Potential of ocean energy to contribute to a sustainable energy future in South Africa

SANEA Lecture – Cape Town
12 November 2014

Prof JL (Wikus) van Niekerk

Contents

- Introduction to Ocean Energy
  - Wave Energy
  - Tidal Currents
  - Ocean Currents
  - Temperature Gradients (OTEC)
  - Salinity Gradients
  - Offshore Wind Energy
- Wave Energy
- Ocean Current Energy
- Potential in South Africa

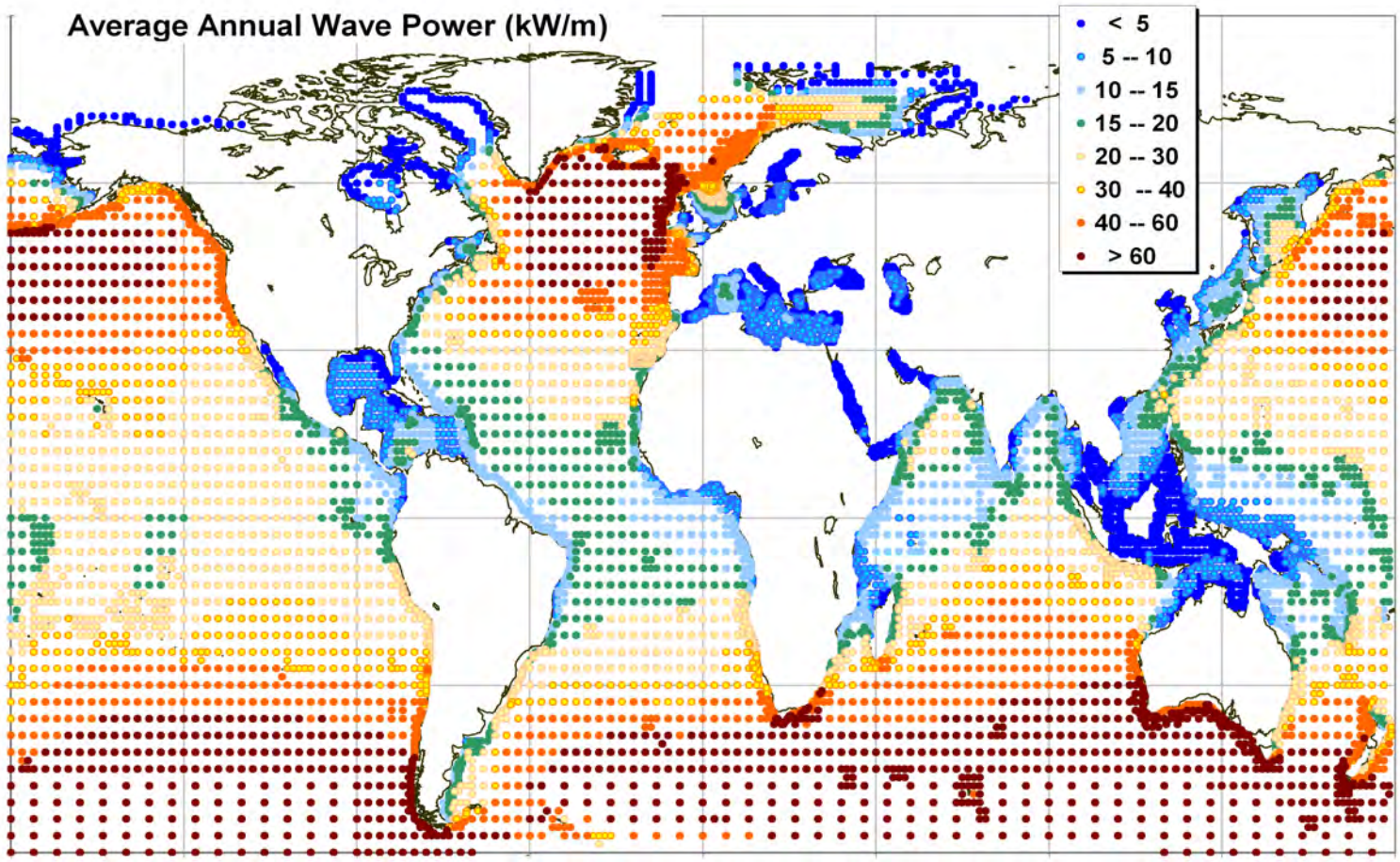
Introduction to Ocean Energy

- Over 70% of the earth's surface is covered by oceans and seas
- Major oceans are:
  - Atlantic Ocean, 77m sq km, 111 866 km shoreline
  - Indian Ocean, 69m sq km, 66 526 km shoreline
  - Pacific Ocean, 156m sq km, 135 663 km shoreline
  - Artic Ocean, 14m sq km, 45 389 km shoreline
- Many seas, i.e. Mediterranean, North, Black and Caspian seas, etc.
- Vast resource that can be exploited for food, energy, minerals, human settlement, transport, etc.

