TIDAL POWER meeting the environmental challenges of tomorrow

A proposal for cooperation between Holland and Norway.

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Contents:

Tide Tec

Summary:

The world meets great challenges substituting coal, oil and gas with non-emission energy. Global heating causes sea-level rise.
Increased vaporization causes more precipitation. This will challenge the flood protection systems. Cities like London, Amsterdam, Hamburg and Bergen and vast land areas in Europe and elsewhere are at risk.

Institute for Infrastructure, Environment and Innovation arranged an international seminar called *OKEANOS project phase II* in June 2010. TideTec AS was invited because we can offer relevant technology. The seminar took place at La Rance, France.

The experiences here have been very influential for new plants under construction or planning - and for new turbine concepts.

This leaflet illuminates the TideTec concept in relation to the Dutch plans and former and new concepts which have been published.

We regard the presented opportunities as very relevant for transnational cooperation.

Market for new technology

Needs in Holland

The flood disaster in 1953 led to the first Delta plan. Climate changes may hit Holland gravely.

Therefore substantial investments for improvements of the flood defence have been decided, involving:

- Reinforcements of the barriers
- Generation of sustainable energy
- Controlled water flow

The patented TideTec concept has qualifications which meet the requirements.

Plans for a new "Mini Delta" project and the invitation to participate suits very well with our own strategy for gaining access into the market.

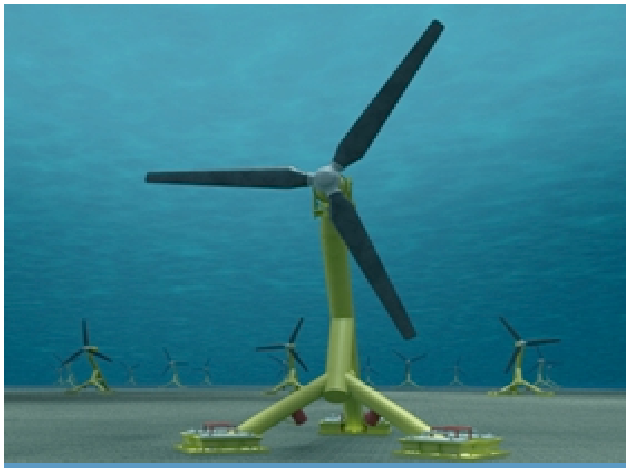
These plans represents the basis for joint Dutch/Norwegian R&D in order to find optimal solutions for turbines/pumps and structure design.

Turbine technologies

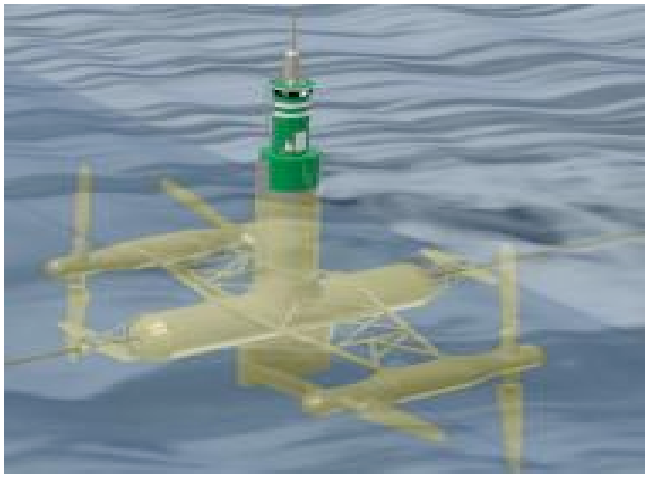
Maine categories

Free stream turbines

These turbines are deployed in open water and harness the kinetic energy like a windmill. Hammerfest Strøm and Hydra Tidal Energy Technology are Norwegian examples of this kind. None of these solutions can offer flood protection or a bridge/pier structure as a bi-product . They are therefore out of question where such demands are in focus.



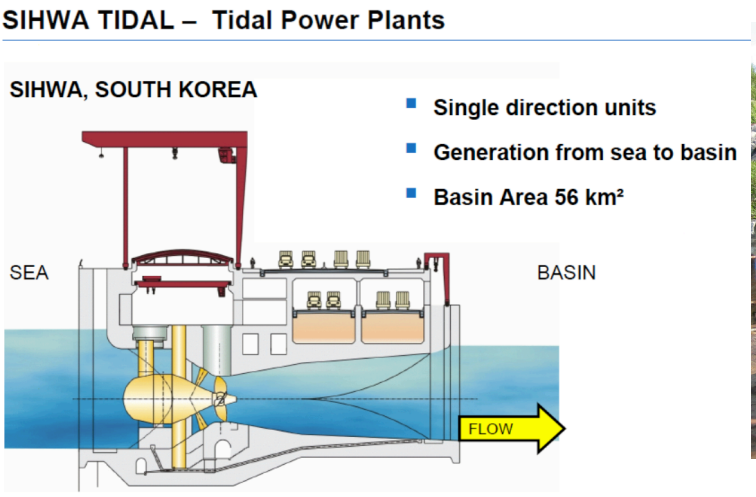
Hammerfest Strøm turbine



Hydro Tidal Energy Tecknology turbine

Tidal turbines in barrages

Kaplan bulb turbines are dominant. Kaplan turbines are first of all designed for river power plants without reservoirs, where heads are very low. The bulb version for axial flow is applied at La Rance and Sihwa in South Korea, and was tested at Kislaya Guba, Russia.



Kaplan runner after 36 years operation at Kislaya Guba, Russia

Kaplan turbine characteristics

This turbine shows excellent performance when the tide flows in the right direction via the guide vanes towards the runner, as in river power plants, but in contrast to rivers the tide flows both direction.

Lacking turbines which may operate two-way with high efficiency several new TPPs are planned, especially in South Korea; all schemes designed with bulbous Kaplan turbines and unidirectional energy generation.

Huge hatches between the turbines are opened to allow the tide to return without energy generation. This scheme reduces energy generation, but enables satisfactory water exchange.

Sihwa Lake tidal power plant with one-way energy generation. Planned finished Autumn 2010.

Atkins + Rolls Royce comments and suggests:

Summary

Existing and Planned Schemes:

- **50% to 60% loss of tidal range**
- **High water velocity**
- **Concerns about migratory fish**

- **Are ebb generation barrages consentable ?**
- **Should Hydro power technology be applied to tidal power ?**

Insert filename

ATKINS Rolls-Royce

Specification for a Tidal Turbine !

- **Bi-directional gives potentially 40% more energy**
- **Lower head and higher flow**
  - **0.5 x tidal range, eg**
  - Mersey spring range = 8.4x0.5= 4.2m
  - Mersey neap range = 4.5 x 0.5 = 2.2m

Insert filename

ATKINS Rolls-Royce

TideTec agrees with Rolls-Royce Atkins that there is a need for special turbines that can harness the tidal energy effectively in both flow directions.

Alternatives to Kaplan that can generate energy both at tide and ebb

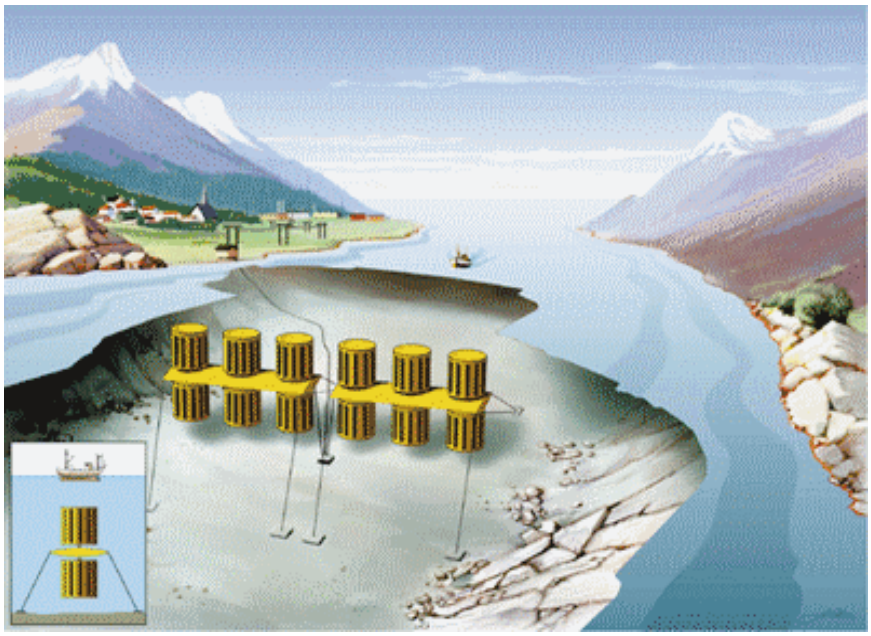
Darrieus turbines (Russian Orthogonal)

Russian scientists have launched a modified Darrieus which they call “Orthogonal”. This turbine operates equally well both ways.

Russian landscape model at the World Exhibition in Tokyo and a full scale runner in workshop before start of tests at Kislaya Guba.

Also Norwegian scientists have worked with the Darrieus turbine (Sintef/Hammerfest Strøm drawing). This turbine type was abandoned.

The efficiency in open water, with firm blades, was recorded by Sintef Research at 20 %.

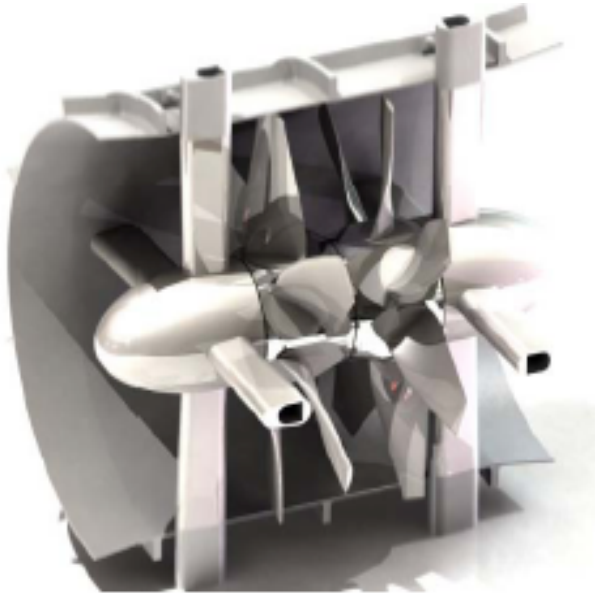


Russian experts are reserved, awaiting the real efficiency records from the site trials.

