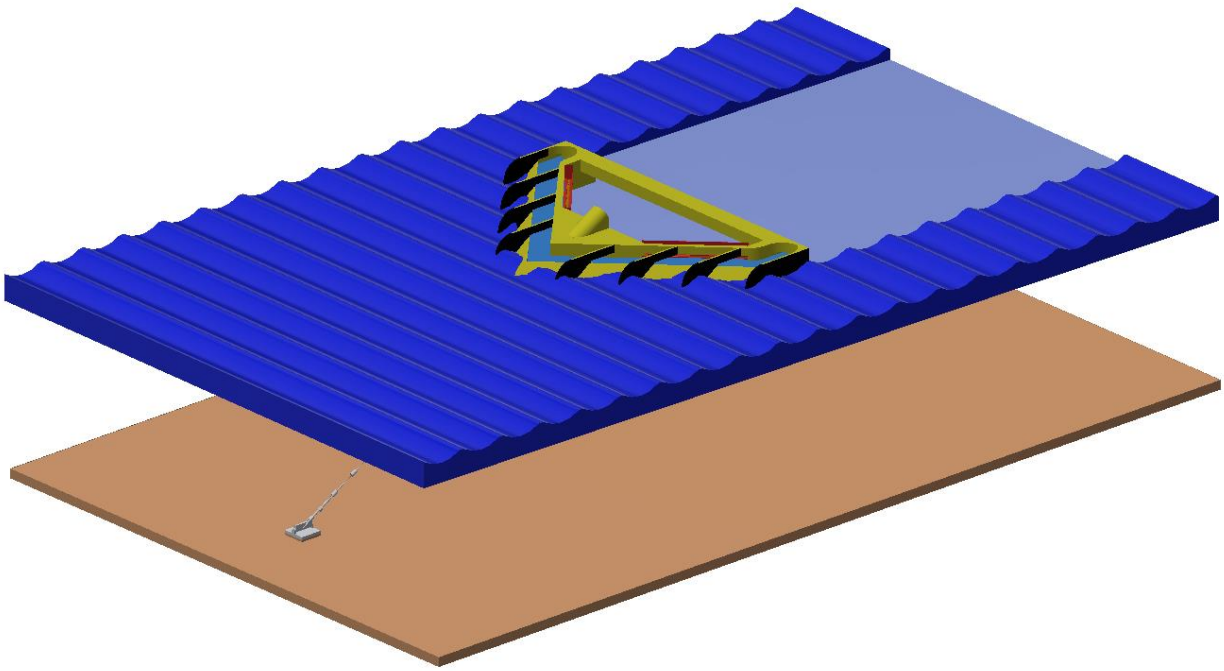
SCOTSTREAM

Scotstream

Wave Energy Converter System

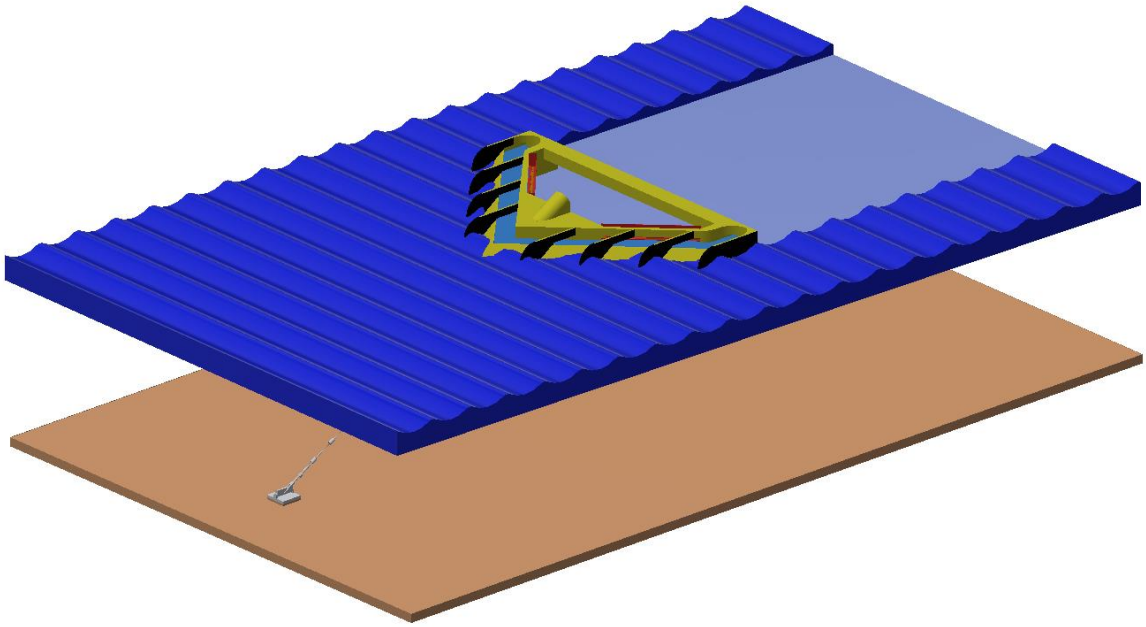


Contents

1.0 INTRODUCTION

1.1 Scotstream Wave Energy Converter

The Scotstream device is an “overtopping” design of wave energy converter. The device is combined with a highly efficient Hydrobox waterwheel generator to provide a unique solution for wave energy conversion.