Introduction to Ocean Energy

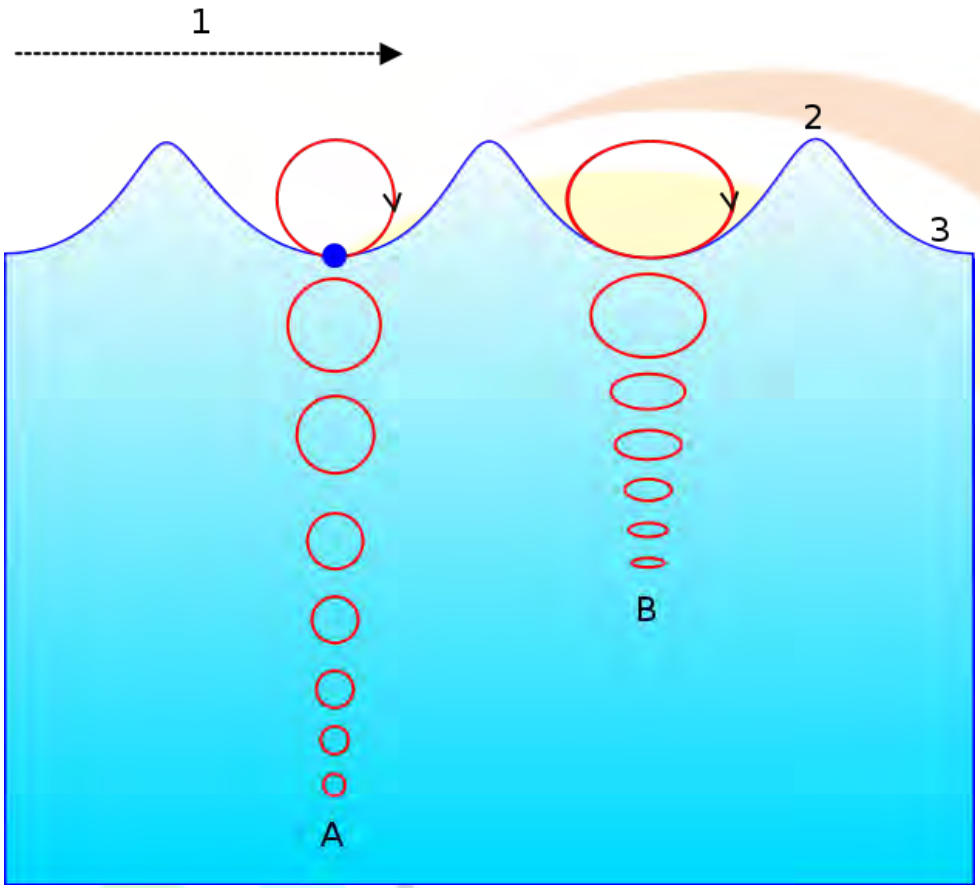
- Ocean energy is not restricted to only waves and currents, the most obvious, but also includes temperature and salinity gradients and even offshore wind energy.
- Oceans are already major sources for ***fossil fuel***; offshore oil- and gas-wells in areas such as the North Sea, West-Coast of Africa and the Gulf of Mexico.
- Challenging and expensive environment to operate in!

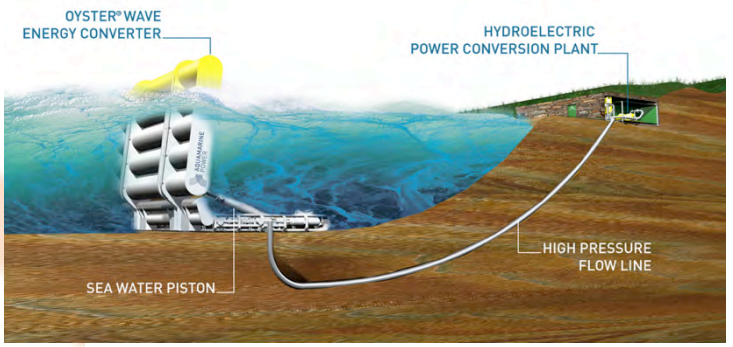
Wave Energy Resource in the World



World Waves data/OCEANOR/ECMWF

Wave Motion





Wave motion is circular becoming eliptical and even linear at shallower depths.

Note that there is kinetic energy available, due to the motion of the water particles, and also potential energy, that manifest as pressure differences between wave crests and troughs.

Heave: Vertical up and down motion

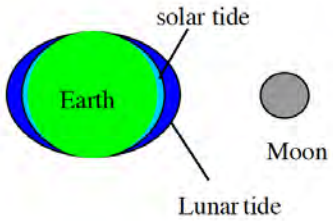
Surge: Horisontal forward and backward motion

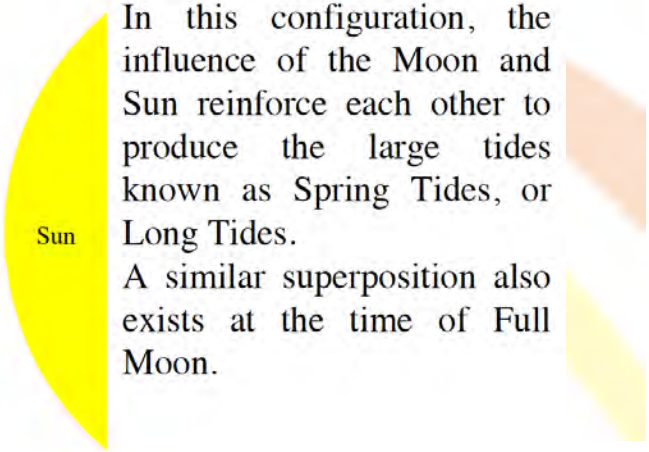
Potential Energy: Water pressure

Tidal Currents

- The water in the oceans on earth are subjected to attractive forces due to two large bodies; the moon (close but smaller) and the sun (large but far away).
- Both cause “bulges” in the ocean, but at different times/periods.
- Tides were well understood by Newton and can be accurately predicted well into the future.
- No “extreme events” such as “storm” tides.