Rolls Royce tandem turbine

Atkins - Rolls Royce has expressed the following in a presentation given i 2009:
" Bi-directional gives potentially 40 % more energy".

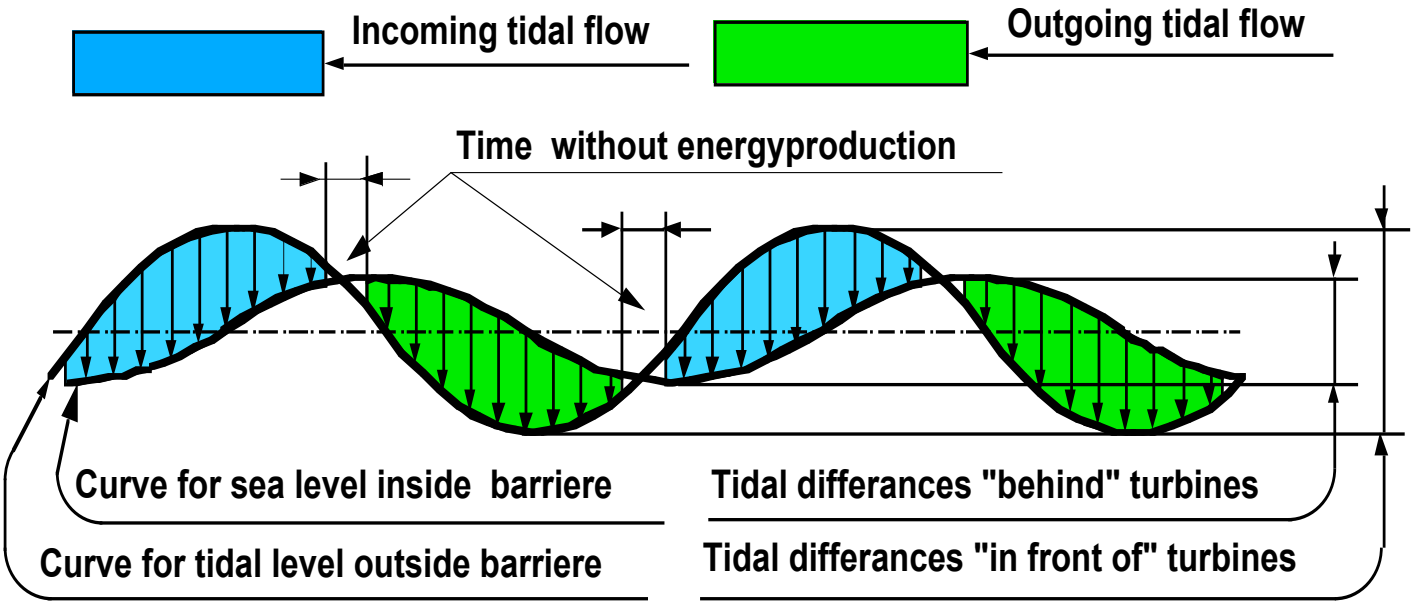
This is a conclusion from a serious industrial actor which is in accordance with the view of us and Russian scientists etc.



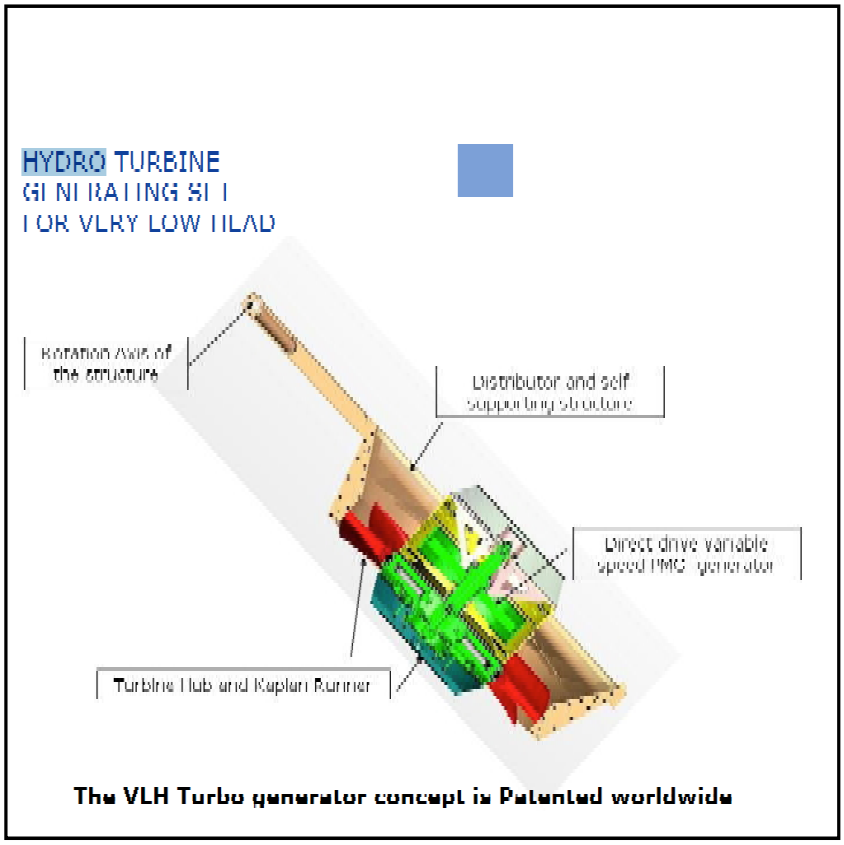
Rolls Royce tandem turbine

Rolls Royce proposes to reduce the pressure fall through the turbine at locations where it might be harmful for migrating fish. However, the danger limits for rapid pressure drops should, in our opinion, be investigated by simple lab-tests. This would show whether the actual pressure gradients at the Brouwersdam are above or under these limits.

For the sake of continuity of energy generation it is important that the intervals between energy generation periods are as short as possible. This demands very low head generation ability.

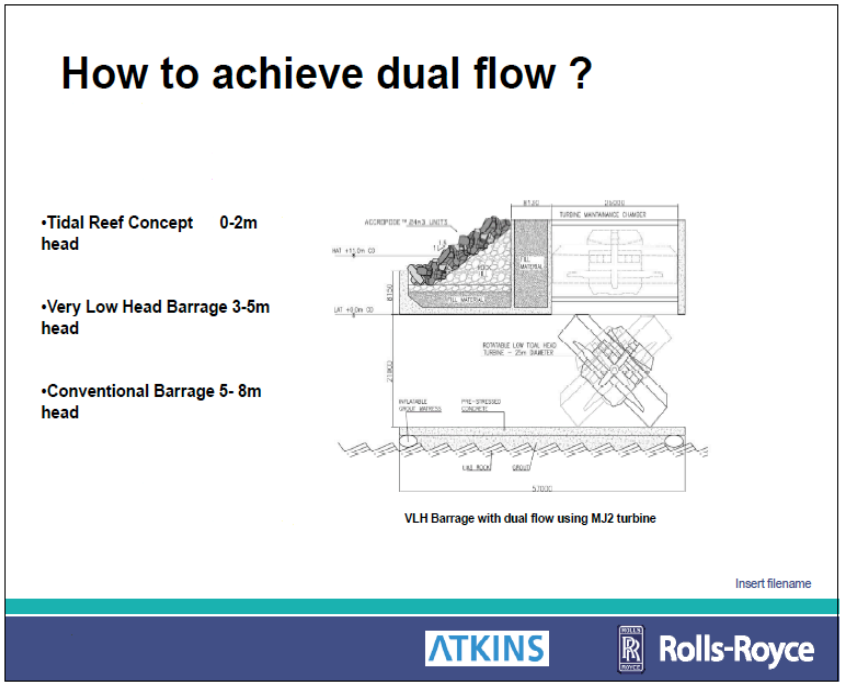


VLH Hydro Turbine



This Canadian/French alternative is presented as especially favorable for low head generation.

It is characterized by a central generator driven by a 8 adjustable blade runner.



Rolls Royce has presented this variant, which operates equally in both directions.

This is achieved by tilting the whole assembly 90 deg. around a horizontal axis.

The concept has some similarities with the TideTec turbine. One question is whether it is favorable to apply a special, submersed generator inside the assembly.

The alternative is standard high speed generators/motors mounted above the highest sea level.

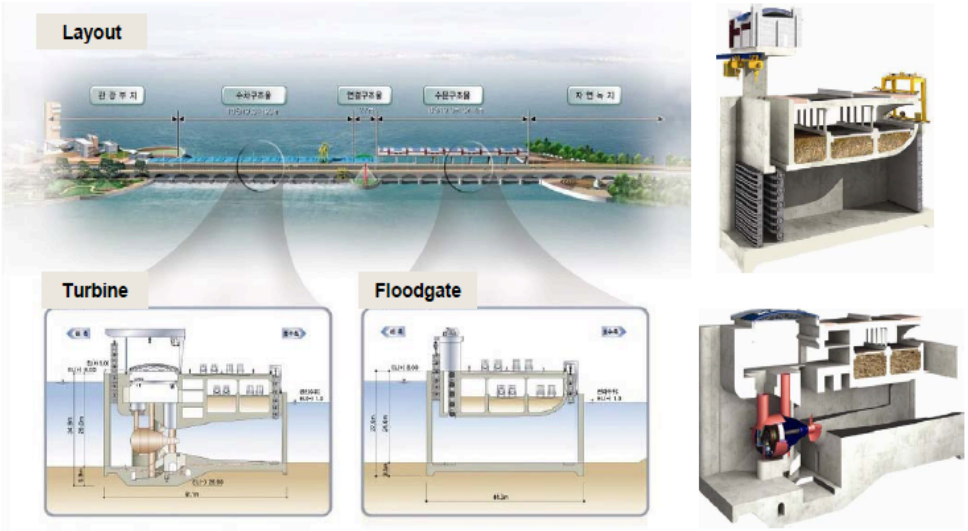
Tidal power in South Korea

Korean authorities expect that during the period 2008-2030 ocean power (tidal andwaves) will increase at average 49,6 % per year versus only 18,1 % for wind power (Source: Innovation Norway, South Korea).

