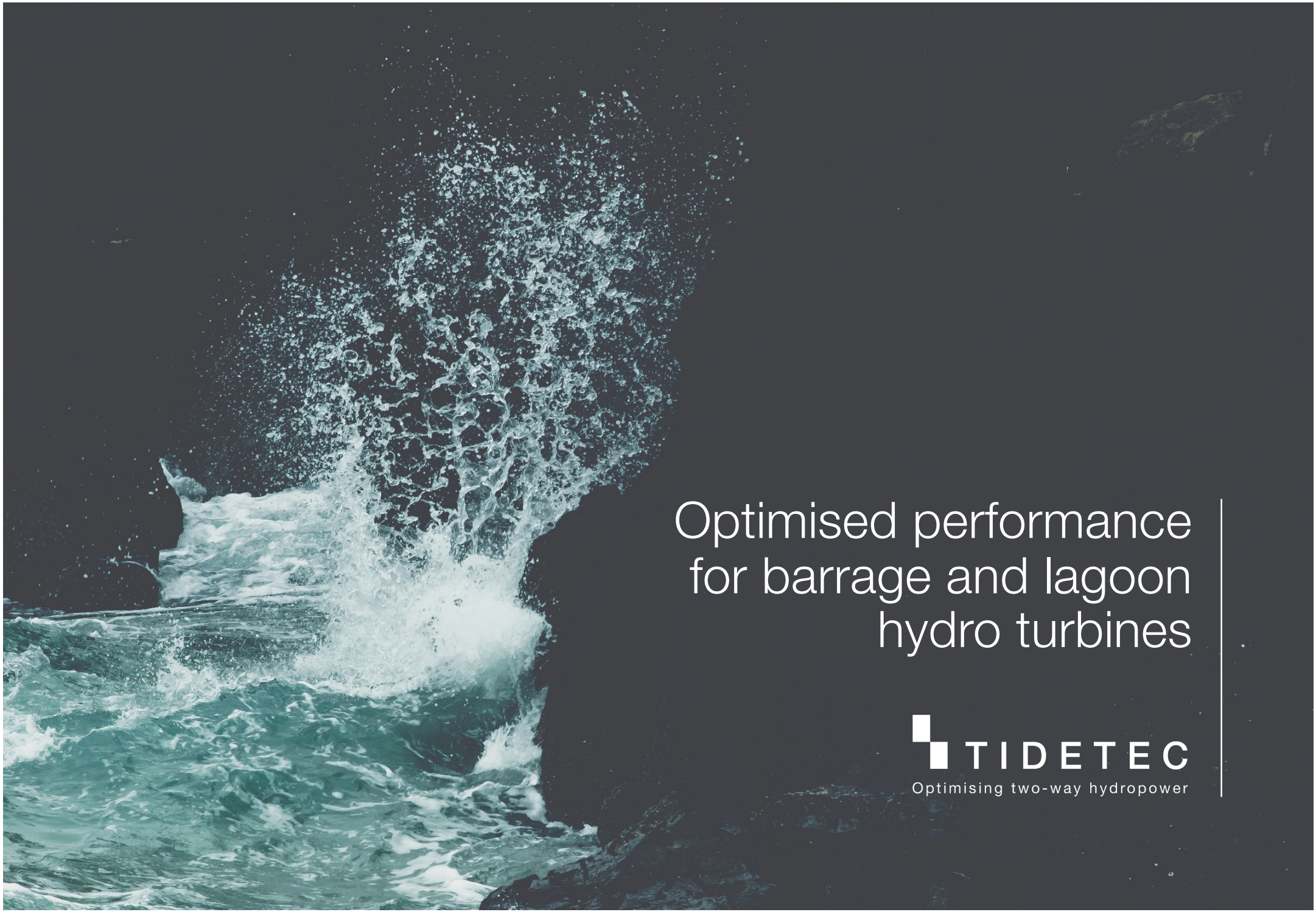

Optimised performance for barrage and lagoon hydro turbines

TIDETEC

Optimising two-way hydropower

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Optimised performance for barrage and lagoon hydro turbines

CONTENT

CONTACT

Arne H. Kollandsrud
Managing Director
+47 907 40 009
arne@tidetec.no

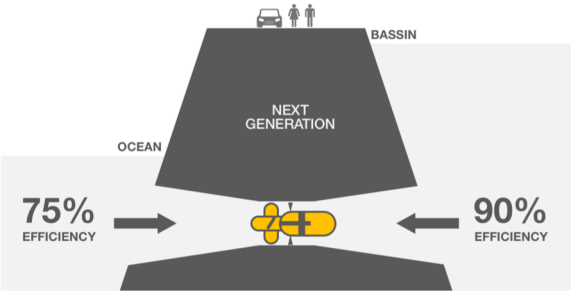
Bjørn-Olav Brelin
Chairman
+47 92248943
bjorn@tidetec.no

Tidetec AS
Mail adress: Munkerudaasen 12 d 1165 Oslo, Norway
www.tidetec.com

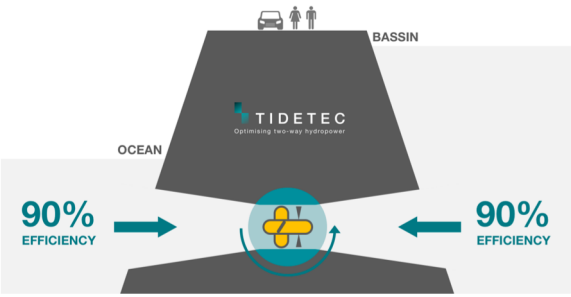
PERFECTLY OPTIMISED TURBINE FOR TWO WAY OPERATION

The Tidetec concept is the most logical way to harness two-way hydropower, such as tidal, in the most cost effective way possible. The concept uses proven technology for all components.

Most tidal power plants today generate power only in one direction. Projected, next-generation tidal plants with two-way production have sub-optimal production, as illustrated below.



Tidetec technology improves efficiency by 11-22% of the most cost effective tidal turbine technology by obtaining optimal efficiency both ways. This is achieved by integrating the turbine into a rotating turret, as illustrated below. The turning mechanism is patented, and has received international recognition.



TECHNOLOGY STATUS

Tidetec has developed a fully functional scale model prototype of the turning mechanism. The turning mechanism prototype has been successfully tested in sea water for two months. Prototyping has shown feasibility of the concept and the model turbine simulations and testing confirm turbine efficiencies much higher than state of the art traditional turbines for 2-way hydropower.

In summary, prototyping engineering, feasibility studies and cost estimations of the Tidetec concept have proven major efficiency increase compared to traditional concepts. The results show that the Tidetec concept is potentially disruptive technology for 2-way hydropower in Tidal lagoons and barrages, and can kick-start this market.

TEAM

Tidetec has built a competent team guided by its co-founder and CEO. Tidetec team has been balanced to meet the commercial phase and Tidetec heading for an establishment of *The Tidetec Two-way Hydropower Consortium* consisting of EPCI partner, State funding partner GIEK /Export Credit and sub-suppliers to be able to deliver for Tidal range projects.

PARTNERS

Tidetec core function is development of market and technology within two-way hydropower. For everything else we use our trusted network of partners. From 2018 Tidetec is collaborating with Engineering company Femkuber AS. *The Tidetec Two-way Hydropower Consortium* consisting of EPCI partner, State funding partner GIEK /Export Credit and sub-suppliers to be able to deliver for Tidal range projects is expected to be in operation during 2018. Tidetec have signed MoU collaboration agreement with several, renowned international developers, turbine producers and sub-suppliers.