Tidal Currents

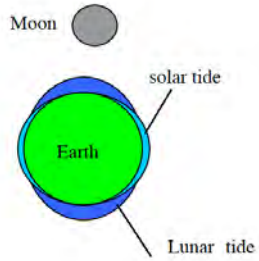




In this configuration, the influence of the Moon and Sun reinforce each other to produce the large tides known as Spring Tides, or Long Tides.
A similar superposition also exists at the time of Full Moon.

Spring (or Long) Tides

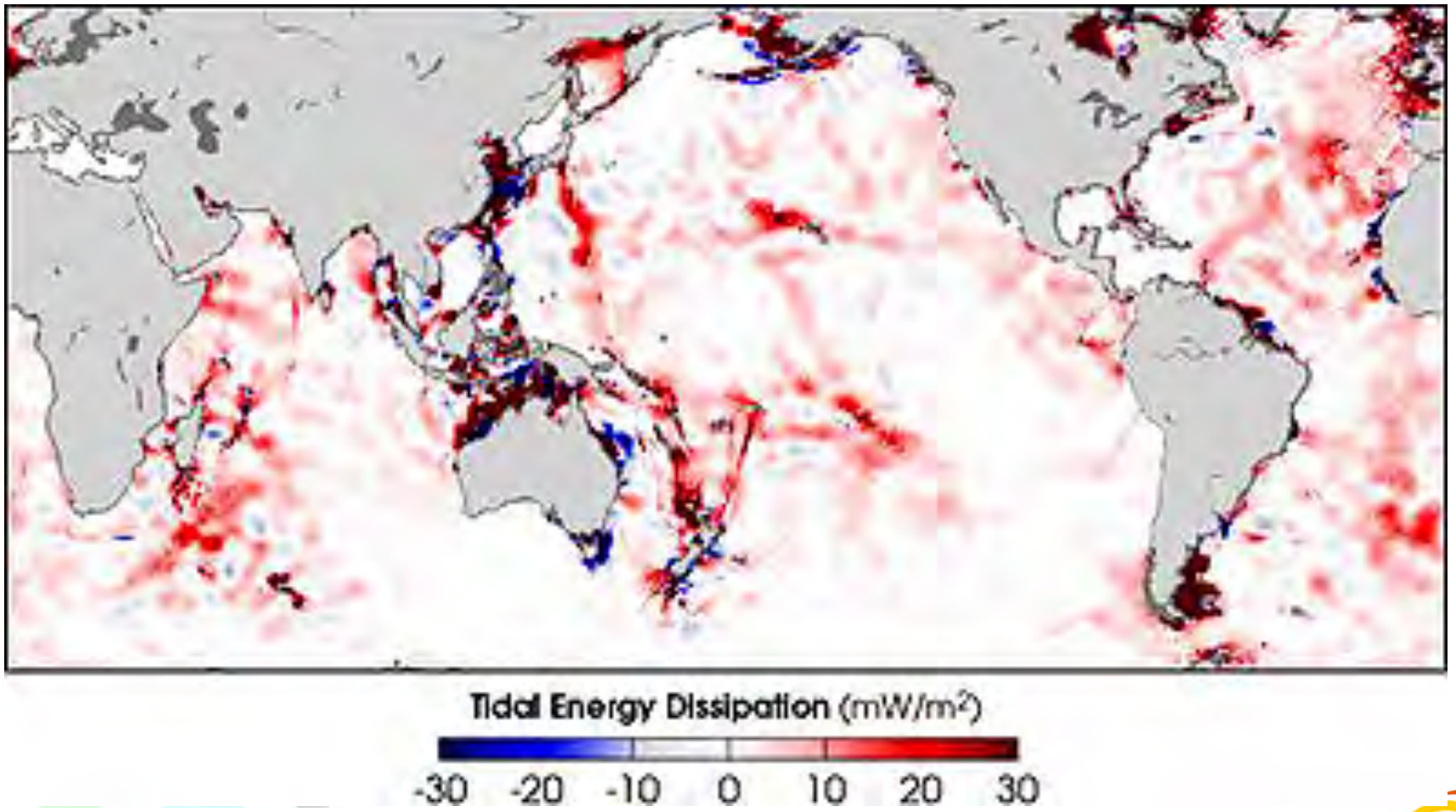
Neap (or Short) Tides



When the Sun and Moon are at 90° to each other, the effect is of cancellation as shown.
This configuration results in Neap Tides, which are also know as Short Tides.