4 tidal power plants are under construction, all based on one-way generation applying Kaplan turbines.

The tides are returned from the basins via big gates without energy generation.

Lake Sihwa tidal project



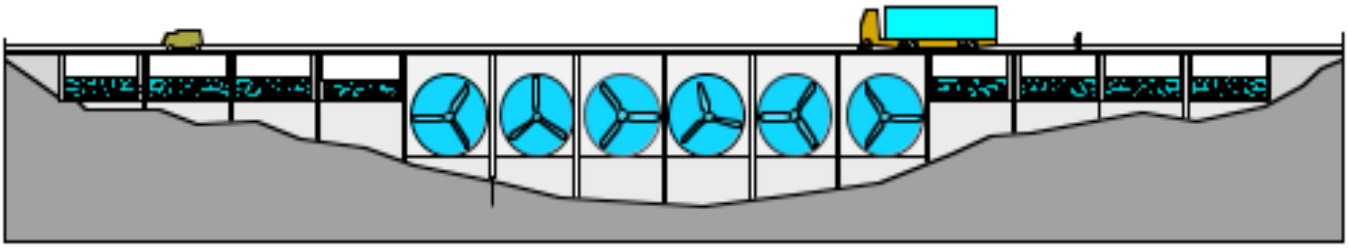
Locality	Basin	Mean tidal	Natural	Production in GWh / year		Exploitation Ratio	
		difference	potenTial Ep	Kaplan	TideTec	Kaplan	TideTec´s
	area	meters	GWh / year	single-effekt	doble-effect	single-effekt	doble-effect
	Km2			operation	operation	operation	operation
Sihwa Lake	43	5,6	2657	553	757	0,208	0,285
Garolim	45,5	4,7	1980	880	1206	0,444	0,609
Incheon	106	5,3	5866	1880	2575	0,321	0,439
Ganghwa	82,5	5,575	5051	1536	2106	0,304	0,417

Applying the same size and number of turbines, which can be turned 180 degrees around a vertical axis at each tidal shift, as patented, an extra 40 % energy generation is expected in average, as advocated by Rolls Royce for their own bidirectional technology.

TideTec is applying a simplified guide vane system without regulation. This is expected to give a lower efficiency than Kaplan. We therefore reduce the 40 % additional energy to 37 %. Our numbers for energy generation and exploitation ratio relative available natural energy are based on the official numbers for the projects, added 37 %. Due to variations of the basin topography the added energy percentage will differ somewhat from project to project, but that is left for more detailed analyses.

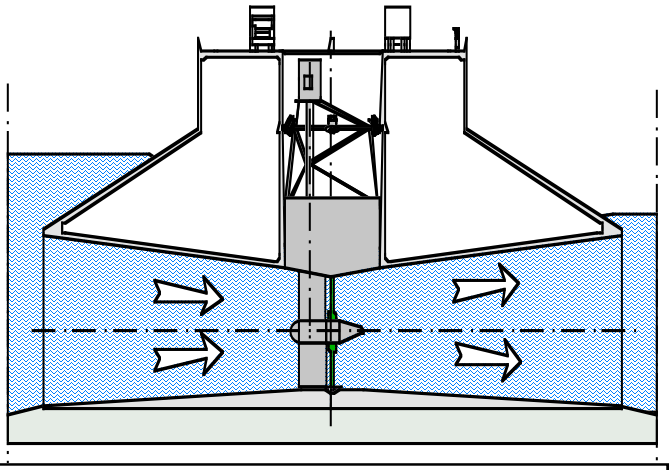
TideTec turbine 1

TideTec AS is a Norwegian company which has specialized on tidal turbines. At locations with moderate tidal differences, but significant wave activity, the wave energy may be harnessed on the same turbines.

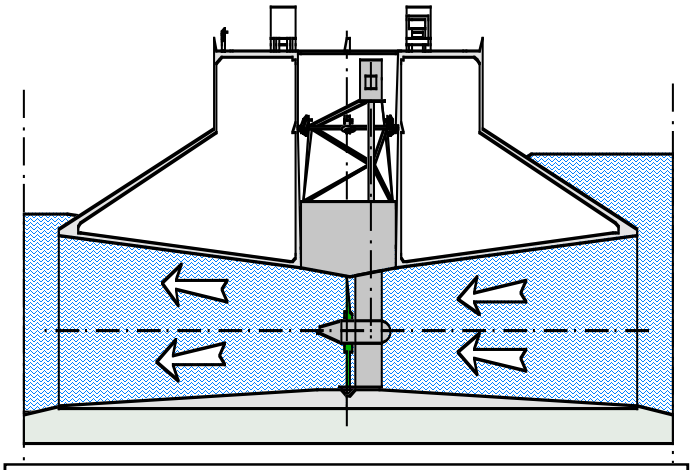


The concept also includes prefabricated concrete modules prepared for roads and rails on the top.

Equal energy generation for both tidal directions is achieved by turning the turbine 180 deg. around a vertical axis between each tidal shift.



TideTec turbine with incoming tidal flow



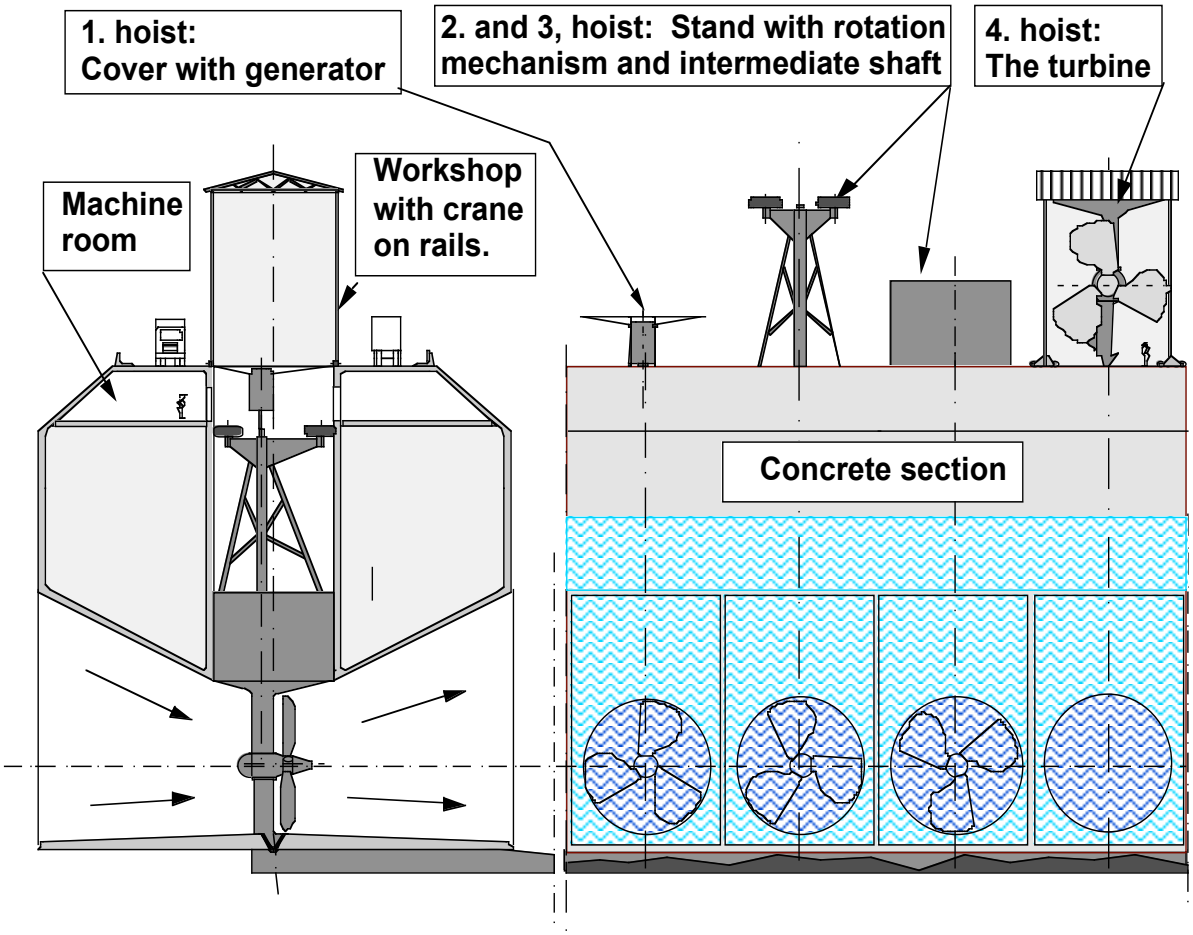
TideTec turbine with outgoing tidal flow

The turbines may be run as pumps in order to lift or lower the sea level inside the dam. This improves the flood protection function and energy generation potential.

The concept is flexible and may be adapted in order to comply with local needs and possibilities.

TideTec turbine 2

Mounting/dismantling of the turbines is conducted by means of agantry crane on rails. By dividing the machinery into 3 parts: generator, turning section and turbine body the demands forlifting capacity and height above the dam are kept reasonable.