The floating structure weathervanes on its mooring system to always face into the prevailing waves. During operation, the waves travel down both sides of the structure and wash up sloping ramps into an impound reservoir. The stored elevated water is then supplied to a Hydrobox waterwheel to produce electrical power that can then be exported to shore.

The structure is designed for high survivability as it has no moving parts and the wave impact on the structure is carefully managed.

The width of the captured wave front and the mean wave power (kW/Metre) of wave crest will dictate the amount of potential wave energy that the device can produce.

The power take-off device is a Hydrobox waterwheel. This device is ideal for low head and high flowrate water and the overshot wheel has an efficiency of over 80%. The waterwheel only has one moving part.

The combination of a wide wave capture profile and high energy conversion efficiency will maximise the generation capacity of the system.

The Scotstream system is a new and novel design of wave energy converter and waterwheel generator. The combined result is an offshore converter that is highly efficient and has high survivability in the offshore environment.

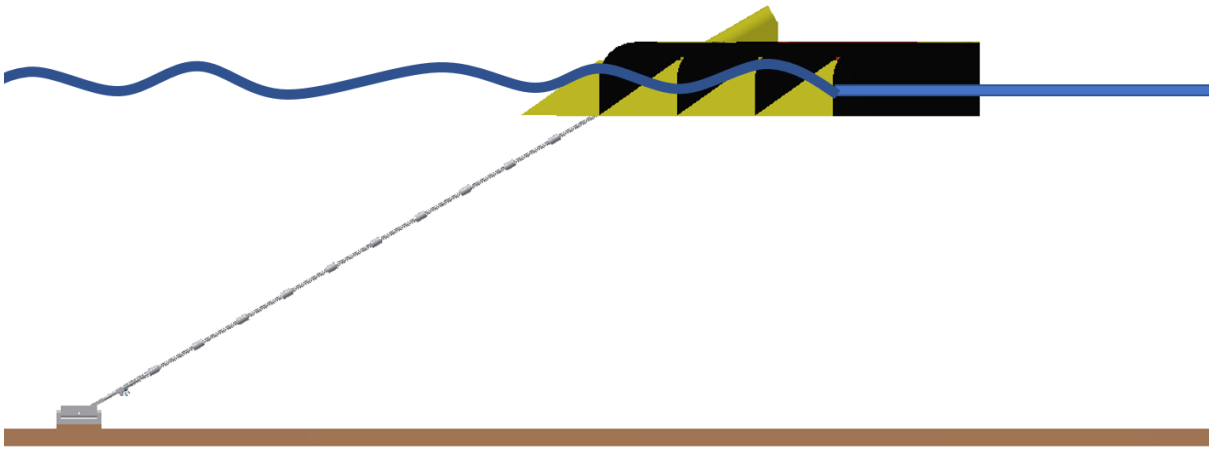
2.0 OVERTOPPING WAVE SYSTEM

2.1 Weathervaning Mooring System

The floating structure weathervanes on its mooring system to always position the bow facing the wave front.

The weathervaning turret mooring system can comprise of either;

- A Multileg mooring array permanently connected into the turret with a separate dynamic umbilical
- A Multileg mooring system with a submerged buoy for quick connect/disconnect with a separate dynamic umbilical
- A Hybrid single line riser with an integrated dynamic umbilical



For illustration purposes the Hybrid single line riser mooring system has been used. In this design, the dynamic umbilical is housed within a steel riser pipe for protection. A number of tension chains and buoyancy buoys are configured around the riser pipe. The single mooring assembly is connected to a flexjoint anchor foundation structure on the seabed.

2.2 Power Generation Capacity

The power generation capacity of the converter will be directly dependent on the wave front capture length.

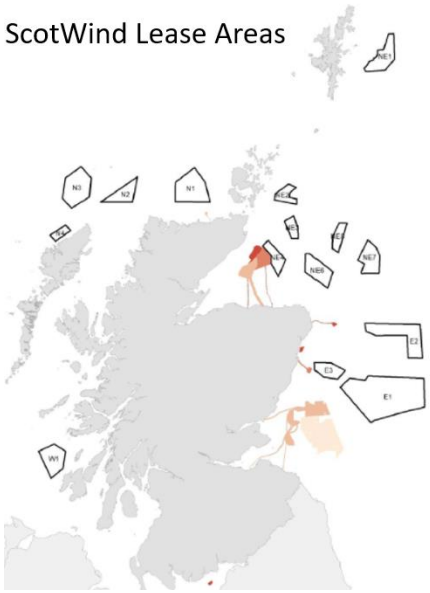
The mean wave power is expressed in Kw/m of wave crest width. The capture width of the current design is 170 metres.