Source: Prof Ian Bryden (University of Edinburgh)

Tidal Currents

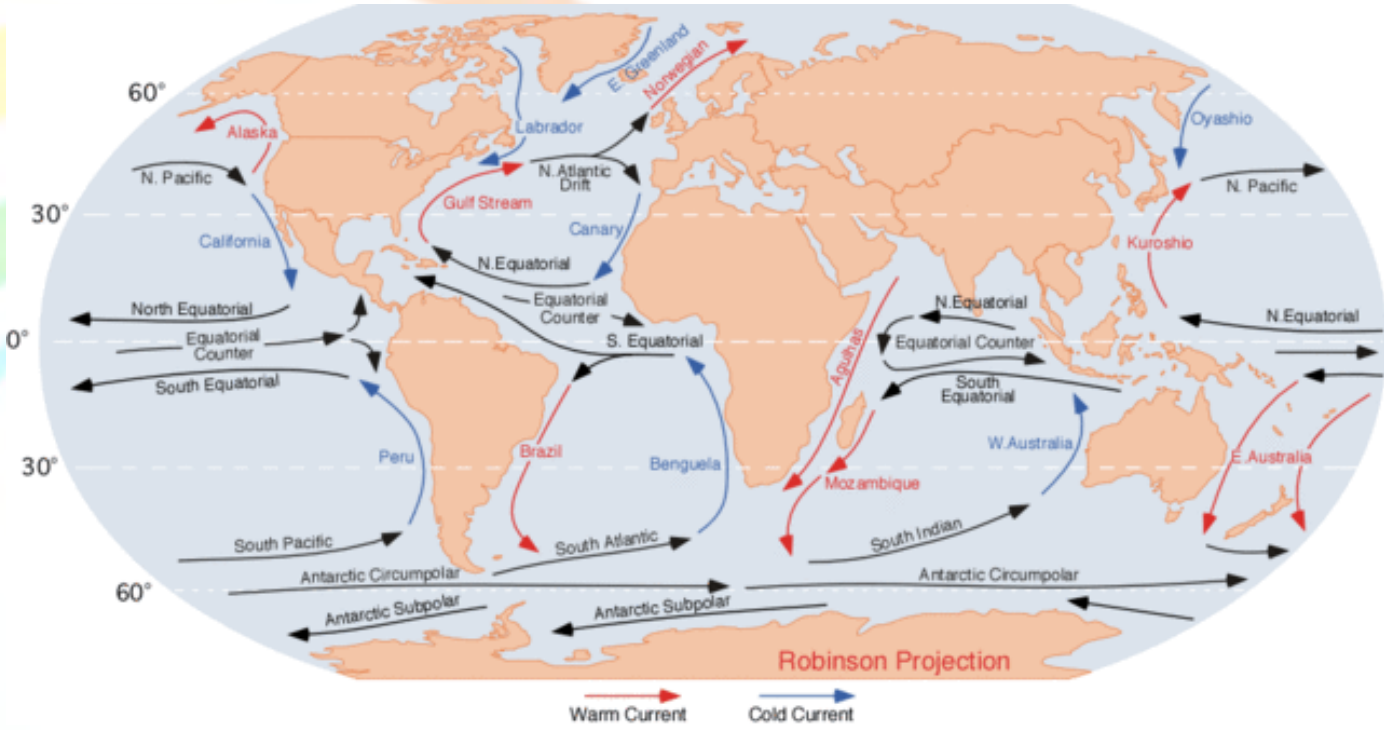


Tidal Currents

- Barrages, Eg. Le Rance in France
- Tidal Lagoons
- Free-stream turbines

Ocean Current Energy

- Major ocean currents:
  - Agulhas
  - Gulf Stream
  - Kuroshio
  - Labrador

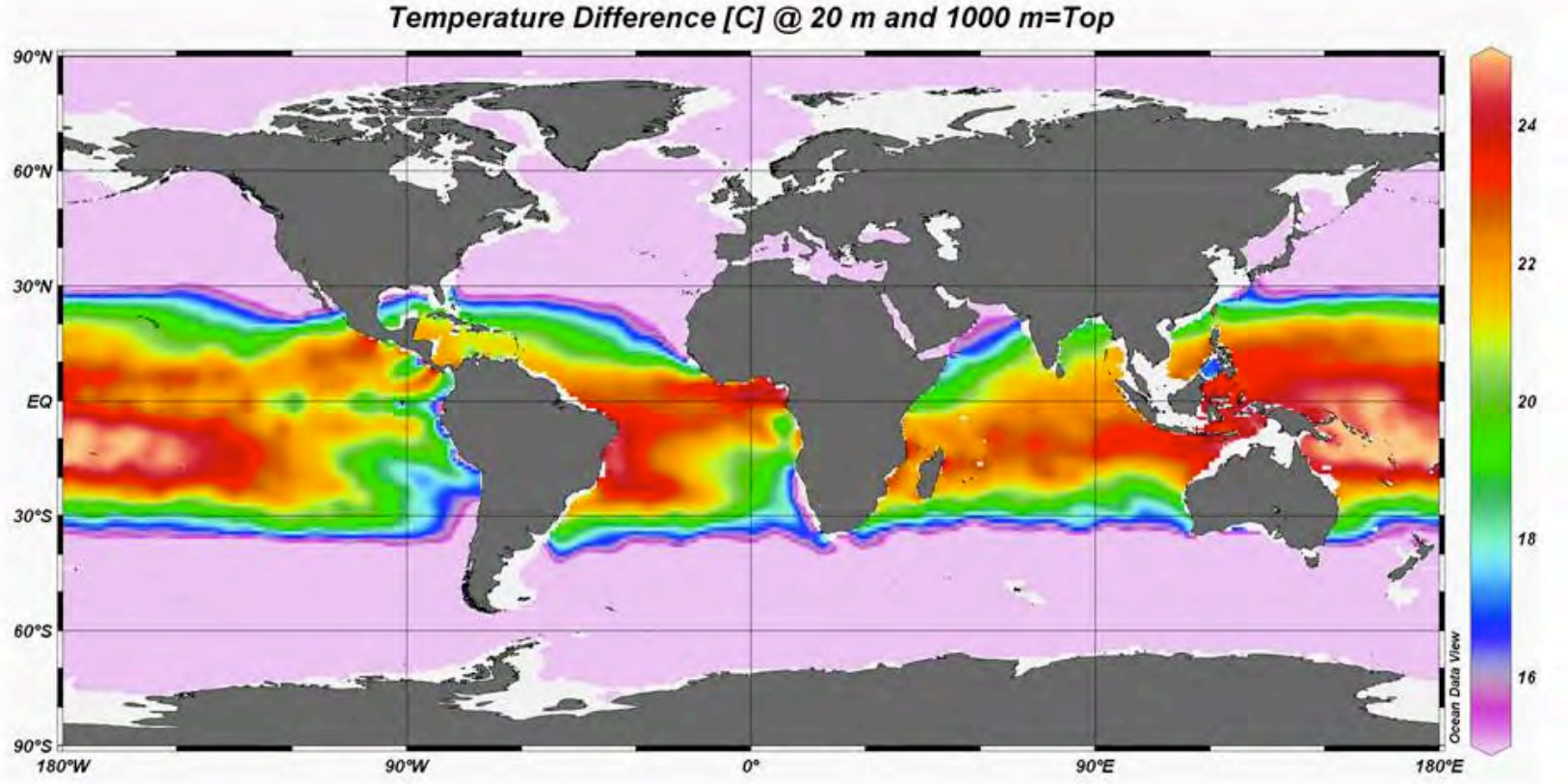


Ocean Current Energy

- Attractive because:
  - More consistent
  - Large density of water
  - "Base load" potential
- Challenges:
  - Further offshore than tidal currents
  - Deeper water
  - Deployment, operations and maintenance are difficult
  - Possible influence on Climate Change