Draft of concrete modules with TideTec turbine

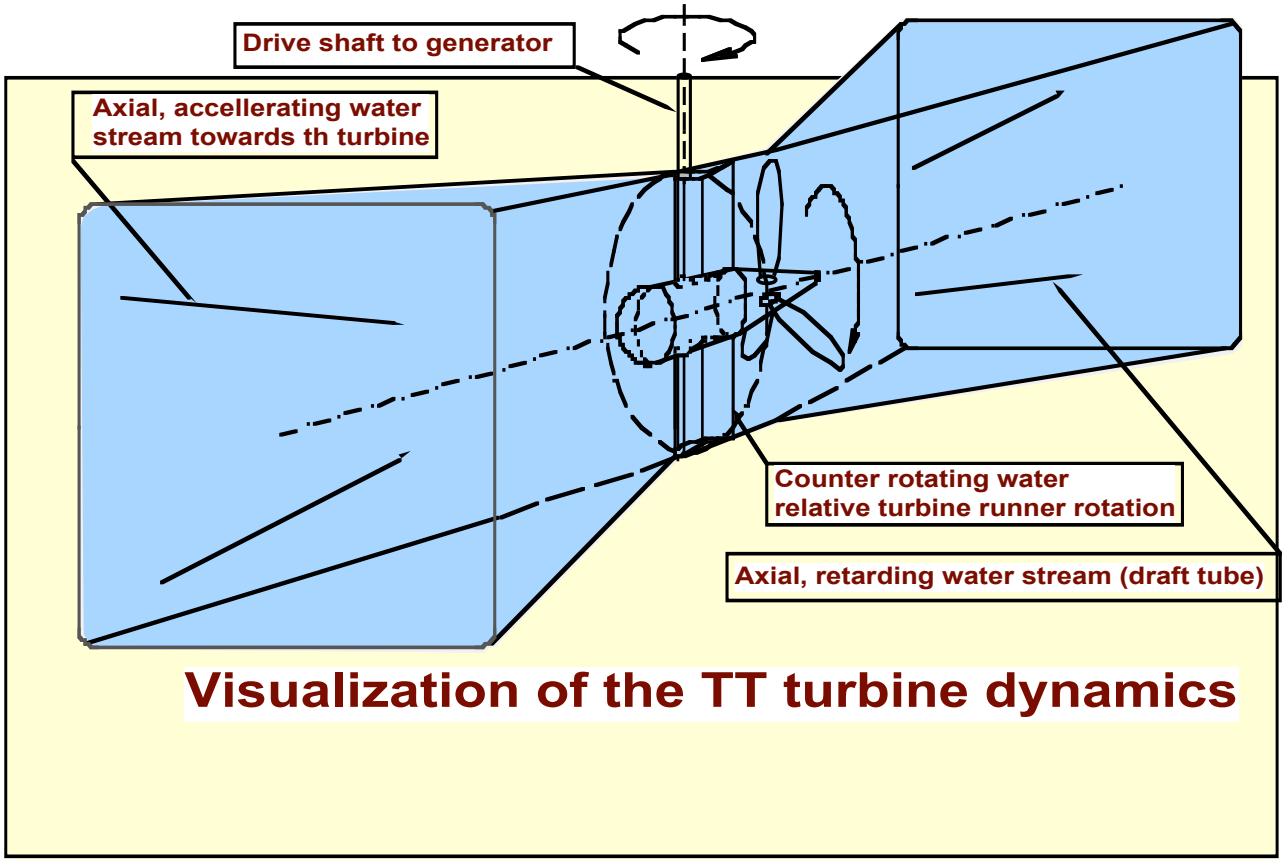
Application of standard high speed generators keeps turbine body weight and cost low.

The turning mechanism consists of three or more inflatable wheels with double planet gears and motor drive in at least one hub. The wheels are forced towards the cylindrical wall. The complete turbine assembly is released for dismantling by deflating the wheels etc.

After mounting the wheels are inflated and secure a stable and vibration damping attachment to the concrete structure.

TideTec turbine 3

The design is based on the properties which give the Kaplan turbine its excellent performance when run in the right direction. Research from Russia, Australia and Canada showing the benefits of conic inlets and outlets, improving the cost/energy ratio.



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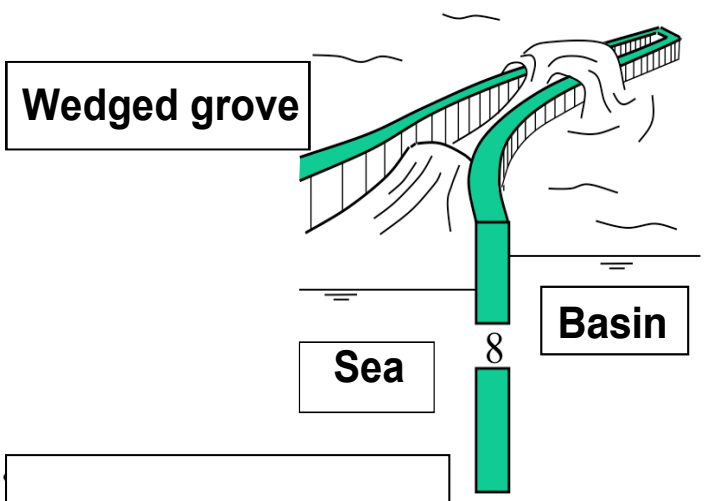
Abstract

Unlike conventional hydro and tidal barrage installations, water current turbines in open flow can generate power from flowing water with almost zero environmental impact, over a much wider range of sites than those available for conventional tidal power generation. Recent developments in current turbine design are reviewed and some potential advantages of ducted or "diffuser-augmented" current turbines are explored. These include improved safety, protection from weed growth, increased power output and reduced turbine and gearbox size for a given power output. Ducted turbines are not subject to the so-called Betz limit, which defines an upper limit of 59.3% of the incident kinetic energy that can be converted to shaft power by a single actuator disk turbine in open flow. For ducted turbines the theoretical limit depends on (i) the pressure difference that can be created between duct inlet and outlet, and (ii) the volumetric flow through the duct. These factors in turn depend on the shape of the duct and the ratio of duct area to turbine area. Previous investigations by others have found a theoretical limit for a diffuser-augmented wind turbine of about 3.3 times the Betz limit, and a model diffuser- augmented wind turbine has extracted 4.25 times the power extracted by the same turbine without a diffuser. In the present study, similar principles applied to a water turbine have so far achieved an augmentation factor of 3 at an early stage of the investigation.

TideTec turbine 4 - Wave energy

TideTec also develops methods where added energy from waves may boost the turbine energy generation. The inclined wedge principle is illustrated below.

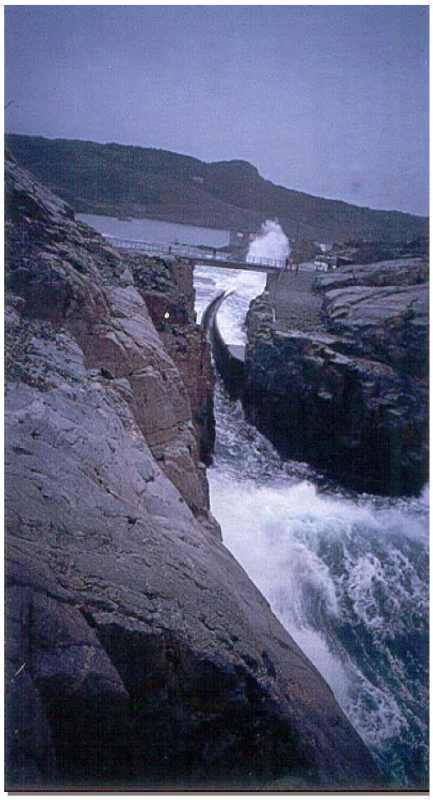
NTNU



A demo site was built in 1985 at Toftestallen.

The sea was lifted up into the basin at 3 m heigth.

The turbine was at 350 KW and linked to the grid.



Copyright: NORWAVE AS, Norway, 1986

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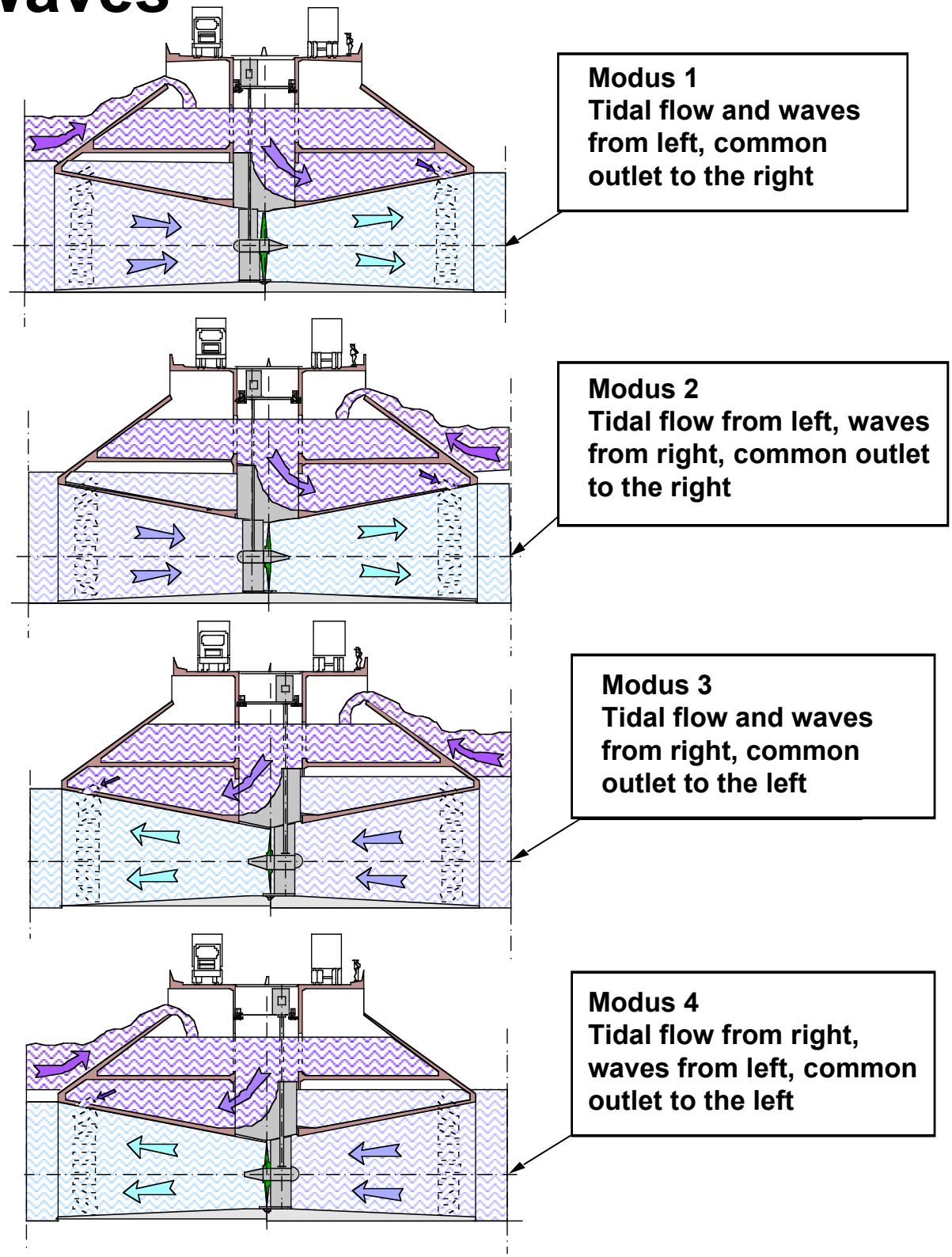
Blasted stone fragments from the construction period were washed up the groove the first winter. Complete breakdown of the installation.