MARKET

The Tidetec market is 2-way hydropower, which means the tidal range market, with a focus on the tidal lagoon/tidal barrier/flood defence industry. Recent studies indicate a potential global market for Tidal Range hydropower up to 30Bn€ (investments).

Tidetec concept is not limited by type of turbine, MW or geographical area and we are looking at solutions for both 500 kW turbines and large scale turbines of 20 MW and above.

MARKET ENTRY

The main partners/clients are developers of tidal range power plants. The innovative Tidetec concept will improve on current technology to enable a substantial increase in operational efficiency versus traditional hydro turbines for tidal applications, with between 11-22% higher energy output. Tidetec is current in discussions with several project developers of large scale pathfinder projects, as well as small scale power plants.

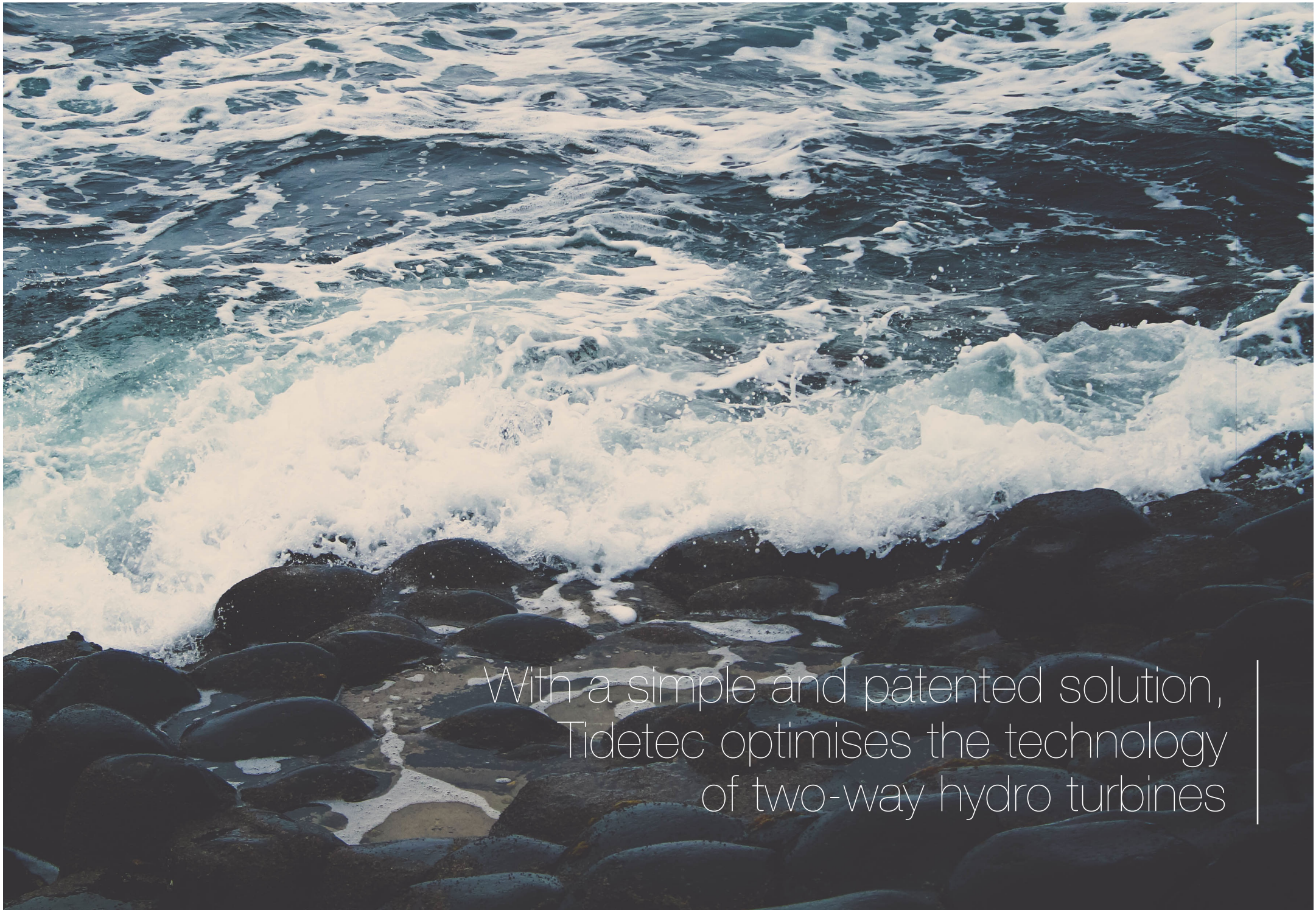
BUSINESS MODEL

The Tidetec business model is divided in two segments:

1) Further development of Tidetec patented technology.
2) Implementation of Tidetec technology in projects and market development by identification and early phase development of two-way hydropower projects.

NEXT STEPS

Tidetec is building a Norwegian consortium with EPCI partner, GIEK/Export Credit (Norwegian guarantee and state funding) and sub-suppliers to be able to deliver to projects mainly in UK. Our focus is a successful development of the first Pathfinder project to demonstrate that the concept will deliver competitive level on Levelized Cost of Energy (LCOE) versus other energysources. The consortium can be a vehicle for upcoming international projects.



With a simple and patented solution,
Tidetec optimises the technology
of two-way hydro turbines

Tidetec history in brief

R&D

2003
Tidetec founded
by Per Kollandsrud
Patent 1 granted

2013
Arne Kollandsrud
hired as MD

2014
MEUR 1.9 Eurostars project

2015
Nomination at
Tidal Energy Summit 2015

2016
Patent 2 filed

2016
Functional scale model turning
mechanism tested in sea water
Patent 3 filed

2017
Tidetec featured as promising technology in Hendry review
Tidetec wins All-Energy Investor Challenge
Laboratory turbine model testing successfully completed

2017
Signed MoU with main project developer
Patent 2 granted

2018
Establishing Tidetec Two-way
Hydropower Consortium

2018
Tidetec Consortium invited to bid on
potential UK Pathfinder projects

FOUNDER INVESTED EUR 800 K

2003-2015
Founder and others
invested €800k

2015
Fundraising EUR 160k
(completed)

2016
Fundraising EUR 140k
(completed)

2017
Fundraising EUR 200k
(completed)

2018
Fundraising

PURPOSE

With a simple turnable and optimized turbine solution, Tidetec can significantly improve energy output in two-way tidal power plants compared to traditional technology. The solution is logical – we simply turn the turbine to produce with the same efficiency in both flow directions. We build our concept on conventional turbines, and proven turret technology.

VISION

Kick-start the tidal range market.
Tidetec technology shall be the key technical component that provides competitive LCOE and thus releases investments in the tidal range industry.