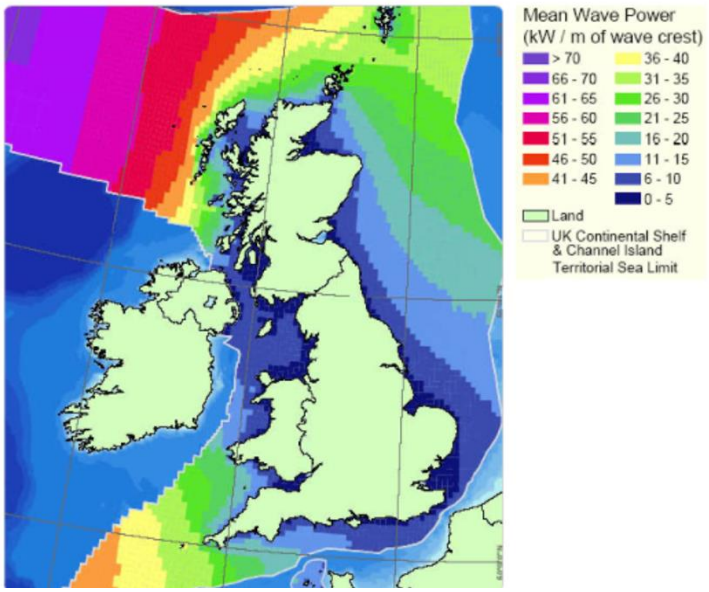
The mean wave power around the UK is shown on the chart below. The ScotWind lease areas are also shown.

For the NE7 and NE1 lease areas, the potential power output has been calculated based on the current 170 metre capture width.

For a much larger unit with a capture width of 400 metre, the power output would be significantly increased.