This principle was tested successfully for a long time until the disaster. But the timing for this energy resource was premature; there were still plenty of cheaper hydro power projects available.

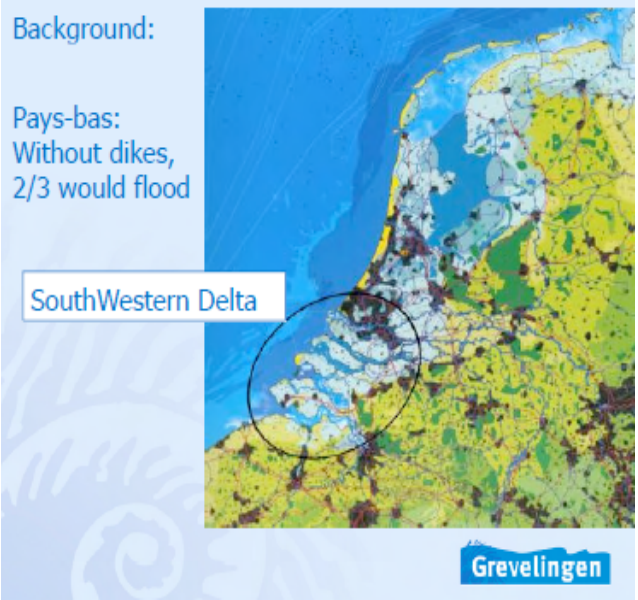
The combination of tidal and wave energy on the same turbine is primarily interesting at locations with moderate tidal differences, but vivid wave activity.

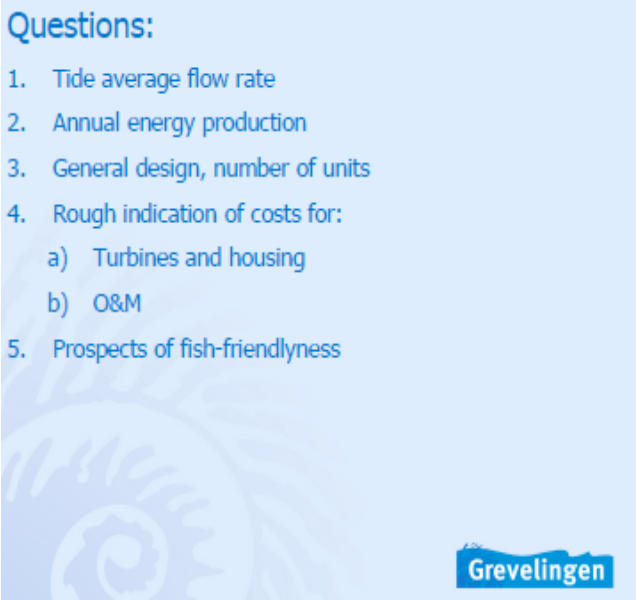
TideTec turbine 5 - Adds from waves



In this case the wave energy is used for increased draft tube efficiency. An alternative would be to increase the pressure on the turbines by outlets in front.

Region Grevelingen
- intention of renewal





Our firm advocates that our concept has the best qualities in order to meet the requirements.

Optimal design and a precise answer to the questions will need thorough collaboration and research.

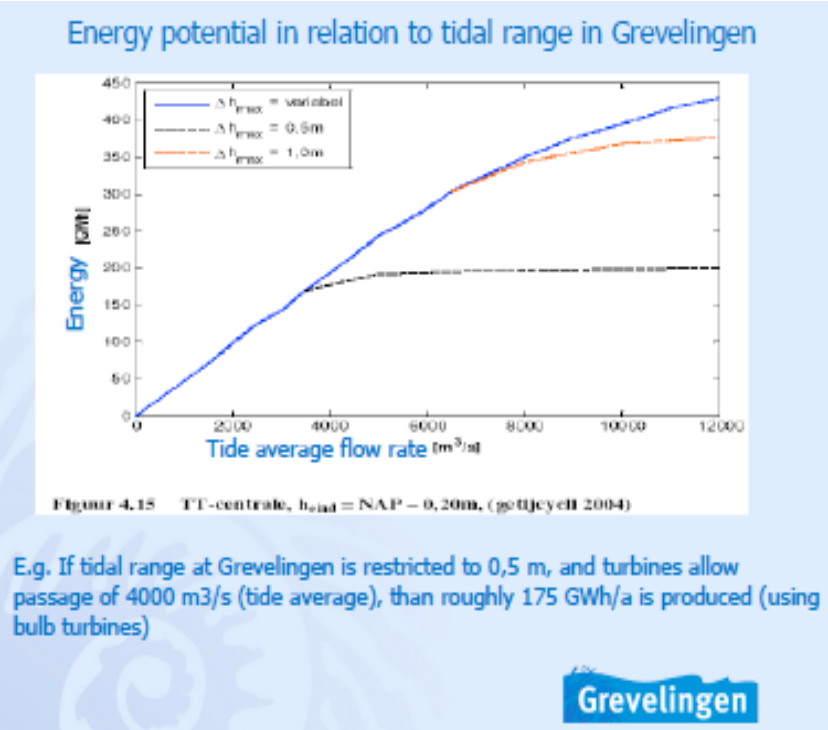
These tasks could be carried out via a Dutch/Norwegian collaboration project.

Comments to some questions

Tide average flow rate

Wishes for a high water exchange rate lead to many and big diameter turbines.

The length of Brouwersdam is 820 m. Assumed applicable length for turbines is 750 m, allowing sailing passages.



Below a calculation example for a full installation, where the intention of high pumping capacity is weighted foremost.

* *Turbine diameter 6 m, which gives a net passage area of approx. 26 m²*

* *Center distance between turbines = 7,5 m*

* *Maximal number of units: 100*

* *Total flow passage area: 2600 m²*

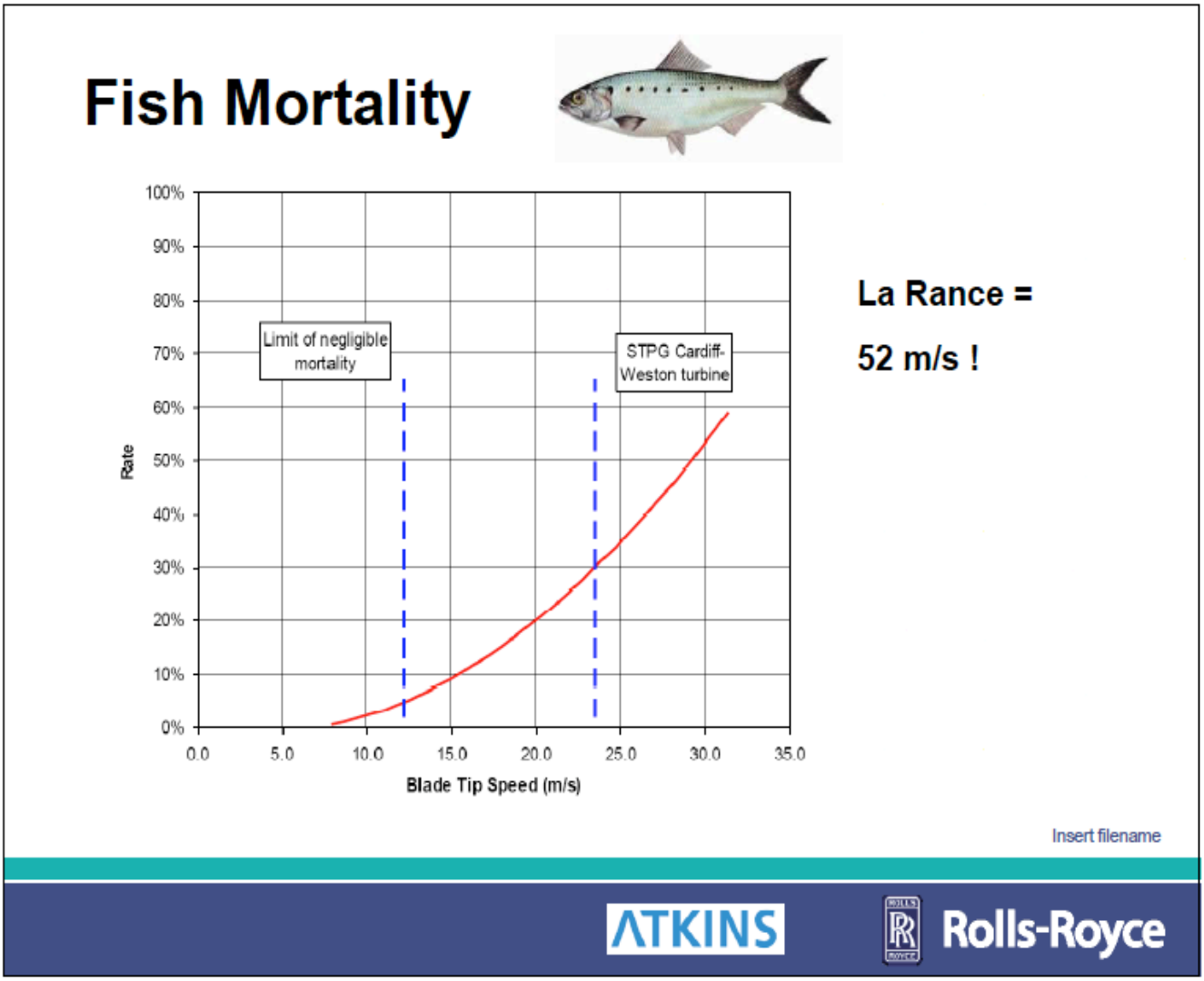
* *Flow speed at flow rate 4000 m³/s is 1.54 m/s.*