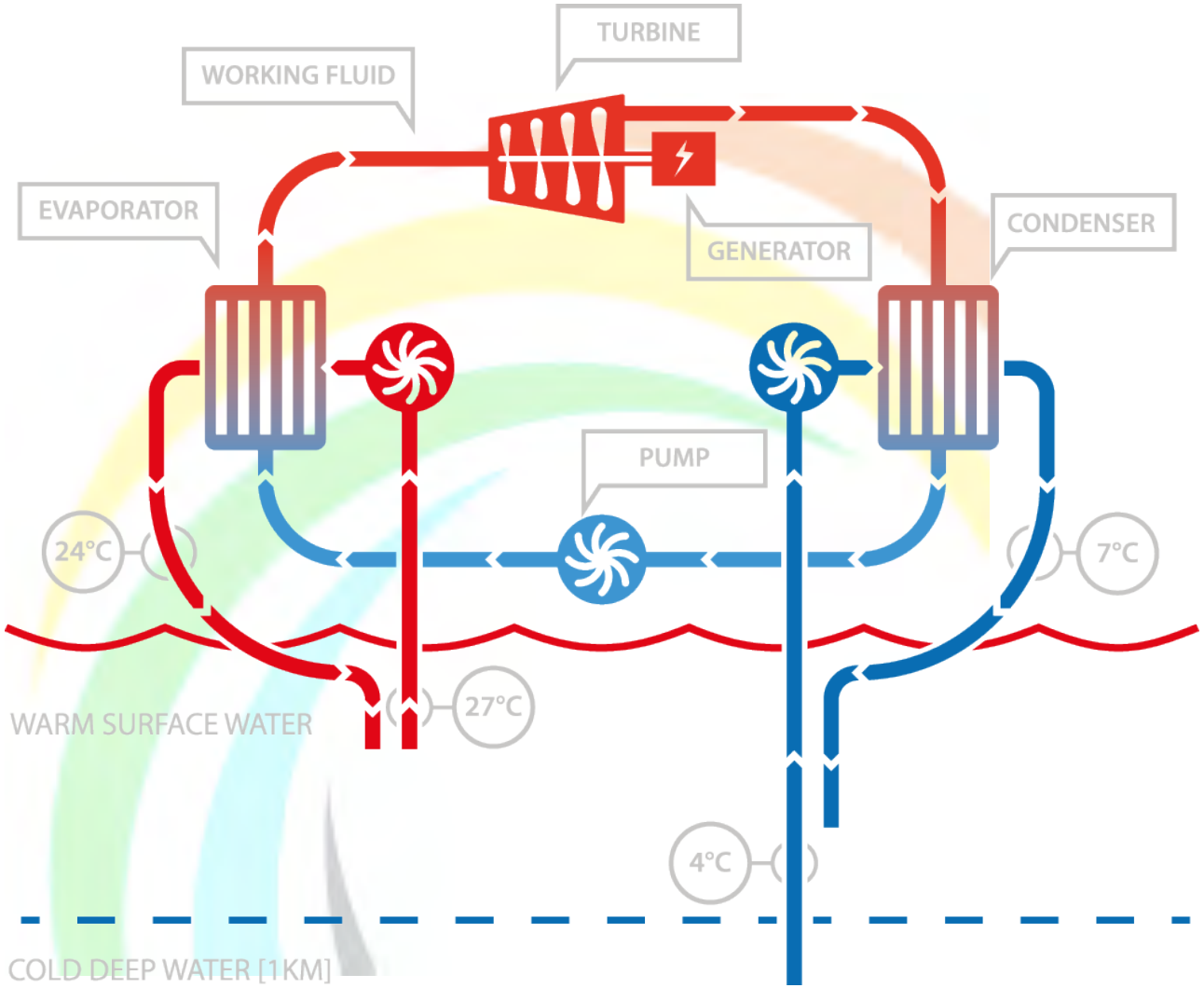
OTEC

- **O**cean **T**hermal **E**nergy **C**onversion (OTEC)
- Make use of ΔT to drive an organic Rankine Cycle