HISTORY

Tidetec AS was established by Per Kollandsrud in 2003. Inspired by the strong tidal currents in the north of Norway, Per - set out to improve the technology on the market – successfully patented a turnable turbine, which led to the creation of Tidetec. 10 years later - with a significant growth outlook for the tidal lagoon market - his son Arne started the commercialisation process. He secured a 1.9 million EUR Eurostar project and got on board other crucial partners for the way forward. In 2015, the team was strengthened by a business developer. In 2016 the team grew further and Tidetec comprised three highly motivated professionals who took the concept towards commercialization. After a successful completion of the Eurostar project Safe*Coast in 2017, Tidetec signed in 2018 MoU with UK project developer and started establishing "The Tidetec 2-way hydropower Consortium" consisting of Norwegian EPCI partner, turbine producer, GIEK/EC and others to be able to deliver for UK Flood defence and tidal power project. The collaboration with Engineering company Femkuber AS was increased, and new Chairman Bjørn-Olav Brelin joined the company. Advisor Frederik W. Mowinckel has been assisting Tidetec since 2016.

PATENTED TECHNOLOGY

Tidetec have developed a fully working patented design for turning low head hydro turbines. The Tidetec technology is covered by patents, with the latest being filed in 2017

Primary Patents awarded (Norway):
2003: Pat.no. 318654
2009: Pat.no. 330474
2012: Pat.no. 334729
2016: Application no. NO-20160419, Granted 2017, and submitted for international PCT patent.
2017:International Patent Application No. PCT/EP2017/05559

Through the PCT system, patents are valid in most countries with significant tidal power resources: UK, Russia, France, Korea, Japan, EU, Germany, China, Canada in addition to Norway.

The patents cover all forms of turning a low head hydro turbine for two way application.

ENGINEERING

With a strong engineering partner Femkuber consisting of highly skilled engineers we have established several robust designs adaptable to different type of low head hydro turbines. All engineering work is covered by strong NDAs where other partners have been involved. The team has strong engineering capabilities regarding operational strategies for tidal power plants. The skills needed for site simulations like 0D and 2D simulations are well covered.

BUSINESS MODEL

The Tidetec businessmodel is divided in two segments:

1) Further development of Tidetec patented technology.
2) Implementation of Tidetec technology in projects and market development by identification and early phase development of two-way hydropower projects.

PARTNERS

We have several long term partnerships with the following organizations:

TUM (Technical University of Munich)
Onsagers AS
Femkuber AS
Advokatfirmaet CLP DA
Kollan AS
Innovation Norway
1-Tech
EPCI partner

Tidetec improves the most effective tidal turbine technology by integrating the turbine into a rotating turret, enabling optimal efficiency in both directions

SUMMARY OF TECHNOLOGY

Most two-way tidal power plants today generate electricity in reverse mode with very low efficiency, less than 60%. In optimized versions, next generation technology based on the same conceptual design, have shown improved reverse efficiency, up to 75%. With Tidetec's innovative solution power efficiency will be equally high in both directions, 90%-90%

The technology enables optimal turbine function (generation and pumping) with bi-directional flow. Tidetec's technology consists of three main technology components; The turret with a turning mechanism, turbine and caisson Tidetec's core competence lies in the integration of these components.

TURRET WITH A TURNING MECHANISM

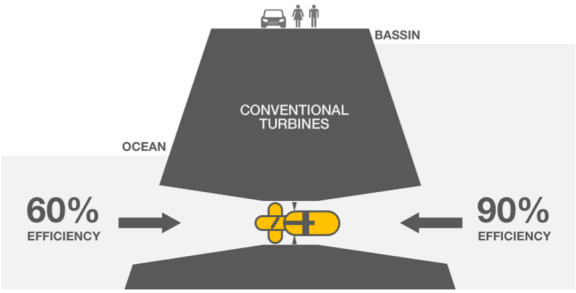
At the core of Tidetec's concept is the rotating turret. Its main function is to allow turning the turbine, enabling optimal bi-directional functionality. Tidetec has a portfolio of turning mechanisms suited to different turbines.

TURBINE

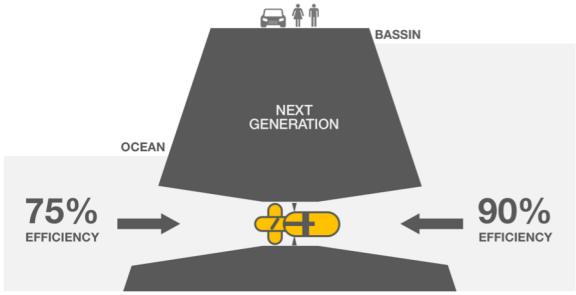
In principle, any turbine can be applied in the Tidetec solution, however some designs fit better than others. Tidetec, in collaboration with TUM, have developed a low head turbine that is capable of generating energy in both flow directions, "basin to sea" and "sea to basin" and also effectively pumping in both directions. The increased discharge characteristics of the turbine is also important in tidal barrage configurations.

CAISSON

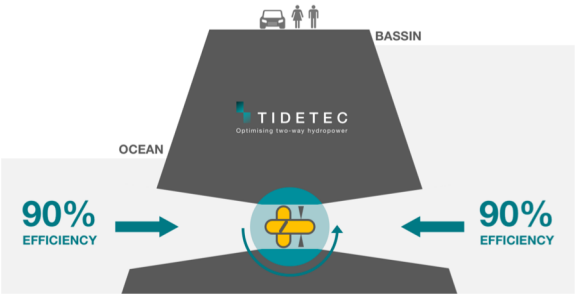
The Tidetec turbine solution is intended to fit into a concrete caisson that will form part of a dam/barrage/lagoon. The construction will likely consist of three elements; sluices, caisson for turbine placement in addition to a passive breakwater.



CONVENTIONAL TURBINES: Current technology only utilizes 60% of streams flowing back into the basin



NEXT GENERATION: Turbine manufactures strive to improve bidirectional efficiencies, but potential efficiency gains are limited



TIDETEC has patented a solution that enables maximal efficiency both ways

Tidetec enables >20% higher efficiency than conventional turbines and >10% versus the most ambitious Next Generation technologies for an overall efficiency in a tidal lagoon power plant

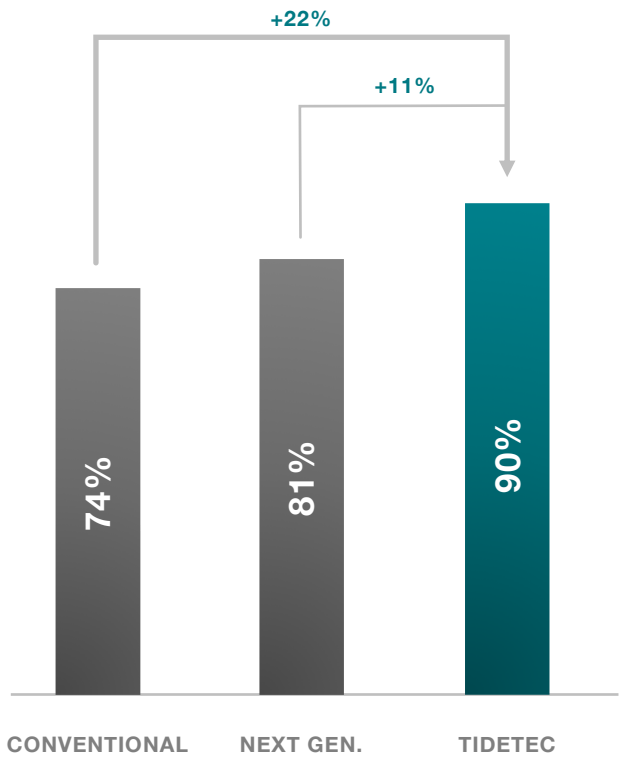
BENEFITS

>20% more efficient than existing "Conventional" technologies due to maximum efficiency also in reverse flow mode