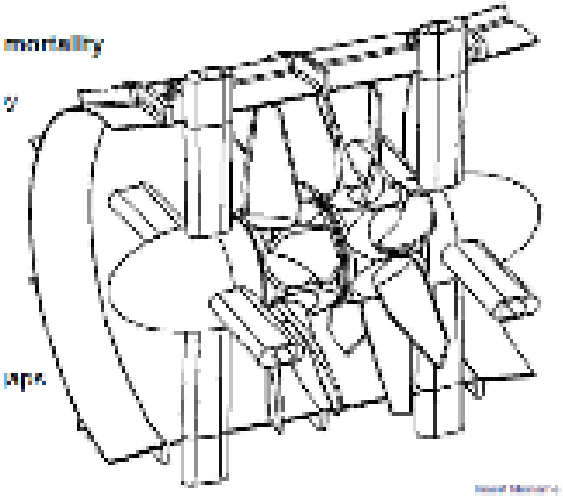
The straight and spacious water passages should contribute to high efficiency of energy generation and pumping.

Pumping may be applied for lifting or lowering the sea level inside the barrage, always with the turbine orientation with highest efficiency. The experiences from La Rance show that pumping contributes to higher energy generation.

Fish friendliness

The information in the Rolls Royce diagram below shows the importance of low turbine blade tip velocity in order to avoid fish killings. However, low turbine rotation speed means higher cost per kWh.





Rolls Royce tandem turbin

Rolls Royce intends to expand the separation between the runners and blades. This is understandable when the objective is to avoid hitting or trapping passing fish.

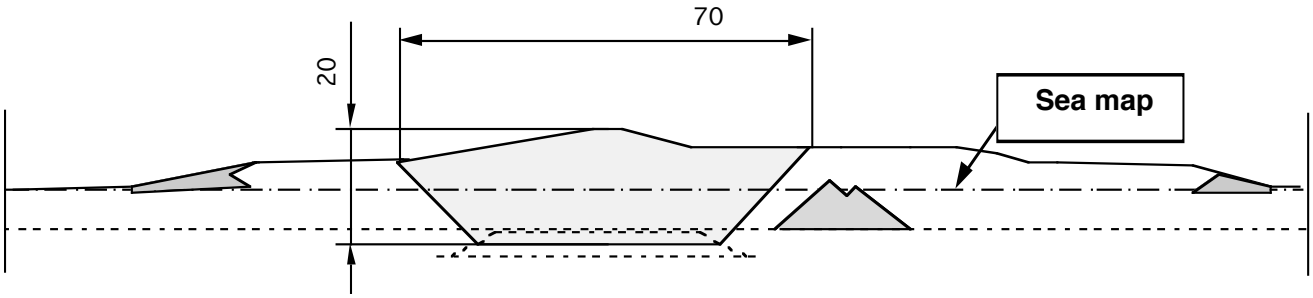
A one runner alternative will be advantageous in this respect.

Reopening of the Brouwersdam dike

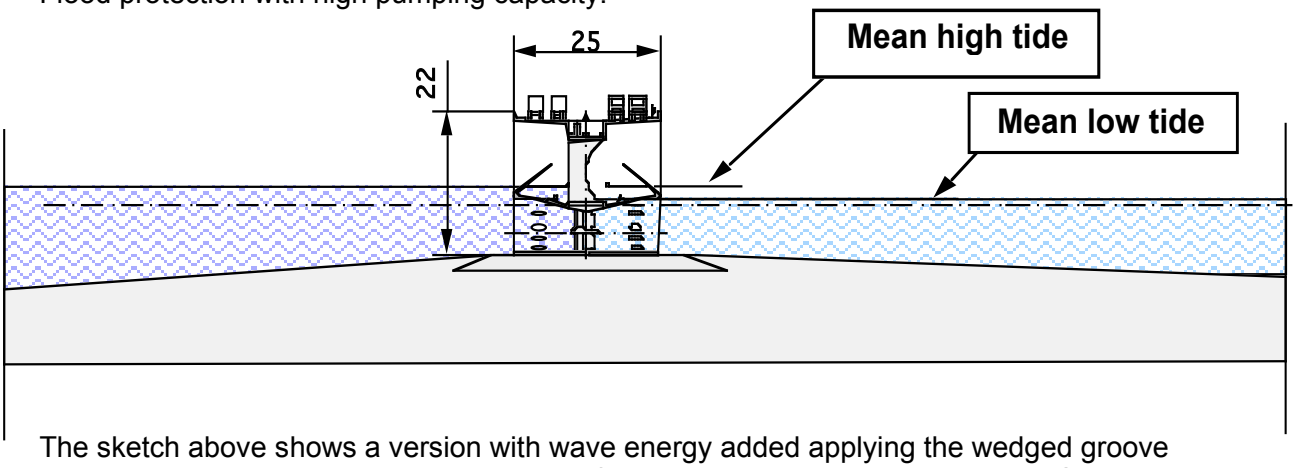
The modification of the dam, involving TideTec turbines, may be performed in steps over time. A multiple-sided value generation may be created:

- ***Renewable energy supply from tid and waves***
- ***Enhanced water exchange insidee dike***
- ***Flood protection with high pumping capacity***

TideTec AS suggests Ø 6 m turbines in on-site cast concrete structures prepared for 2 roads, pavement and cycle lane on top on either side of the lids to turbines in the middle. Center to center distance between turbines 7,5 m (minimum).



Renewable energy supply from tides and waves, enhanced water exchange inside the dike. Flood protection with high pumping capacity.



The sketch above shows a version with wave energy added applying the wedged groove principle. Norway has long experience with fish ladders past river power plants. Similar solutions for fish bypass should be considered here.

Energy and pumping potential at Brouwersdam

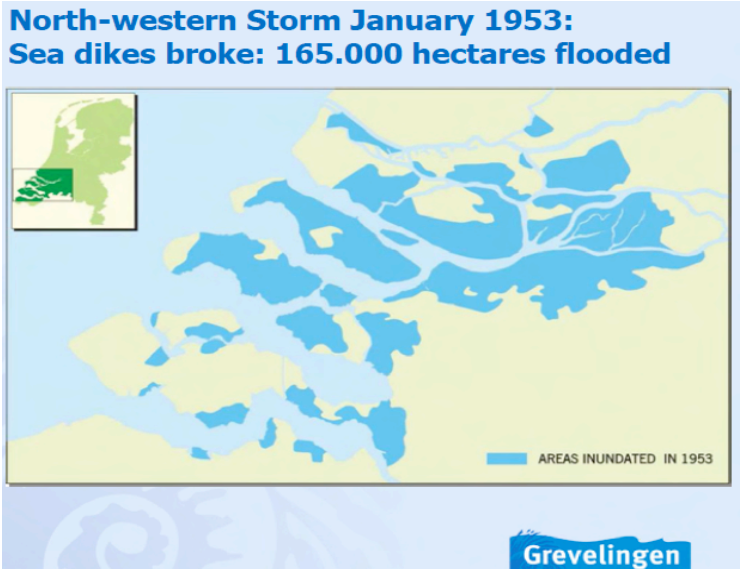
Locality	Basin	Mean tidal	Natural	Production in GWh/ year		Explotitation Ratio	
		difference	potensial Ep	Kaplan	TideTec	Kaplan	TideTec`s
	area	meters	GWh / year	single-effect	double-effect	single-effect	double-effect
	Km2			operation	ratio	operation	operation
La Rance	22	8,2	2914	540		0,185	
Garolim	45,5	4,7	1980	880		0,444	
Brouwersdam	110	2,5	1354		825		0,609

The calculations for Brouwersdam are based on the same rate of natural energy exploitation as at Garolim in South-Korea (page 10), adjusted for an expected 3 % lower efficiency for TideTec in Brouwersdam versus Kaplan bulb at Garolim. Also 40 % extra generation as stated by Rolls Royce for bidirectional schemes are included at Browersdam. The 24-unit installation does not represent the optimum installation for La Rance, which should be in order of 40 units (Gibrat, 1976).

The natural energy potential is calculated according to the Gibrat formula. Added energy from waves are not included.

The effective head may be increased by pumping between each tidal shift.

TideTec turbines may be used as pumps in order to increase the effective head for both ingoing and outgoing tide.



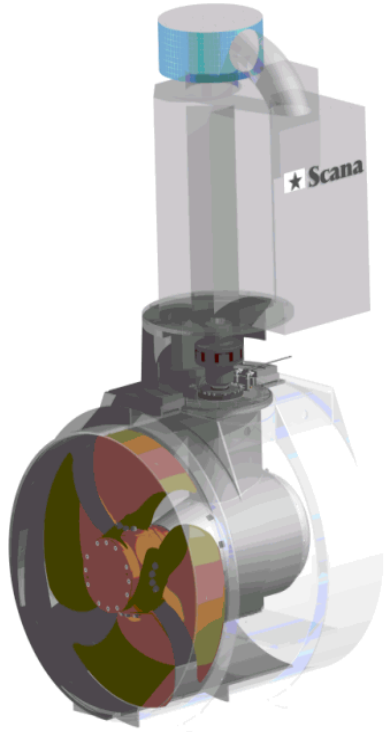
The length of the dike will allow a maximum of 100 turbines after full renewal. At un-normal high precipitation and hence extra need for pumping the pumping capacity may be increased applying frequency converters. At high migration rates of big fish or eels the turbine rotation speed may be turned down in the same way in order to avoid elevated fish mortality rates. High pumping capacity will increase the flood protection ability.