Width (Metre)	NE7 (25 kW/m)	NEI (40 kW/m)
170	4.2 MW	6.8 MW
400	10 MW	16 MW

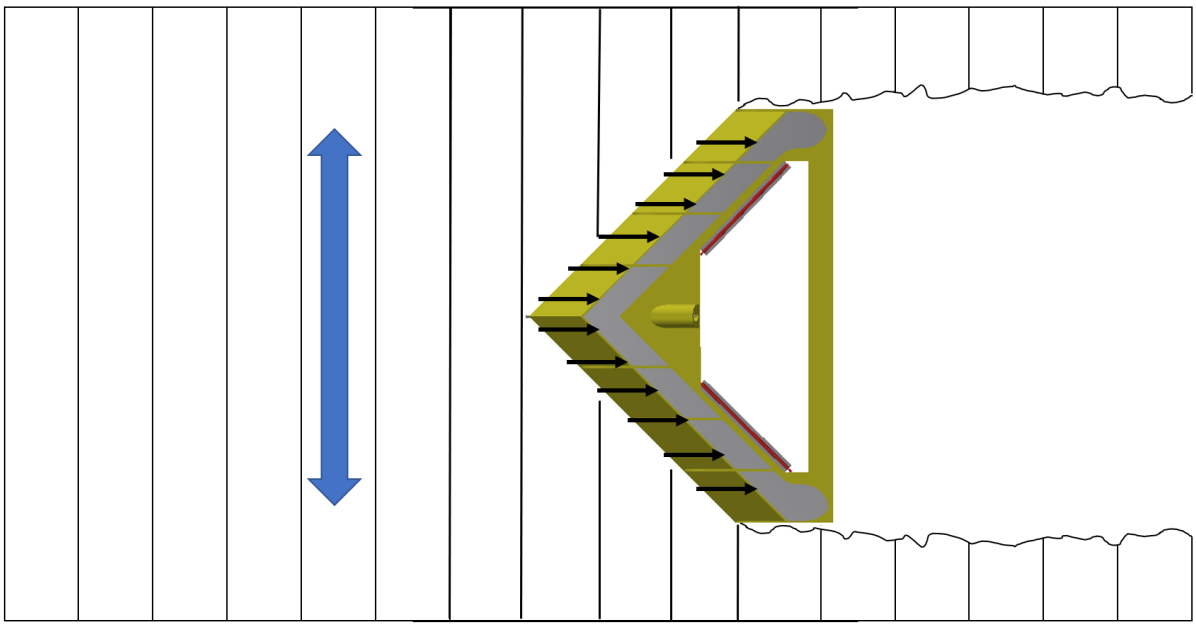




2.3 Overtopping Action

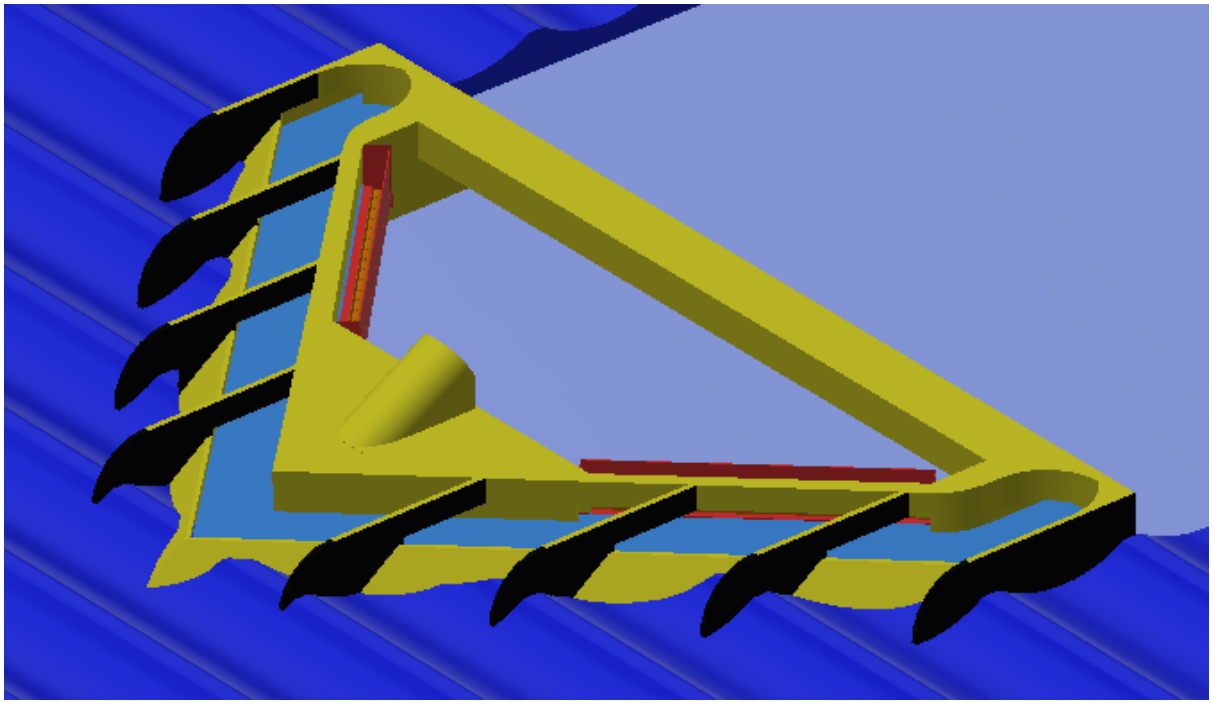
During operation, the wave front will approach the floating structure. The wave will have potential energy in the peaks/troughs. The wave will also have kinetic energy due to the speed it is traveling.

As the wave impacts on the bow of the floating structure, it will split in two and travel down each side of the structure.



The wave will impact the sloping ramps on the sides of the structure. Due to the energy and momentum in the wave, the water will naturally move up the sloping ramp and into the impound reservoir.

The water will also move horizontally along the ramp face. A number of elevating guides will be provided on the sloping ramp to guide the water upwards into the impound reservoir.



The combination of sloping ramps and elevating guides will maximise the water transferred from the oncoming waves into the impound reservoir.

The potential and kinetic energy in the wave will be converted into potential energy in the form of the elevated stored water in the impound reservoir.

This process is called overtopping.

Below are some video links showing the overtopping action caused by a wave impacting a seawall at an incident angle.

https://www.youtube.com/watch?v=wPRQDpXHj6w

https://www.youtube.com/watch?v=A_V67_-kKg8

https://www.youtube.com/watch?v=DYWLCzSpL6o

https://www.youtube.com/watch?v=pBN9vVFRFH4

Note that, as shown on the videos, all seawalls are designed with vertical or curved concave faces to prevent overtopping.

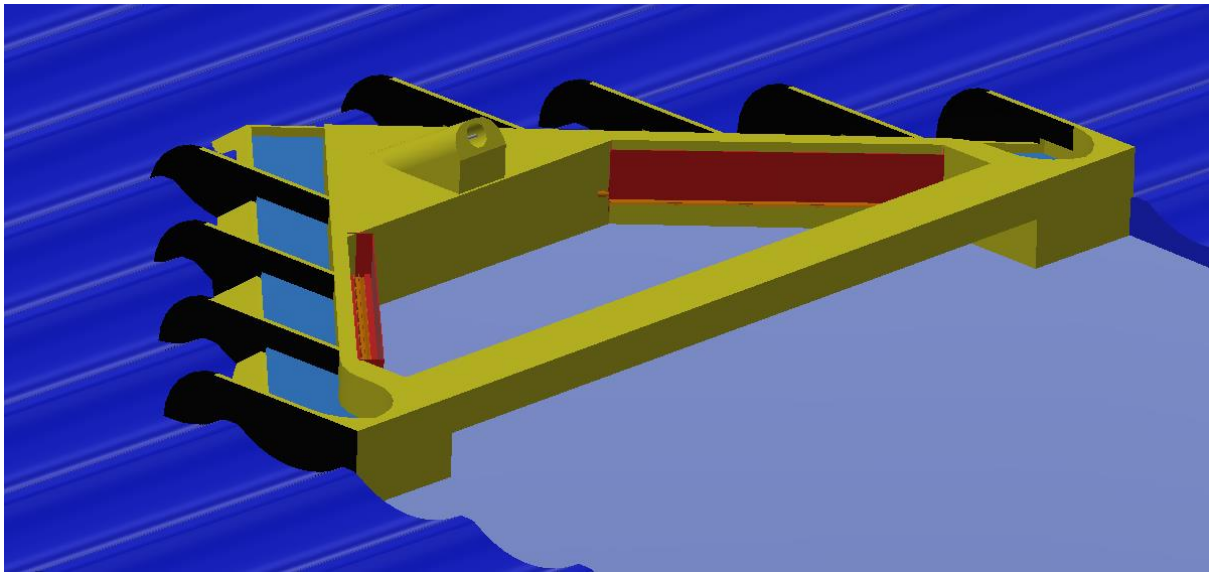
The Scotstream sloping ramps and guides are designed to maximise the overtopping effect.

3.0 POWER TAKE-OFF SYSTEM

3.1 Impound Reservoir

The impound reservoir is 1.5 metres deep and the maximum stored water volume would be about 4000 M^3.

