driven by its purpose of safeguarding life, property and the environment, DNV GL enables organisations to advance the safety and sustainability of their business. DNV GL provides classification and technical assurance along with software and independent expert advisory services to the maritime, oil & gas and energy industries.

It also provides certification services to customers across a wide range of industries. Combining leading technical and operational expertise, risk methodology and in-depth industry knowledge, DNV GL empowers its customers' decisions and actions with trust and confidence. The company continuously invests in research and collaborative innovation to provide customers and society with operational and technological foresight. DNV GL, whose origins go back to 1864, operates globally in more than 100 countries with its 16,000 professionals dedicated to helping their customers make the world safer, smarter and greener.

 Design: Coor Media **Print:** Coor Media, volume 200, paper: Scandia