Appropriate generator size will be in the interval 1 - 2 MW, depending on the claims for pumping capacity, ia aggregated pumping capacity in the interval 100 -200 MW.

The heat from the generator cooling is a resource

The application of high speed generators/motors located in dry surroundings above sea level imply many advantages.

One is the access to the substantial heat energy from the generator cooling systems, which may be exploited in many ways. Examples might be heating of buildings, houses, fish breeding activities etc.



Norway has a leading position in the field of ship and offshore vessel thrusters.

The resemblance with the TideTec concept is quite obvious, a fact which gives TideTec access to worthy experience.

The example of an azimuth thruster shown here has a power of max. 5000 kW.

The manufacture is carried out by the Norwegian company Scana Industrier ASA in Poland.

Flooding water may often contain abrasive particles which may hurt water lubricated bearings which are applied in some tidal turbines.

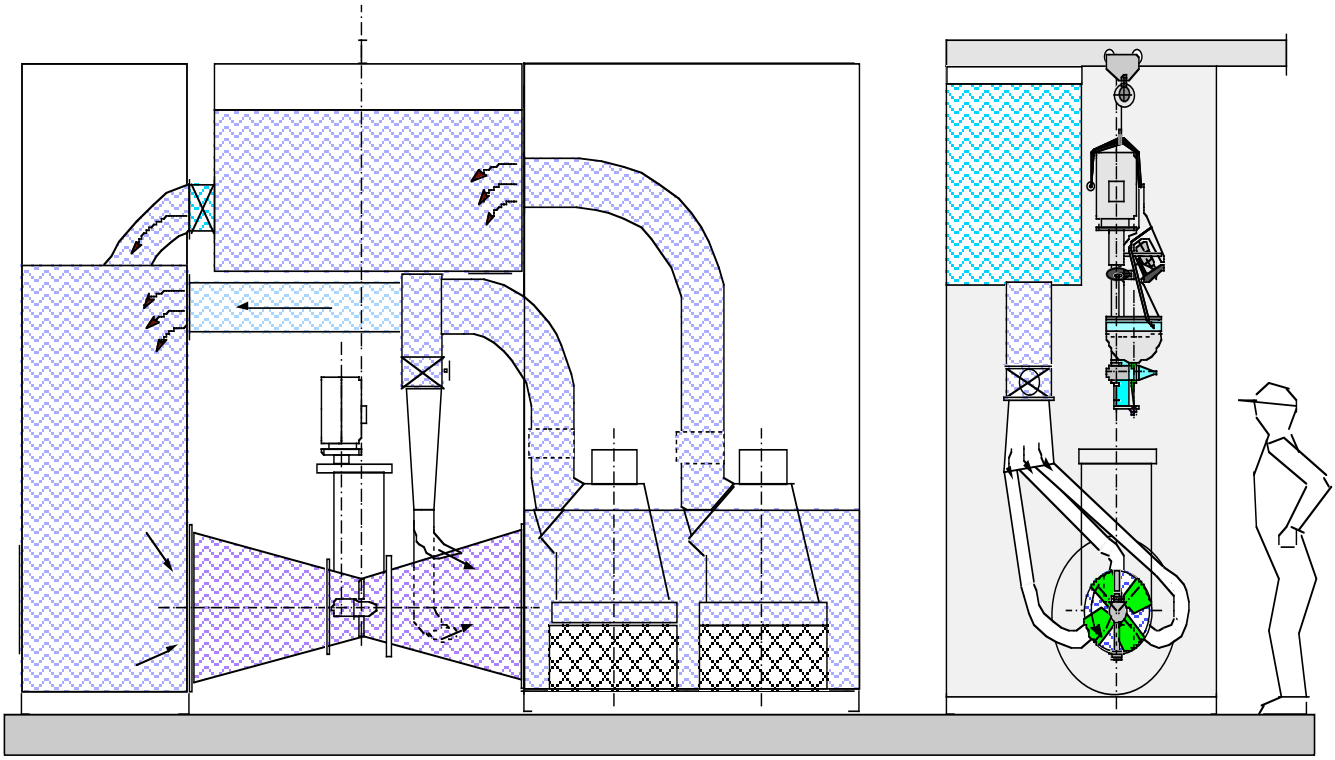
The TideTec concept combines high speed/low weight and cost generators with low speed and fish friendly turbines/pumps.The power transmission vertically between turbine/pump and generator/motor is in 2 steps applying angle and planet gears.

An internal transmission line over-pressure relative the outside water pressure is automatically secured from the control centre. This secures a long life of the transmission system. The central surveillance system also controls the amount and quality of lubricating oils.

Small-scale research model

In order to optimize and secure the quality of the calculations a down-scaled research model should be built and tested.

The sketch a suggestion of a lay-out in order to verify and optimize the add-effect of wavesbelow is .



Norwegian universities and labs experience a capacity overload due to many assignments from large companies. TideTec AS, being a small company with limited resources, has to line up in the 1-2 years long queue.

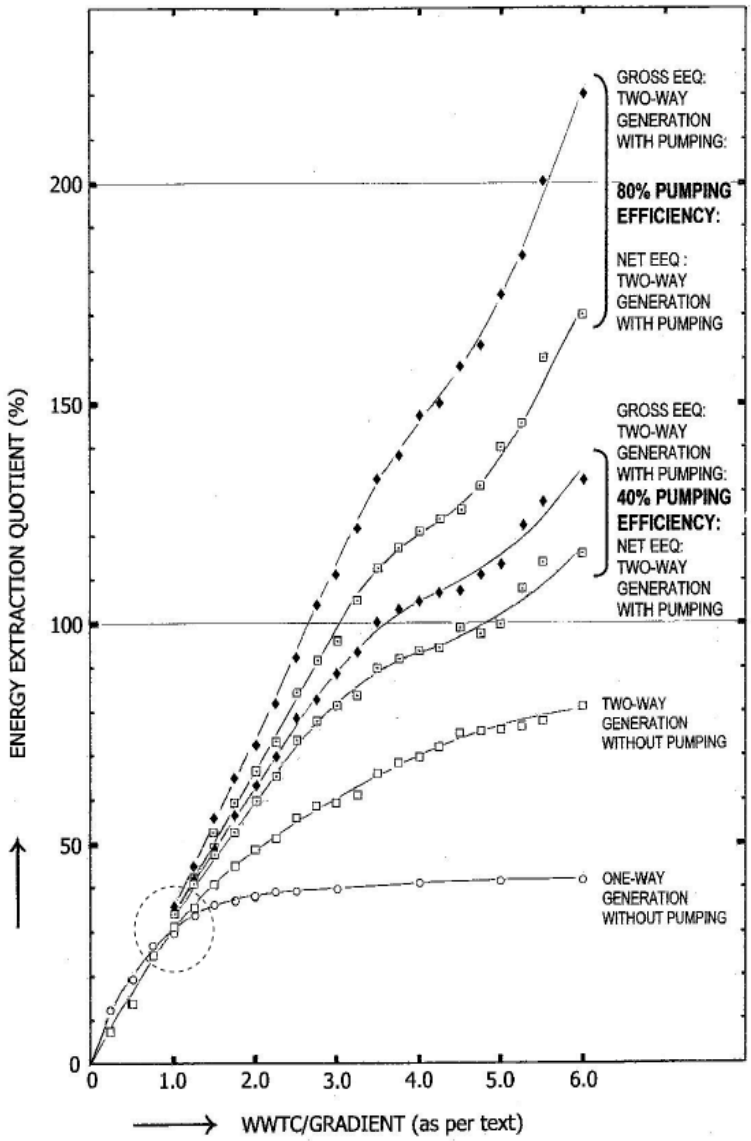
A Russian turbine manufacturer (Inset Ltd) and the Faculty for Hydro Power and Renewable Energy at The State Polytechnic University of St. Petersburg have proposed a budget for a TT-turbine design, manufacture and test.

However, the funding is not established yet.TideTec AS is interested in cooperation for lab. or prototype testing also in other countries in order to optimize the design and verify the performance at specific sites.

TideTec is open for licensing and local manufacturing of the equipment.

Pumping for both increased energy generation and better flood protection

The curves to the right (Dr. Stuart H. Anderson, Conwy County Borough Counsil) show the benefits of two-way generation and high pump efficiency.



An extra head may be achieved by stopping the flow a while during tidal shift or by lifting or lowering the sea level in the basin by pumping.

This is especially effective during neap tide.

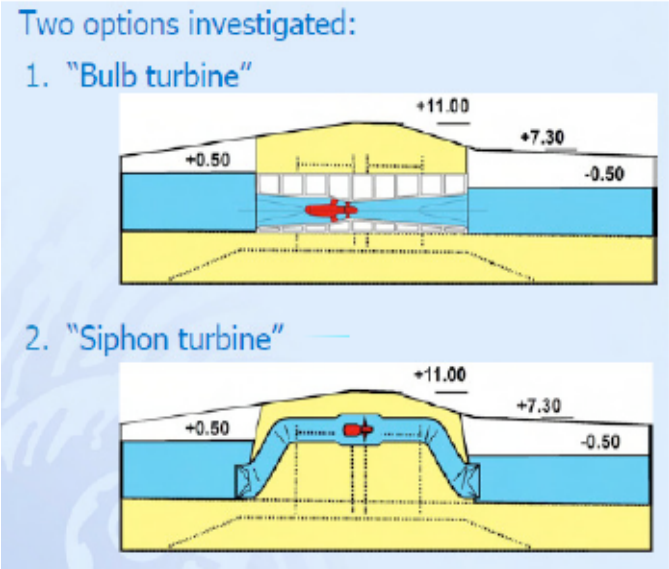
Pumping may also be used in order to control the sea level inside the dike.