The stored water would be routed to the power take-off unit through channel openings.

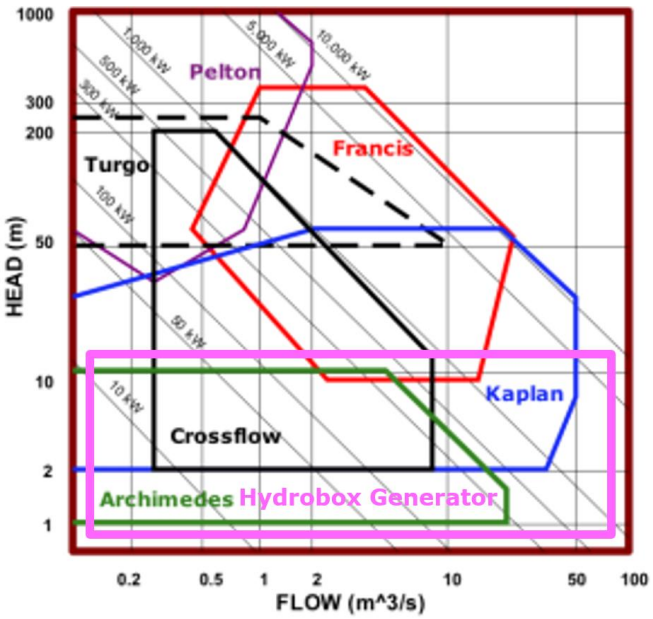


3.2 Power Take-Off Options

For very low head applications, less than 10 metres head, the choice of power take-off technologies are limited.

Kaplan and Crossflow turbines can be used, however at less than 10 metre head they would be operating at the bottom end of their pressure capability. A large number of individual turbines would be required in order to generate the power required.

Archimedes Screws can cope with the low water head, however, cannot deliver much flowrate. A large number of screws would be required in order to manage the high flowrate required.



Waterwheels are ideal for the low pressure operations and the diameter can be specified to suit the head height available. Traditional waterwheels have narrow buckets and can only handle low volume flowrates. However, the Hydrobox waterwheel has large segment buckets and the length can be specified to suit the flowrate required.

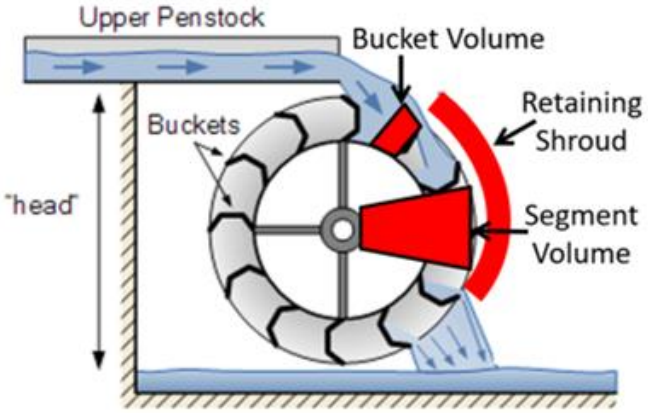
4.0 HYDROBOX WATERWHEEL POWER TAKE-OFF DEVICE

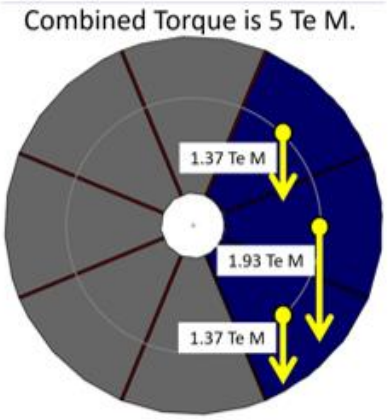
4.1 Hydrobox Waterwheel Generator

The Hydrobox Generator is based on a traditional Overshot Waterwheel design, which is over 80% efficient.

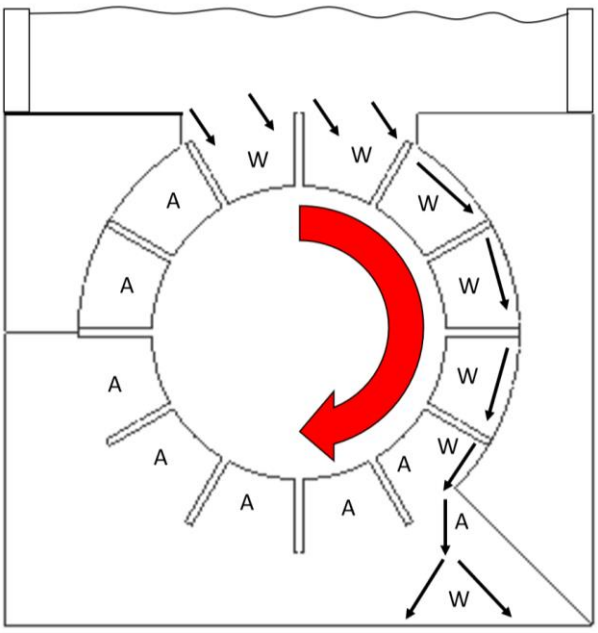
Traditional waterwheels are large diameter with small buckets that are not very wide, this results in low bucket water volumes and very low power output.