Centre for Renewable and Sustainable Energy Studies

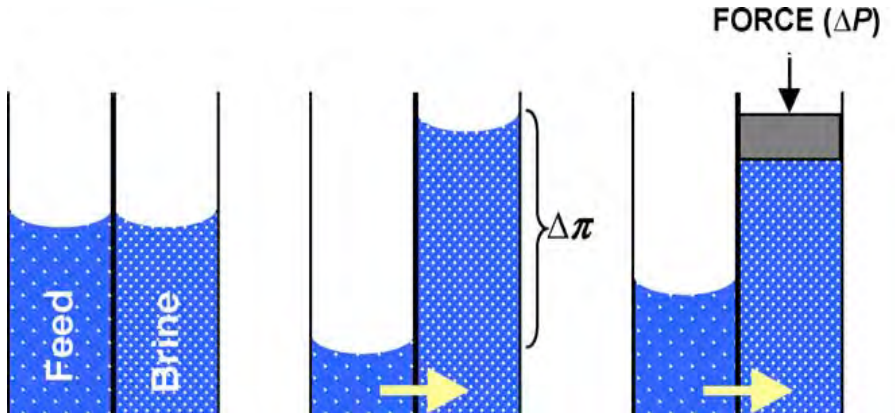
OTEC



http://www.bluerise.nl/wp-content/uploads/2012/12/OTEC-cycle.png

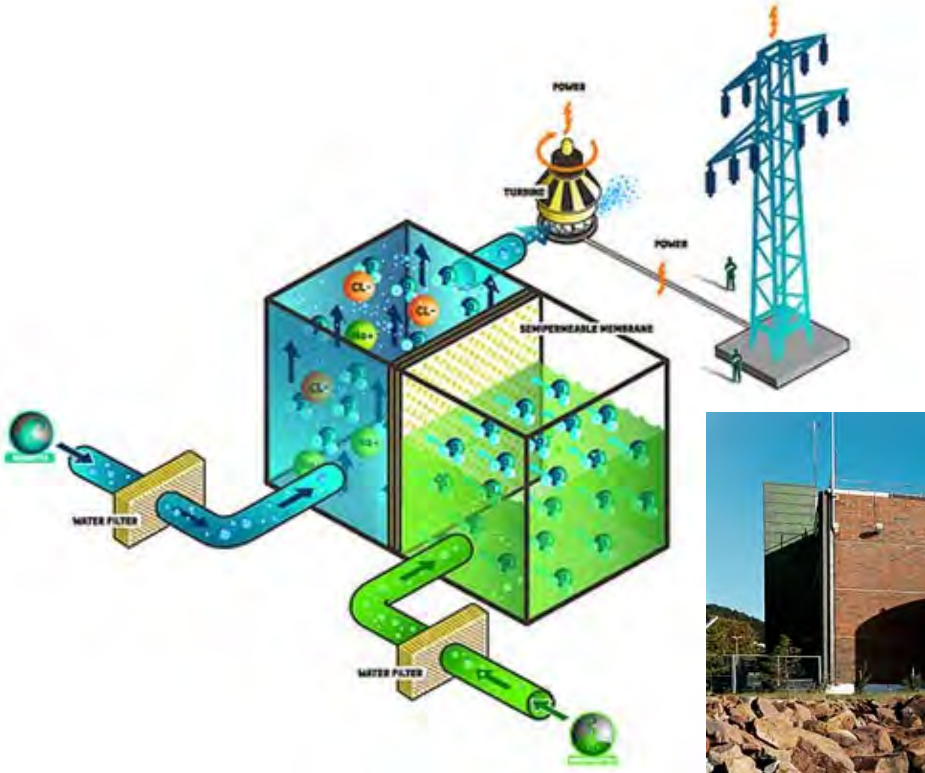
Salinity Gradient

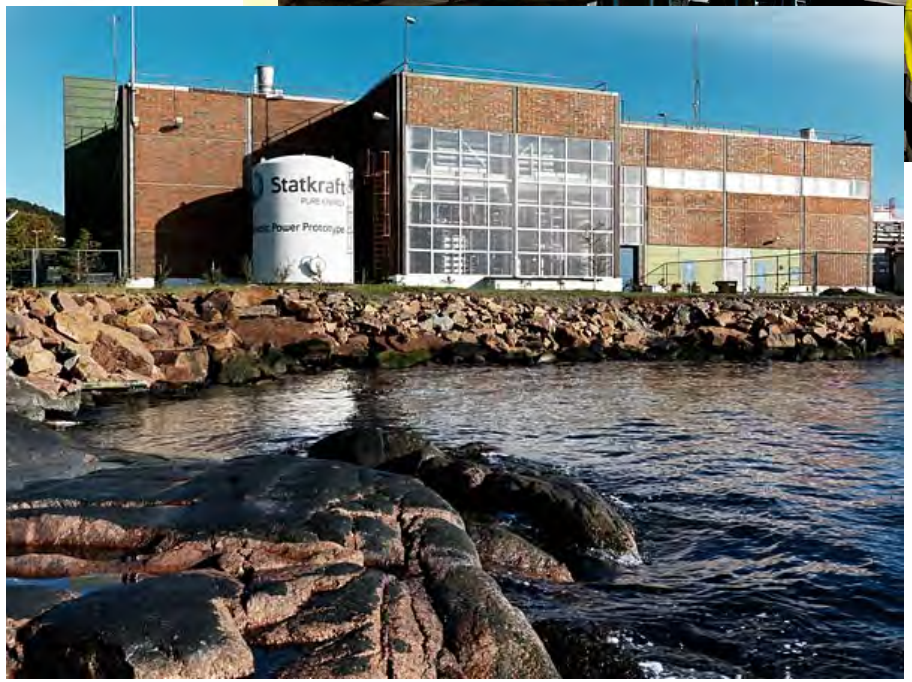
- Make use of osmotic pressure where fresh water moves through a selective