During extreme precipitation periods which cause flooding from the rivers flowing into the basin, the pumping may be extended in time and capacity in order to avoid or reduce flood-caused damage, given that necessary electric power is available from the grid.

The conditions for high efficiency of the installation is present: straight water passages, conic in- and outlets, mechanical transmissions, high efficiency generators/motors etc.

The generators/motors, being located well above sea level in spacious surroundings, should be of standard low cost/high efficiency type with high capacity for pumping mode operation.

Construction techniques



The Okeanos report 29-30/6 2010 informs that the Brouwersdam was built by means of big concrete caissons which were filled with sand.

In order to avoid the demolition of the caissons the report show an alternative (right) where the water flow is led over the caisson via a turbine.

Our opinion is that these savings in the long perspective will be overrun by the loss of efficiency at both energy generation and pumping mode operations. We also anticipate that the "high" turbine alternative will lead to more cavitation problems. Maybe the solid dismantled concrete caissons may be reused for new purposes? Hence we conclude that the upper alternative should be chosen.


The Okeanos group on the Couesnon dam in front of Mont Saint Michel

Operating with moderate tidal differences and moderate speed the turbines do not have to be very deeply submersed.

That reduces the size of the housing and need for deep excavations.
The photo shows the group at a visit to the preserved St.Michel where large sediments are to be moved away by means of the tide.

Also at the Brouwersdam large sediments must be moved. We believe that the same method can be applied here after the new turbine structures are in place. The existing bridge structure gives a good basis for stepwise construction and application of cranes and excavation machines on wheels or belts.

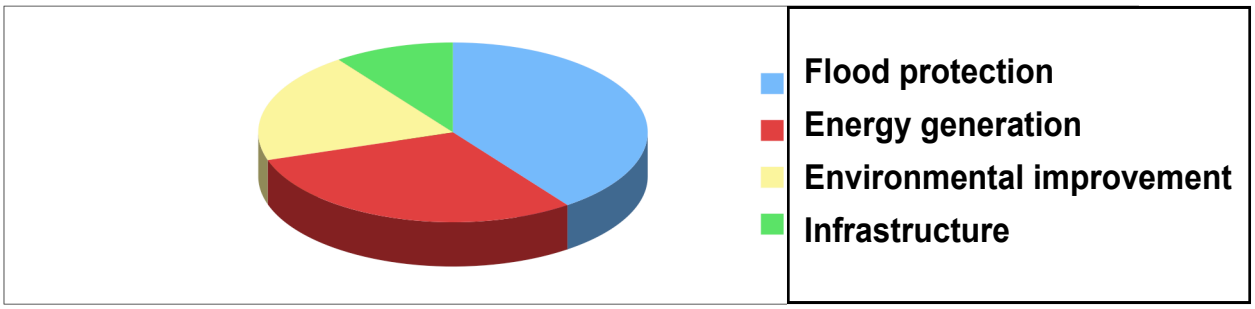
TideTec will make a special design of the turbine blade arrangement which enables a full closure of the water passage cross section, making costly gates obsolete.

Costs - added value

Summing up: Application of standard high-speed/low cost generators above sea level also implies low-cost maintenance and use of heat from the cooling system. The generators are applied as motors when pumping, and frequency converters will improve the efficiency of operations.

This lay-out gives the freedom to design for high speed of generator / motor and low rotation speed of the turbine - or high speed pumping if needed at emergency flooding incidents. Norway has a leading position regarding modern vessel thrusters in the same power class and designed for the same environment as the TideTec turbines.

The long-lasting and demanding construction period of Norwegian hydro power has given valuable knowledge and experience - also relevant for this project. Our concept is based on well known and proven technology which can be adapted to suit the needs at Grevelingen.



How the added value is distributed will vary from location to location and country to country. This cake diagram shows 40 % allocated to flood protection, 30 % to energy generation, 20 % to environmental improvements (water exchange) and 10 % to infrastructure (tourism etc.) just as an example.

Conclusion and project funding possibility

We hope that this information shows that the patented TideTecTechnology has the best prerequisites to satisfy the needs for the renewal of Brouwersdam.

This is a good case in order to develop the TideTec technology, with partly state funding via the IFU/OFO-system of Innovation Norway (IN).


VINNERKONTRAKT

INNOTEKET 2007


INNOVATION NORWAY

March 2008

Commitment to collaboration pays off

Research and development contracts are among the services Innovation Norway offers to the industry and the public sector. The objective is to promote the development of new products, services and solutions for both the national and international market.

TideTec has a winner contract with IN which opens for such financing tools. IN budget for 2010 is closed. New applications will be for 2011. TideTec is pt free to choose industrial partners. One or more Dutch companies may join the project funding application if the project group wish it and the company is able to compete and willing to invest manhours and / or capital.

Norwegian state part funding via IFU/OFU-agreement with IN.

Group of suppliers:

TideTec AS
in cooperation with Norwegian and / or foreign partners

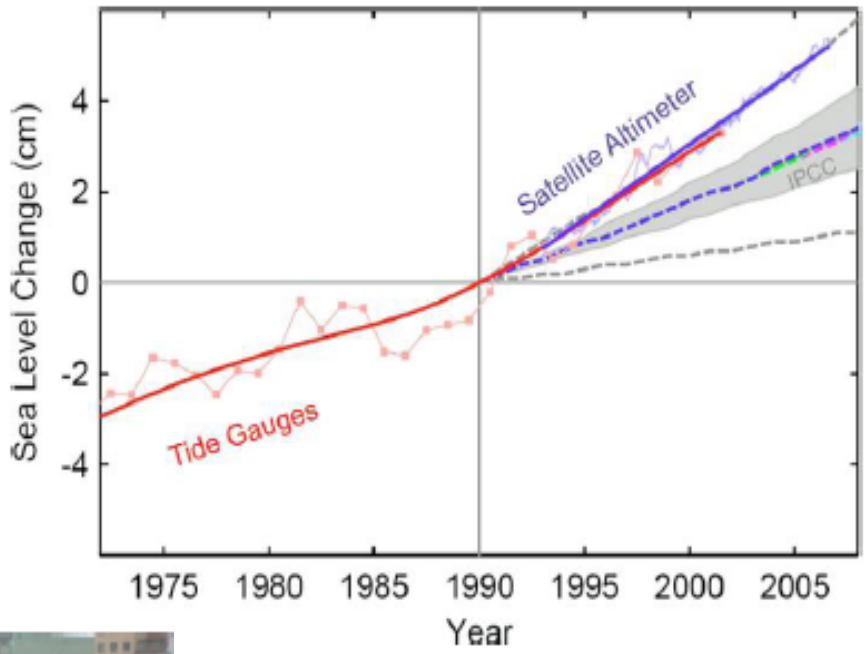
User group :

Group Grevelingen
Ministry of transport, public works and management
Rijkswaterstaat, Prov. Zeeland and Zuid-Holland

Sea level rise - a global problem

The increasing sea level partly caused by global heating is a world-wide challange.

When spring tide meets flooding rivers the danger of overflow damages arises.

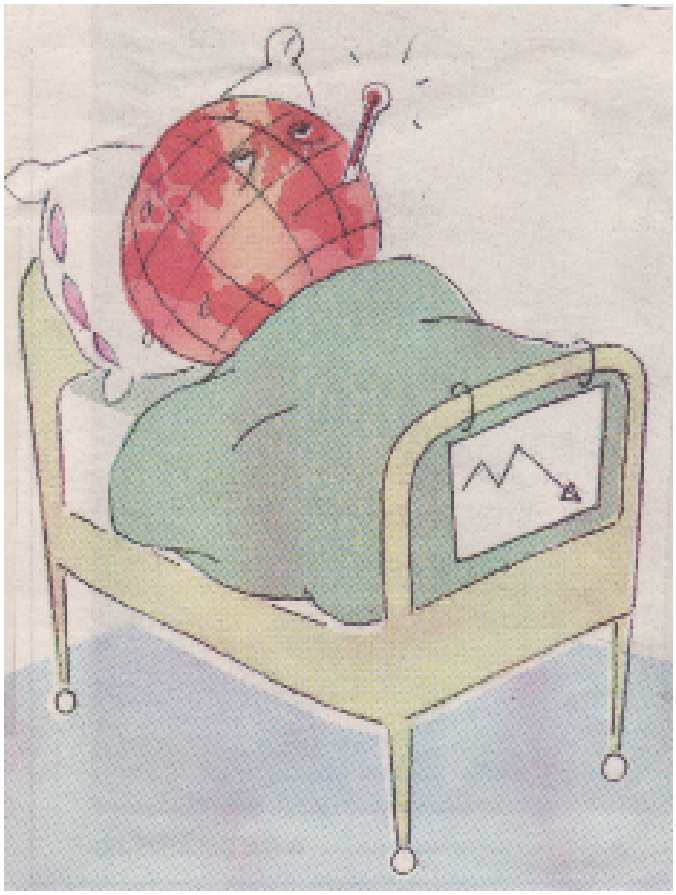


London is at special risk. Existing flood control means must be reinforced. Also Bergen with the preserved "Tyskerbryggen" is threatened.

Flood defence by means of dams with turbines, which can generate "everlasting" renewable electric power from both tides and waves, offers a versatile value creation tool.

TheTideTecs concept is based on proven technology. The barrage consists of prefabricated concrete modules to be floated from dock to site. The concrete modules are prepared for transport facilities on the upper side and mounting of turbines without divers and crane vessels. At Brouwersdam the existing structure may be used as a cofferdam while the concrete sections are cast on site.The patented turbines from TideTec are designed to exploit both the incoming and outgoing tides at high efficiency. At locations with much waves this added energy may be harnessed in the same turbines.

At flood hazar incidents the turbines may be run as pumps. While excluding the high sea level outside the barrage the sea level inside may be lowered simultaneously. This arrangement requires access to sufficient emergency energy supply from the grid in order to operate the generators as motors to drive the turbines as heavy duty pumps.



Tegning fra Dagbladets ukemagasin

Tide Tec