The Hydrobox design has segment shaped buckets and a retaining shroud on one half of the wheel. The shroud enables the full volume of water to be retained in the segment bucket. The large water volume results in very high torque and a high power output, in a very compact package size.





During operation of the Stingray converter, the water in the impound reservoir would be supplied to the inlet at the top of the Hydrobox waterwheel.



The water would flow into the segment spaces on the rotor. As the wheel rotated clockwise, the water in the segment would be retained by the housing shroud.

When the segment reached the bottom of the shroud, the water would be released back into the sea.

The segments on the right-hand side of the rotor would be full of water and the segments on the left-hand side would be full of air. This weight difference results in a very high torque on the rotor.

The power generated by the rotor would be dependent on the torque and speed of rotation. An AC Generator would be provided on the rotor end shaft to convert the rotation into electricity.

The diameter of the rotor would be specified to suit the head height between the bottom of the impound reservoir and the sea in the calm area in the lee of the structure, this is estimated to be 3 metres.

4.2 Hydrobox Applications

The Hydrobox is a modular design and a number of units can be connected to provide MW+ of power generation capacity.

The wheel diameter and length can be specified to suit the water supply available.

In addition, the Hydrobox can be packaged into an ISO shipping container size, either 6 metre or 12 metre long, for ease of road transportation and sea freighting.

The Hydrobox is ideal for low head / high volume applications, such as wave energy.

One or two, Hydrobox units can be specified to provide all of the power conversion, rather than requiring multiple smaller units.

The rotor directly drives the AC generator.

One of the main benefits of the design is that there is only one moving part i.e the rotor.

The Hydrobox can be used on any low head, high flow water energy application, namely;

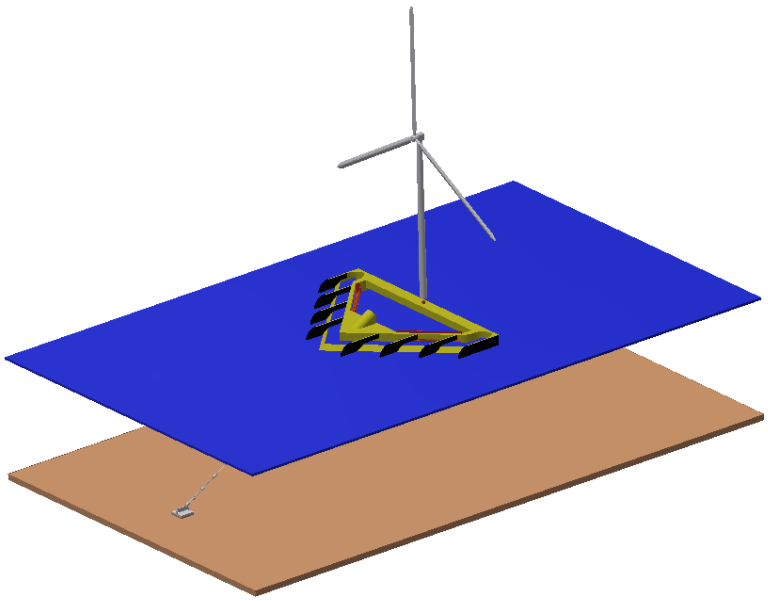
- Run of River Hydro
- Water Treatment Plants
- Pumped Hydro Energy System (PHES)
- Clean water Conduits
- Tidal Lagoon Energy

5.0 FLOATING WIND

5.1 Floating Wind Turbine

The Scotstream floating structure can be used as a mounting platform for a wind turbine, or a number of wind turbines.

The wind turbine would be centrally mounted on the transverse member on the stern of the floating structure. The member buoyancy would be specified to accommodate the weight of the turbine. A 15MW wind turbine is shown for illustration.

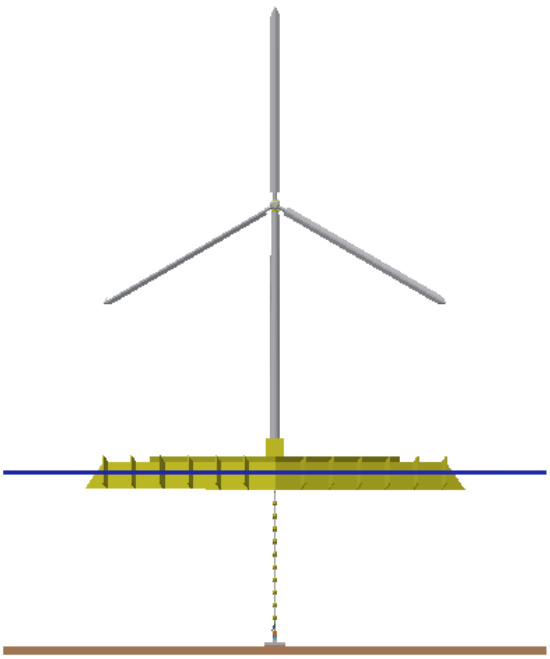


Due to its size, the floating structure will be very stable during operation, this is a requirement for wind turbine performance.

Personnel access to the wind turbine would be from the stern, in the calm water area.

Combining floating wind technology and the wave energy converter technology on one Multi-Purpose Platform will result in capital and operational cost savings and provide two separate revenue streams for the developer.