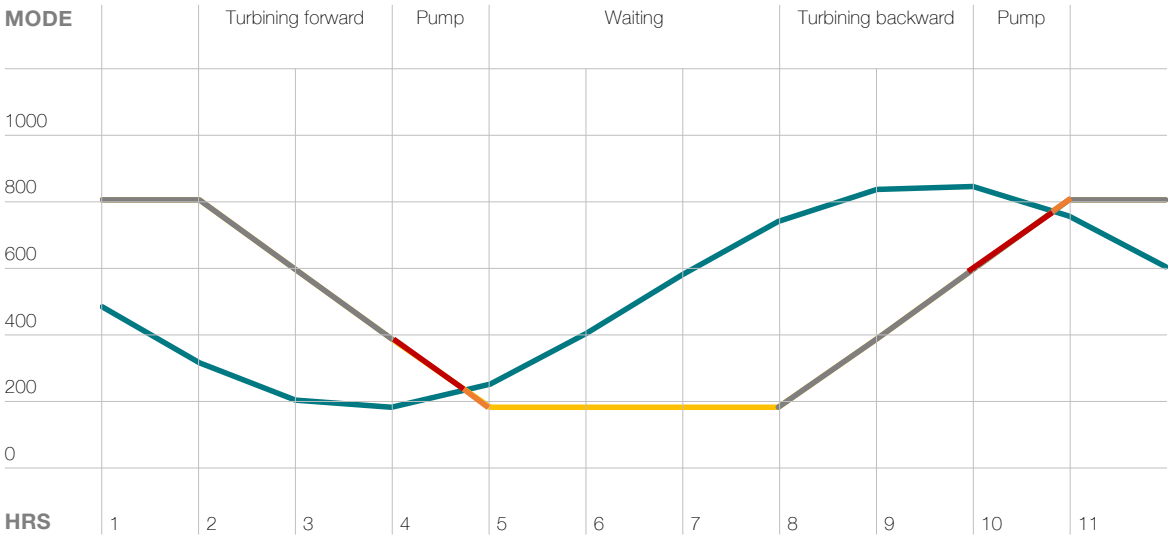
>10% more efficient than the most ambitious "Next Generation" turbines

Simpler design; turbines are optimized for only one direction

Operational advantages, as sediments are handled more effectively with the turret acting as a sediment remover



Overall efficiency of turbine weighted for operation mode in tidal power plant



FORWARD MODE

BACKWARD MODE

MODE	Turbining forward	Pump	WEIGHTED AVERAGE	Turbining backward	Pump
%	46%	4%		46%	4%
CONVENTINAL	90%	60%	74%	60%	60%
NEXT GEN.	90%	60%	81%	75%	60%
TIDETEC	>92%	>65%	>90%	>92%	>65%

ENERGY GENERATION THROUGH A TIDE CYCLE

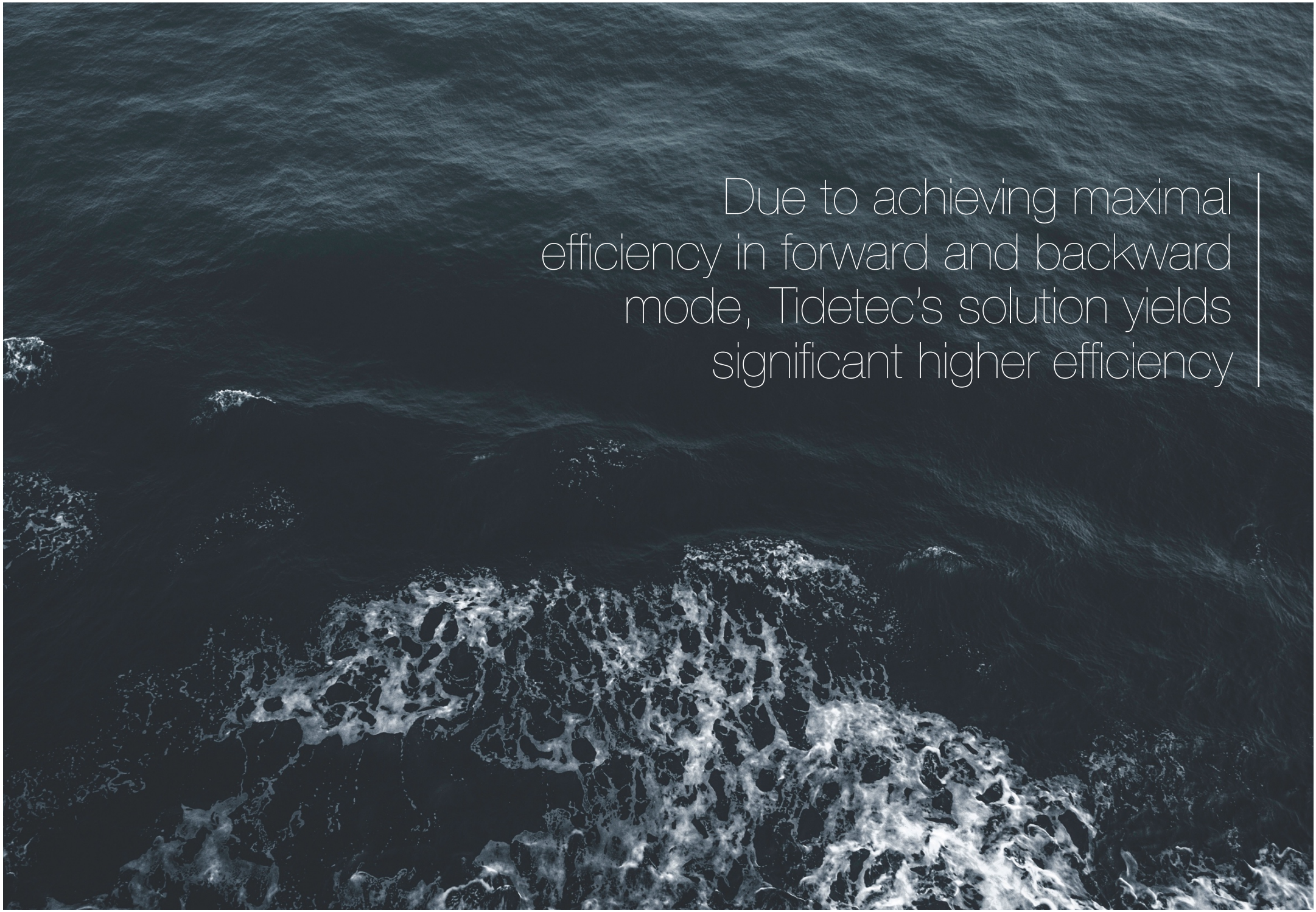
With Tidetec's solution, energy from in- and outflows are utilized at 92% and pumping mode at 65%, yielding a weighted average utilization of 90%

This is contrasted with conventional turbines, yielding 74% average efficiency

Next generation turbines, that are currently under development, strive at reaching an average efficiency of ~81%

The energy yield is not a direct consequence from maximum turbine efficiency for a tidal range turbine, since they do not operate at maximum efficiency but rather closer to the maximum discharge. This favorizes the Tidetec turbine and its ability to pump to higher levels and at a higher efficiency than a Next generation turbine based on Kaplan Bulb design. The Tidetec turbine is also capable of producing at lower heads than the Kaplan Bulb solution. To summarize, the Tidetec solution yields 11-22% more energy than the competing Kaplan Bulb technology.