membrane to a saltier solutions and hence create a pressure (or “head”) on the other side, up to 120 m.
- This pressure difference between the fresh and salty water solutions are then used to drive a turbine.
- Demonstration plant in Tofte, Norway.



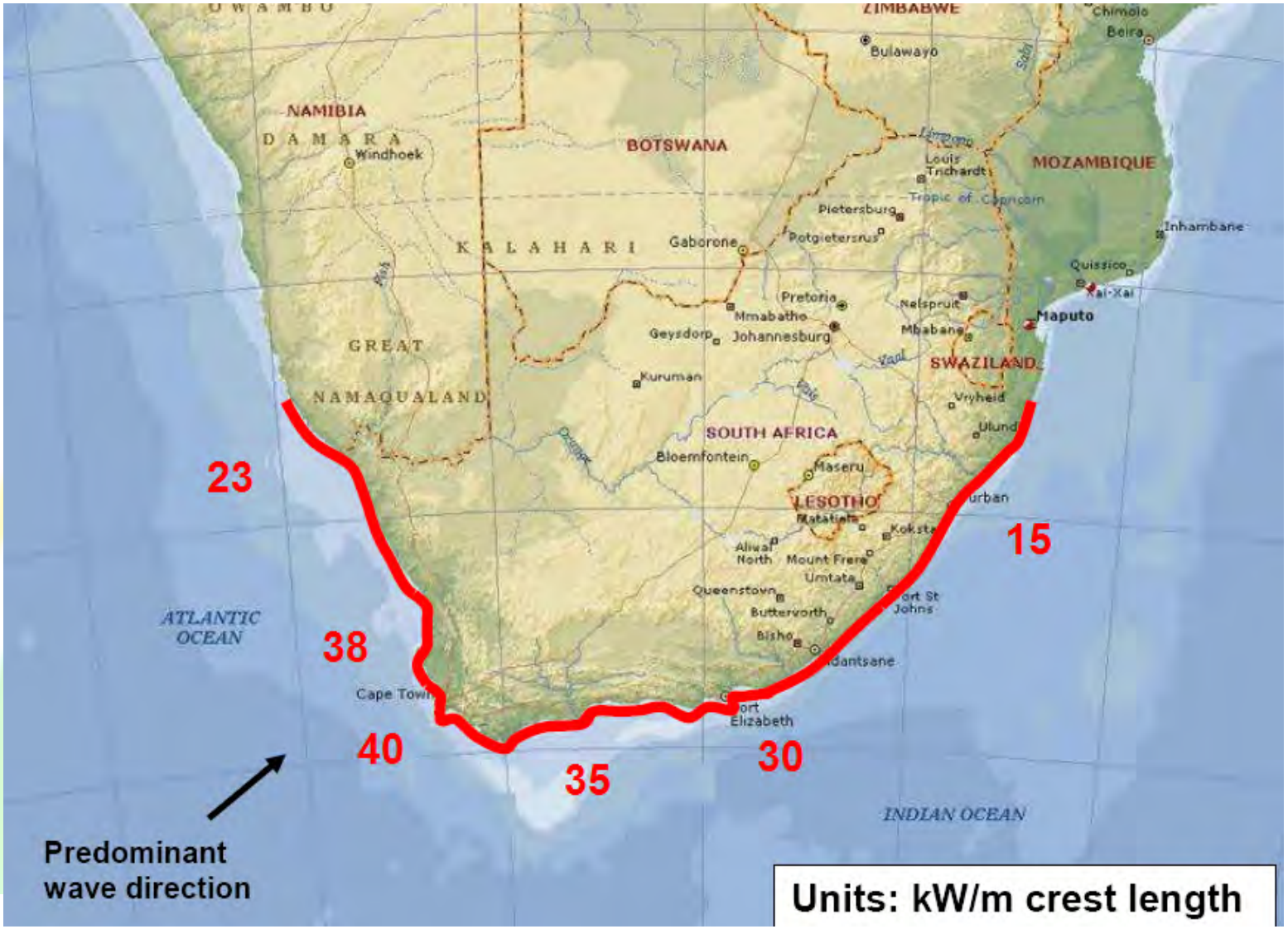
http://www.statkraft.com/energy-sources/osmotic-power/