This approach should be considered for all the floating wind lease areas, in order to maximise the business case for each offshore installation.

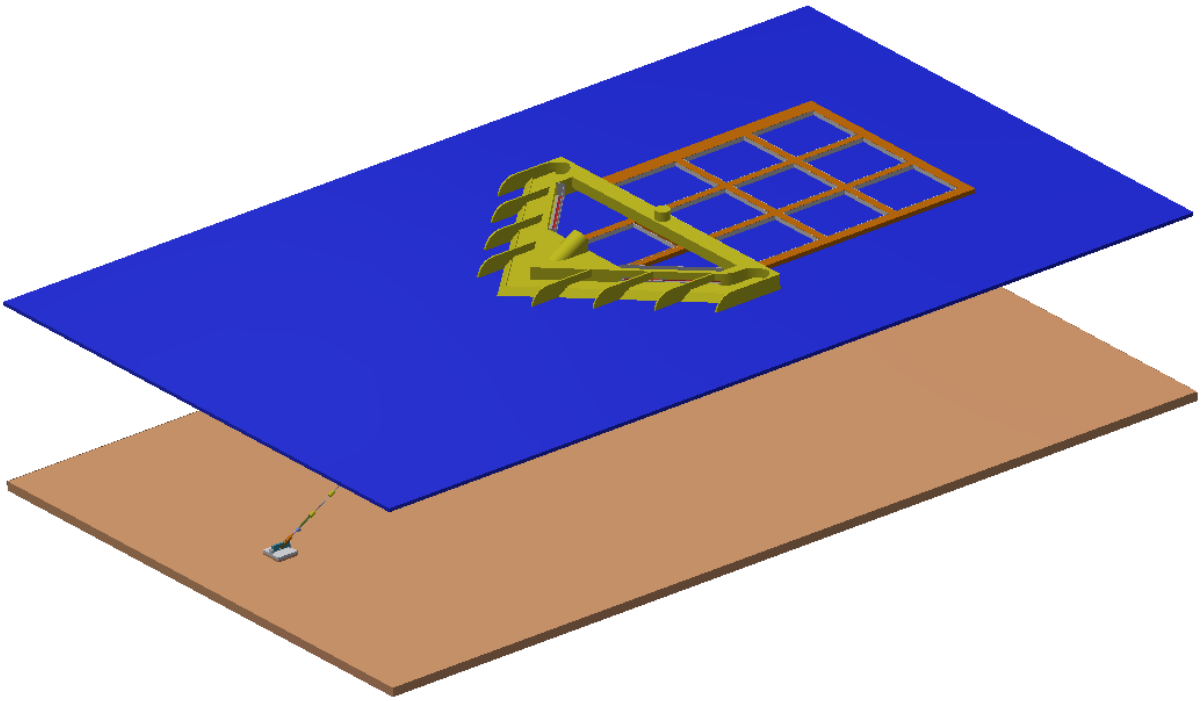


6.0 OFFSHORE AQUACULTURE

6.1 Offshore Fish Farm

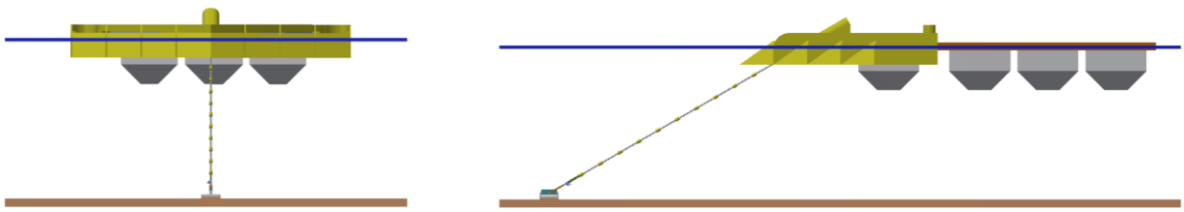
The Scotstream floating structure can be used as a mounting platform for an offshore aquaculture system.

The aquaculture system could be located in the calm waters in the lee of the floating structure. As the structure weathervanes to face into the oncoming waves, the aquaculture system would always be protected at the stern of the structure.



It should be noted that locating the aquaculture system in the calm area astern of the main structure will mean that existing “plastic” cage systems and equipment can be used.

This will remove the requirement for the development of large steel cages or floating vessels. The cost-effective aquaculture systems currently used in inshore lochs can be use offshore.



Combining offshore aquaculture and the wave energy converter technology on one Multi-Purpose Platform will result in capital and operational cost savings and provide two separate revenue streams for the developer.