Tide level
Lagoon level
Turbining
Sluice
Pump



Due to achieving maximal efficiency in forward and backward mode, Tidetec's solution yields significant higher efficiency

Complete system

Tidetec's technology consists of three main technology components; the Turret with turning mechanism, the turbine and the caisson. Our core competence lies in the turning mechanism and the integration of all components.

Turret with turning mechanism

A COST EFFECTIVE AND FEASIBLE WAY TO TURN A TURBINE

The rotating turret is the core of the Tidetec concept. The main intention of the turret is to turn the turbine, to enable optimal bi-directional functionality. Tidetec have a portfolio of patented turning mechanisms suited to different turbines.

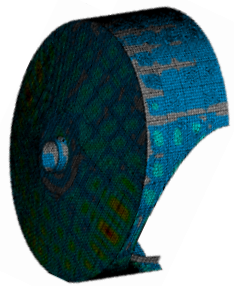
The turret solution allows for a lighter, and thus less costly turbine. The total cost of a complete Tidetec turbine system is equal to the cost of the systems planned today. The cost of the turret, is compensated by a lower turbine cost due to simpler and lighter turbine design. Feed engineering has been conducted for the complete turning system, to have a reliable cost estimate.

TURNING MECHANISM

The rolling turret, is based on a cylinder rotating around a horizontal axis. It has bearings on each side of the cylinder, avoiding the need for a thrust bearing. A hollow axle (shaft) is mounted on one side of the cylinder, where all cables and cable management evacuates into a dry room in the caisson. This axle is also where the rotating movement of the turret is actuated.

DIMENSIONING

Dimensioning and stress tests have been conducted on a 6 meter diameter turret. The turret has more than sufficient capacity to withstand the hydrostatic pressure and the axial force of the turbine during operation.



Turbine

As the Tidetec turret solution is a new conceptual way of using a low-head hydro turbine, in principle any low-head hydro turbine can be applied. However, Tidetec in collaboration with TUM have developed a compact, low head turbine optimized for turret installation. This means a turbine which can operate in all four quadrants of a head discharge-diagram. Basin to sea, sea-to basin and pumping both ways.

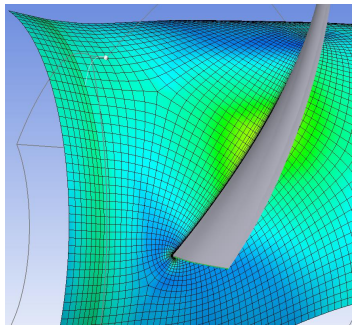
A variable speed tubular Straflo turbine is used in the design of the Tidetec turbine.

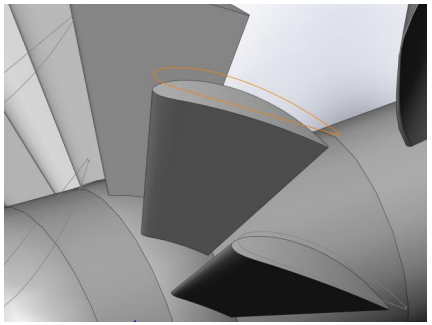
The variable speed turbine will be equipped with adjustable guide vanes, fixed runner blades and a turning mechanism. This design permits an optimal four-quadrant-operation. Turbine efficiency in turbining mode is simulated to be above 90%. The turbine runner and guide vanes have been optimised for 2 to 8 meter head using ANSYS and Solidworks.

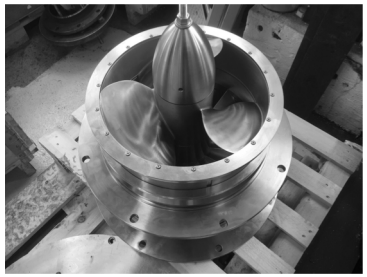
The Straflo turbine is a well known turbine with almost 100 existing installations. It has also been used in tidal barrage application at Annapolis Tidal power plant.

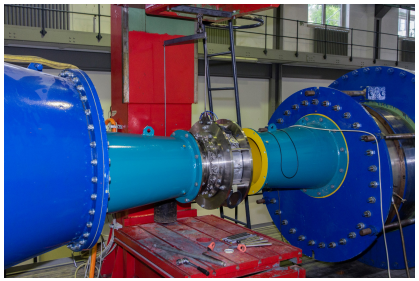
The model turbine testing in Munich, proves that we have reached:

1. High two-way energy efficiency
2. High pumping efficiency
3. High discharge capacity
4. Compact size









design and simulation work at TUM.

Caisson

Tidetec's turret solution is intended to fit into a concrete structure (caisson), which is part of a dam/barrage/lagoon. The purpose of this construction is to separate two water masses, as well as housing the turbine. The construction will consist of three elements; sluices, caisson for turbine placement in addition to a passive breakwater.

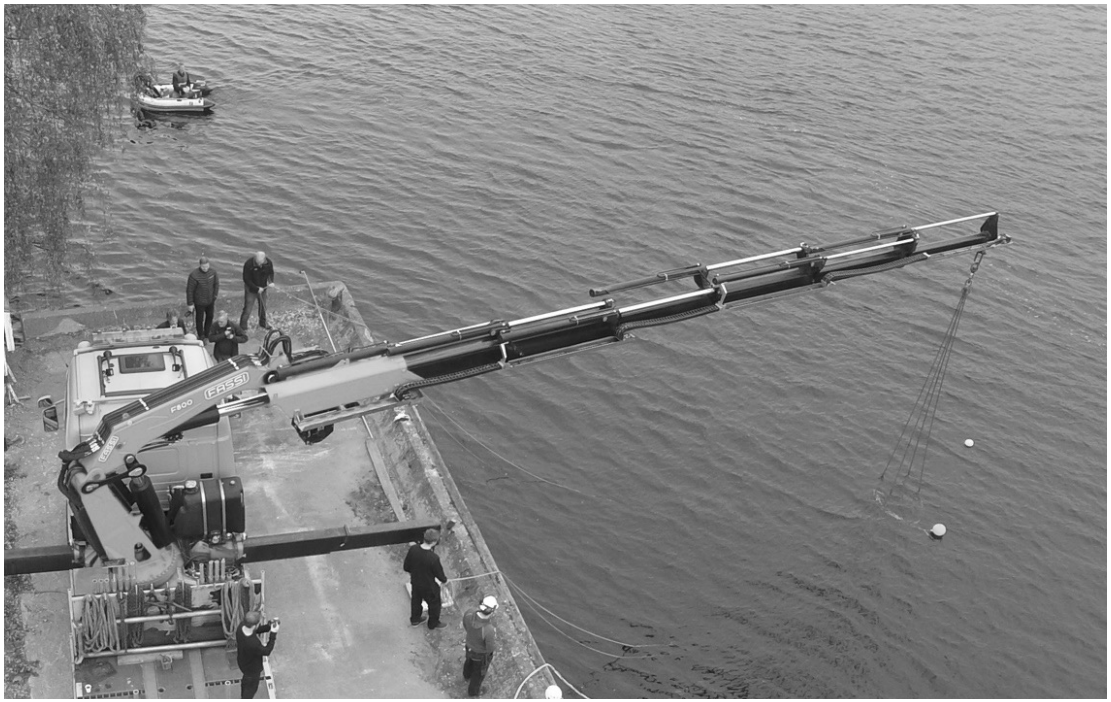
The caisson is constructed with ease of maintenance in mind, so all critical areas are easily accessible.

A conceptual design has been evaluated regarding cost, installation method and strength.

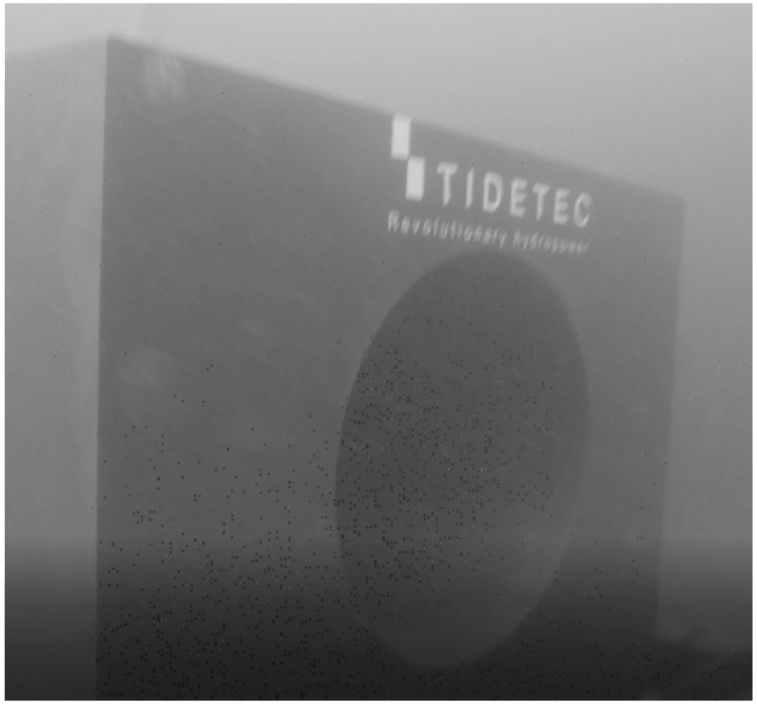
Scale model

The Tidetec prototype for the turret and turning mechanism was tested in the Svelvik tidal stream during September to October 2016. The main purpose was to showcase and prove the concept, to show the robustness of the turning mechanism, the ability to keep the intended areas dry and operational in harsh sea water conditions.

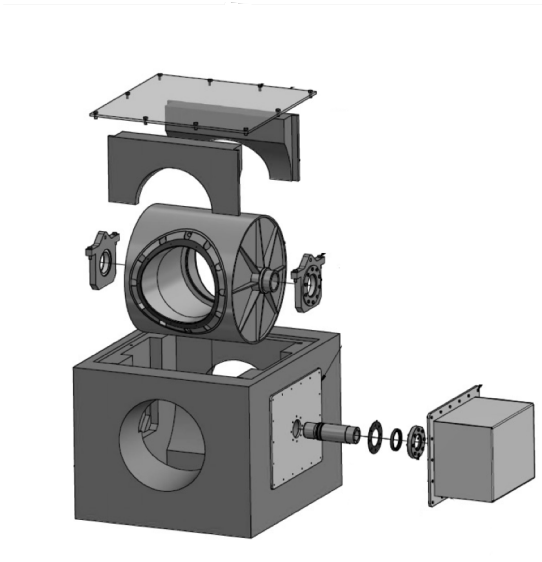
The prototype consists of a polymer caisson, a steel turret with a turbine and a rotating drive and CPU to control the timing and set points of the rotation. The prototype is instrumented to make sure that all activity is logged, and to secure that the system is working as intended. Test data and additional documentation can be acquired on request.

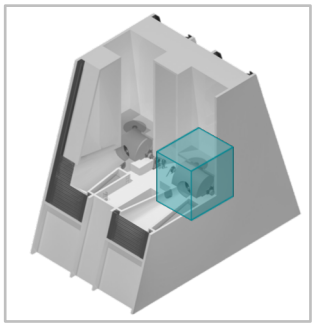


The Tidetec model was successfully installed in the Svelvik tidal stream on September 21st 2016



The scale model was submerged during September to November 2016 showcasing the turning mechanism





MAIN DIMENSIONS
Size: 1000 x 1000 x 1200 mm (without lifting frame)
2200 x 3500 x 2000 mm (with lifting frame)
Weight: 3,5 tonnes
Designed for easy placing and retrieval

PURPOSE OF TESTING
Small scale sea water testing of Tidetec turning mechanism with turbine

LOCATION SPECIFICATIONS
Two-way flow
Sediments in the water
The depth at the location is about 4,5 meters
Close to power supply and grid
Possibility to use crane
Workshop for assembly
Proximity to airport to display turbine to potential clients

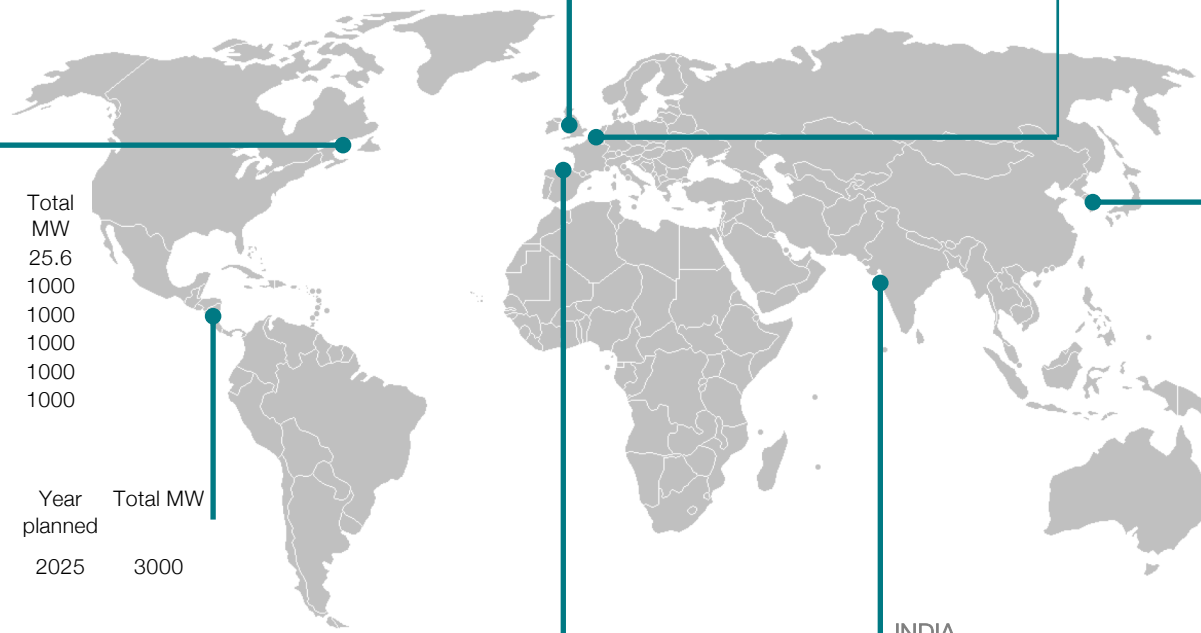
LOCATION
Svelvik - one hour drive from Oslo

TESTING SCHEDULE
The prototype was operational from mid September to end October 2016.