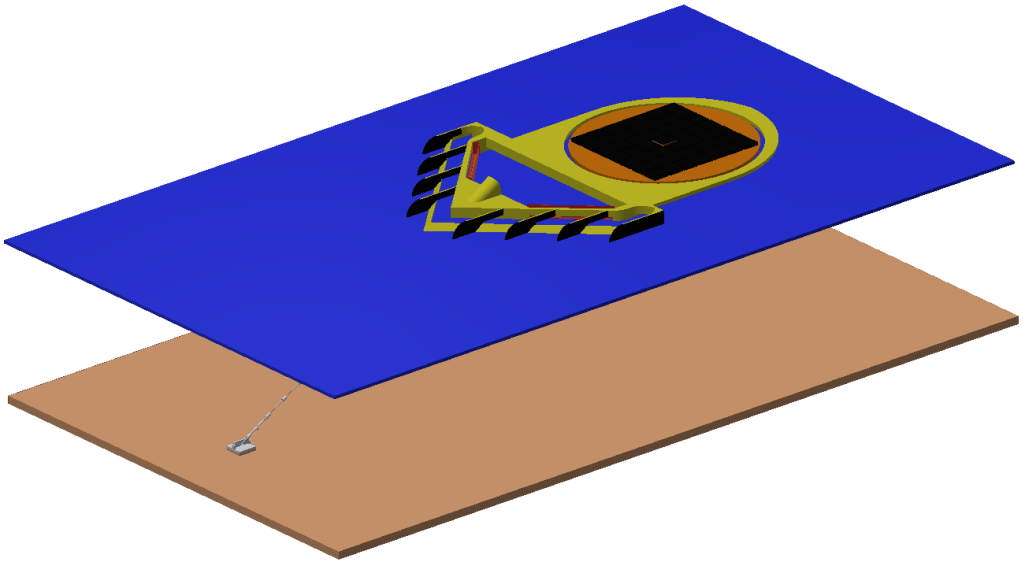
Note that the revenue stream from the aquaculture system could be 5 time the revenue stream from the wind system.

7.0 FLOATING SOLAR

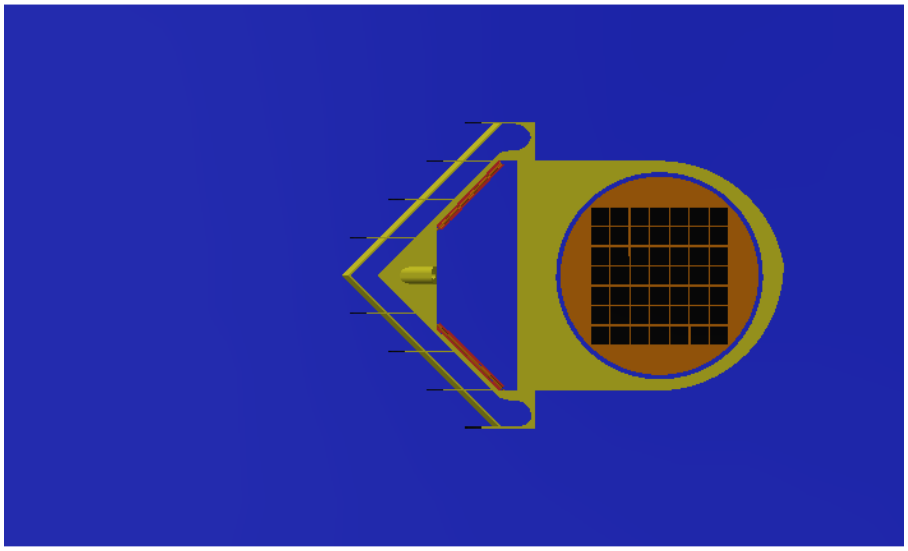
7.1 Floating Solar

The Scotstream floating structure can be used as a mounting platform for an offshore floating solar system.

The floating solar system could be located in the calm waters in the lee of the floating structure. As the structure weathervanes to face into the oncoming waves, the solar system would always be protected at the stern of the structure.



It should be noted that locating the floating solar system in the calm area astern of the main structure will mean that existing “plastic” PV Float systems and equipment can be used. This will remove the requirement for the development of large steel protection structures. The cost effective floating solar systems currently used in inshore lochs, lakes, dams and reservoirs can be use offshore.



Combining floating solar and the wave energy converter technology on one Multi-Purpose Platform will result in capital and operational cost savings and provide two separate revenue streams for the developer.

8.0 SCOTSTREAM WAVE ENERGY CONVERTER SUMMARY

8.1 Wave Energy

The Scotstream system is a new and novel design of wave energy converter and waterwheel generator.

The floating structure is designed for high survivability as it has no moving parts and the wave impact on the structure is carefully managed.

The Hydrobox overshot waterwheel is ideal for low head and high flowrate water and has a power-take off efficiency of over 80%. The waterwheel only has one moving part.

The combination of a wide wave capture profile and high energy conversion efficiency will maximise the generation capacity of the system.

The combined result is an offshore converter that is highly efficient and has high survivability in the offshore environment.

8.2 Multi-Purpose Platform Applications

The Scotstream floating structure can also be used as a stable operating platform for floating wind. A 15 MW wind turbine can be mounted centrally on the stern of the structure to provide two revenue streams for the offshore installation. This combined solution should be considered for the current tranche of offshore wind lease areas, namely, ScotWind, Celtic Sea and Norwegian Sea.

The area to the stern of the floating structure is very calm and should be considered for offshore aquaculture and floating solar applications.

The main challenge with these technologies offshore is survivability, the current approach is to develop heavy steel cage and protection structures. As the area is in calm waters, the existing “plastic” fish farm cages and PV Floats can be used. This will minimise the capital costs and provide a commercial solution for these technologies in an offshore environment.

The business case for combining wind, solar and aquaculture systems on the Scotstream wave converter should be considered as a route for commercialising all of these technologies.