Tidal energy has a huge
worldwide potential, pioneered by
UK, South Korea and Canada

Market potential

Academic studies have identified over 300GW of potential tidal range capacity globally.



UK

Project name	Year planned	Total MW
Swansea Bay	2018	320
Cardiff	2020	3000
Wyre	2020	120
Newport	2022	1600
Churchill Barriers	2022	26
Colywyn Bay	2024	1600
Picardy coastline 1	2025	2000
Picardy coastline 2	2025	2000
Scots bay	2025	1100
North Wales	2025	2000
Bridgwater	2026	1600
West Cumbria	2028	1600

NETHERLANDS

Project name	Year planned	Total MW
Grevelingendam	2022	80

CANADA

Project name	Year planned	Total MW
Pennamaquan Project	2019	25.6
Bay of fundy 1	2030	1000
Bay of fundy 2	2030	1000
Bay of fundy 3	2030	1000
Bay of fundy 4	2030	1000
Bay of fundy 5	2030	1000

SOUTH KOREA

Project name	Year planned	Total MW
Garolim	2020	520
Incheon	2025	1440
Ganghwa	2030	838
Sihwa	2011	254

MEXICO

Project name	Year planned	Total MW
Baja California, Mexico	2025	3000

FRANCE

Project name	Year planned	Total MW
Cotentin Peninsula 1	2025	2000
Cotentin Peninsula 2	2025	2000
Cotentin Peninsula 3	2025	2000

INDIA

Project name	Year planned	Total MW
The Gulf of Khambhat 1	2022	5500
The Gulf of Khambhat 2	2022	5500

Areas eligible for tidal energy generation

Examples of existing and planned projects.

Several large prospects are coming up near-term in UK and South-Korea.

SWANSEA BAY
Design completed
Installed capacity (MW): 320

CARDIFF
Feasibility study completed
Installed capacity (MW): 3000

WYRE
Planning phase
Installed capacity (MW): 120

NEWPORT
Feasibility study completed
Installed capacity (MW): 1600

CHURCHILL BARRIERS
Feasibility study completed
Installed capacity (MW): 26

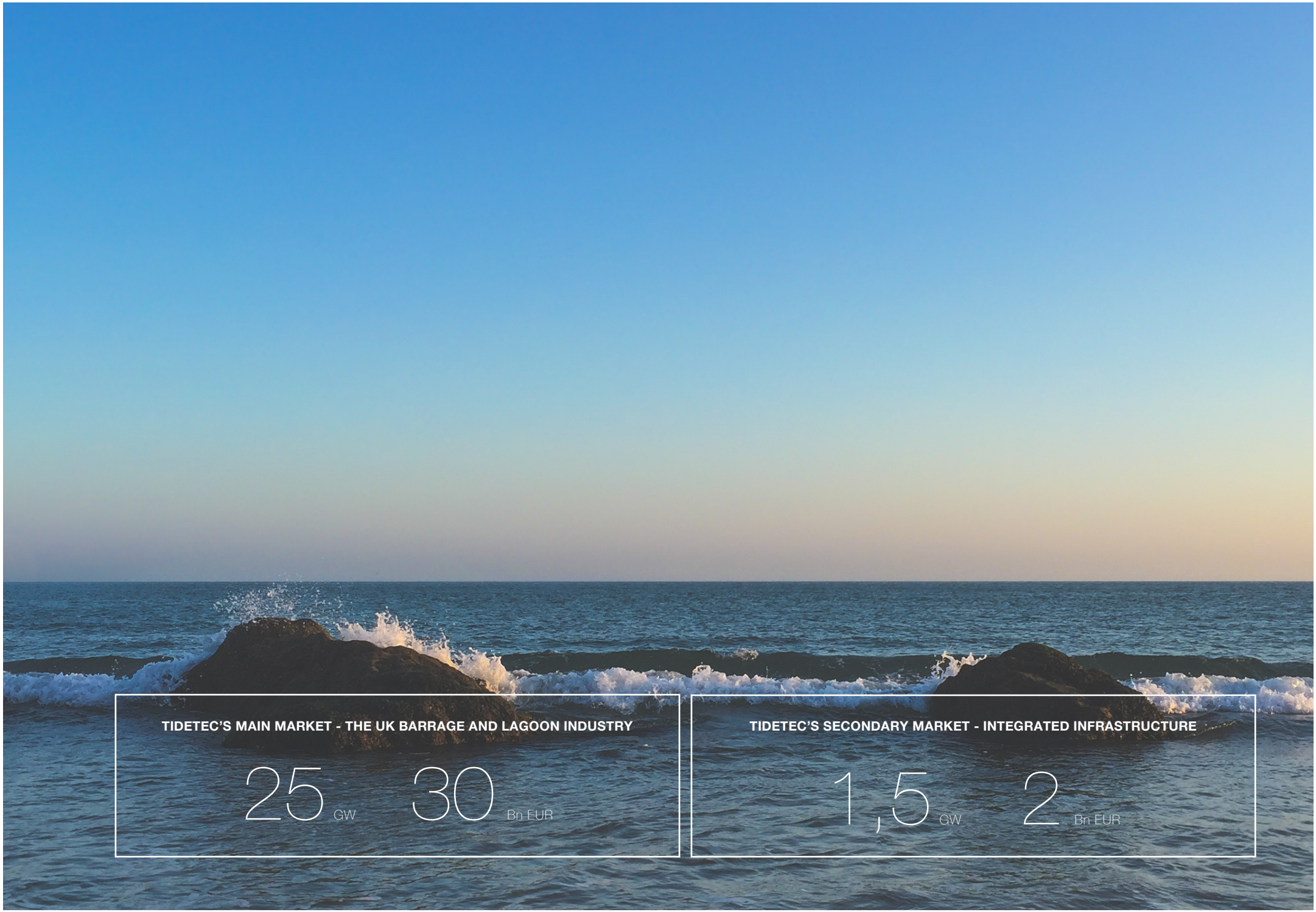
GAROLIM
Design completed
Installed capacity (MW): 520

INCHEON
Feasibility study
Installed capacity (MW): 1440

GANGHWA
Pre-feasibility study
Installed capacity (MW): 26

SIHWA
Completed (2011) and operational
Installed capacity (MW): 254

ULDOLMOK
Completed (2009) and operational
Installed capacity (MW): 1.5



TIDETEC'S MAIN MARKET - THE UK BARRAGE AND LAGOON INDUSTRY

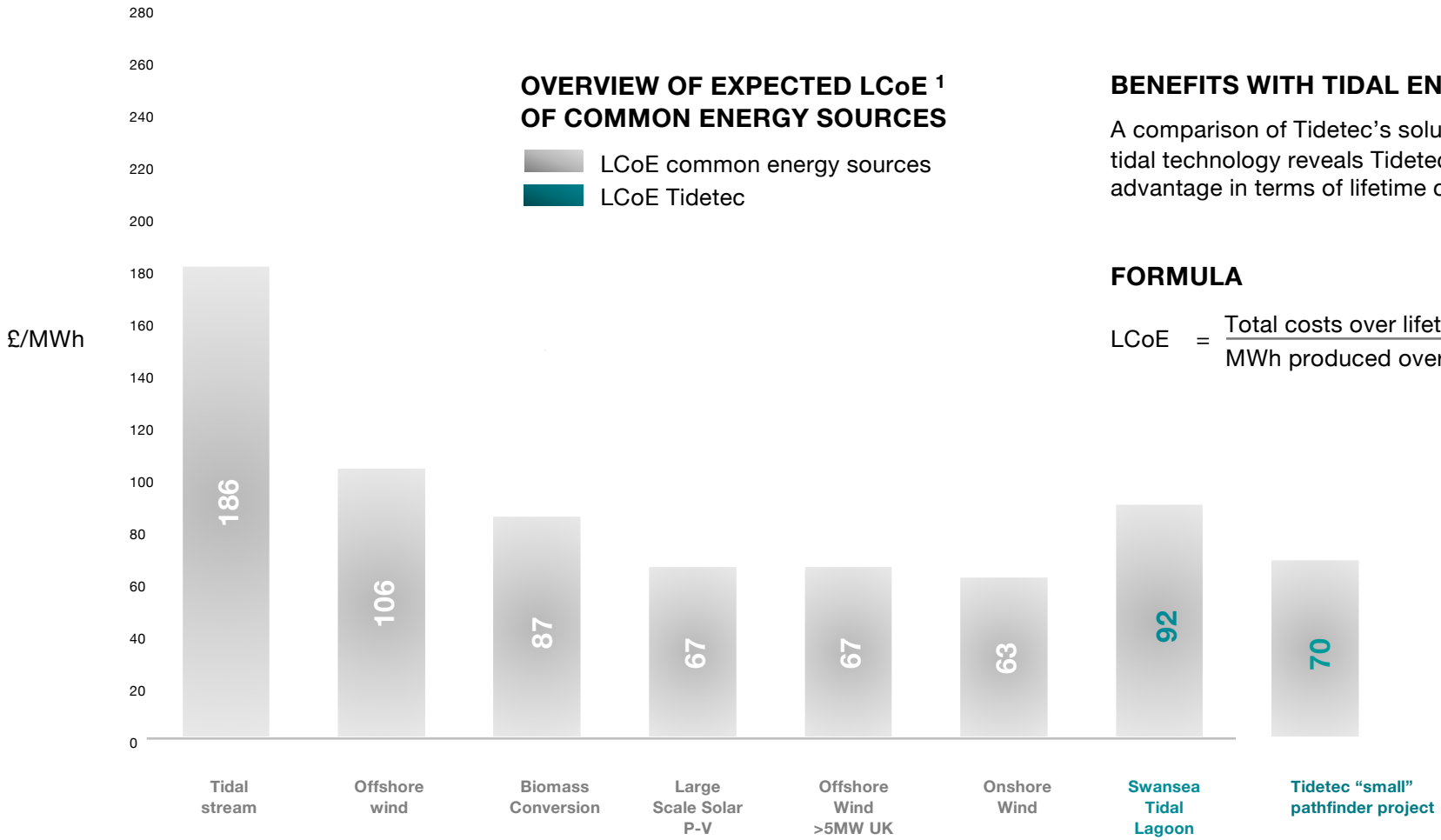
25 GW 30 Bn EUR

TIDETEC'S SECONDARY MARKET - INTEGRATED INFRASTRUCTURE

1,5 GW 2 Bn EUR

Levelized Cost of Energy (LCoE) Estimates for Projects Commissioning in 2020

To be noted: Tidal power is predictable and adds flood protection capabilities



BENEFITS WITH TIDAL ENERGY

A comparison of Tidetec's solution for tidal technology reveals Tidetec's advantage in terms of lifetime costs

FORMULA

$$\text{LCoE} = \frac{\text{Total costs over lifetime}}{\text{MWh produced over lifetime}}$$

Figure: BEIS_Electricity_Generation_Cost_Report.pdf , Nov 2016, Page 22

TIDETEC
Optimising two-way hydropower

Tidetec's Team

CORE TEAM

Arne H. Kollandsrud
CEO Tidetec, Co-founder and Investor

Arne has been working as the CEO since 2013 and is a co-owner of Tidetec. He has been Member of the Board in Tidetec since his father Per Kollandsrud founded the company in 2000.

Bjørn Olav Brelin
Strategy advisor
Chairman Tidetec

Investor and top-level executive with background from leading positions in the international Solar Energy Industry. Current: co-founder and CEO of circular economy venture Nuvosil AS. Former: CEO and General Counsel of Norwegian wafer manufacturer NorSun AS, General Counsel of Scatec AS and partner at Langseth Law DA

Arne Ziegler
Analysis Engineer, MSc
Partner& General Manager
Femkuber AS

Arne has 20 years of experience with structural and mechanical engineering predominantly within the oil&gas industry. He has been leading analysts and engineers on a large variety of projects. He also has experience as a Warranty Surveyor from high-value projects mainly in the Norwegian offshore industry. His Femkuber team is at Tidetecs disposal

ADVISOR

Frederik W. Mowinckel
Strategy and network advisory

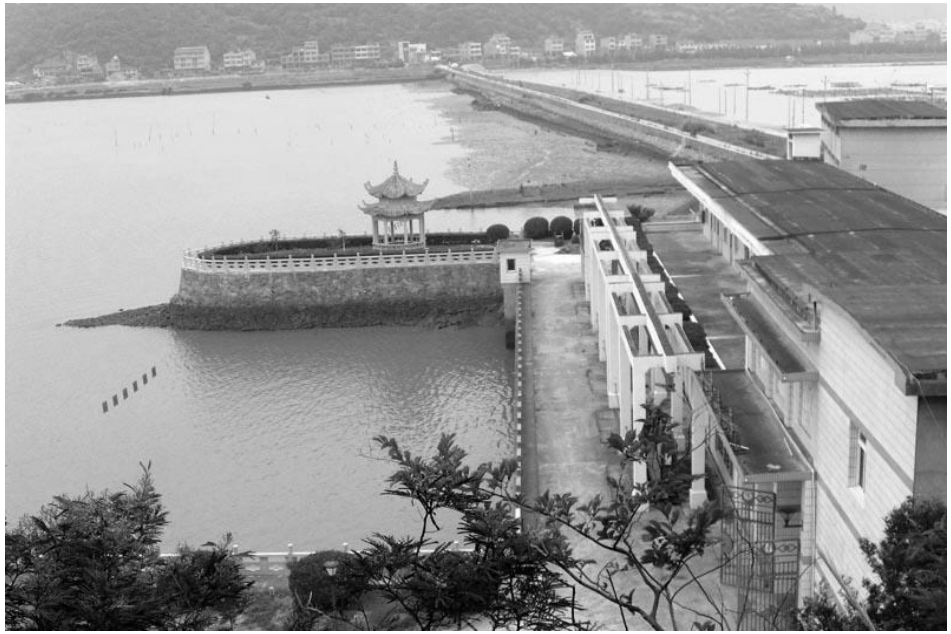
Frederik has over 25 years' experience as an investor, board member and advisor with numerous environmental businesses. Frederik sits on the board of a number of cleantech companies and maintains a wide international network of contacts focused within environmental business.

Tidal power plant examples

Annapolis Royal generating station
Nova Scotia, Canada

Sihwa Lake Tidal Power Station
South Korea

La Rance Tidal Power Station
Brittany, France



Jiangxia Tidal Power Station
China

TIDETEC

Optimising two-way hydropower