Salinity Gradient



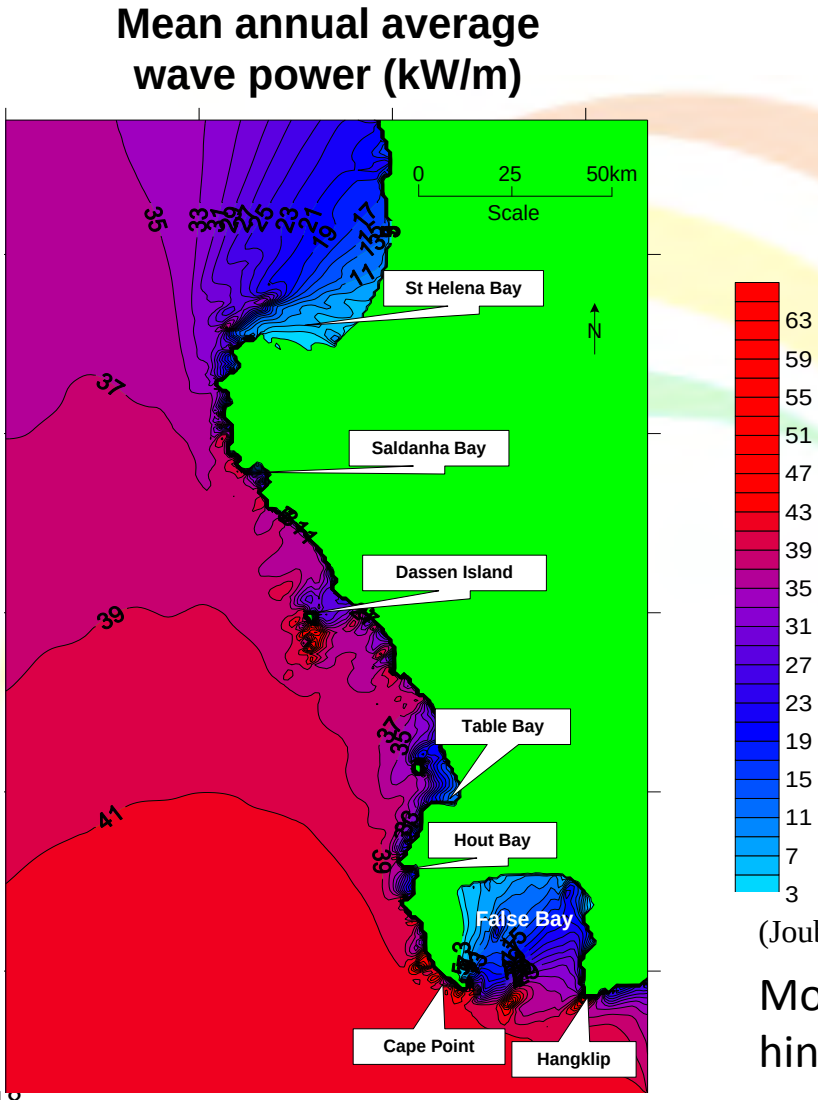


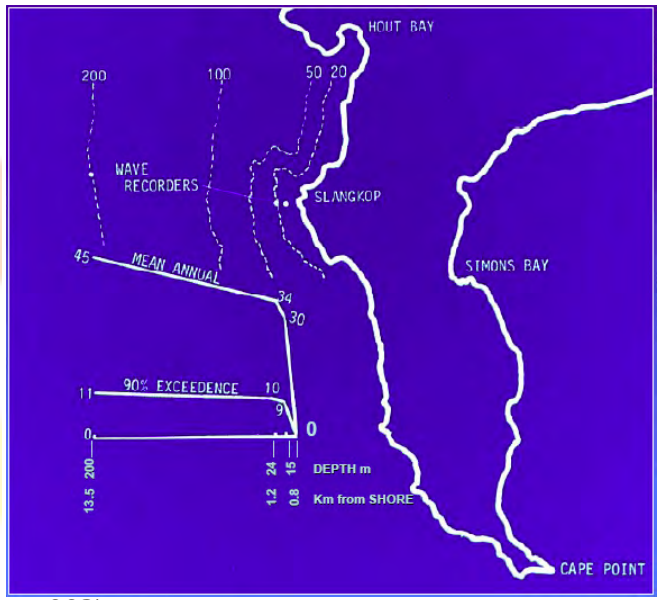
Wave Energy Resource in SA



Centre for Renewable and Sustainable Energy Studies

Wave Energy Resource





(Geustyn, 1983)

The Cape southwest coast has the best documented wave energy resource along the SA coastline.

(Joubert 2007)

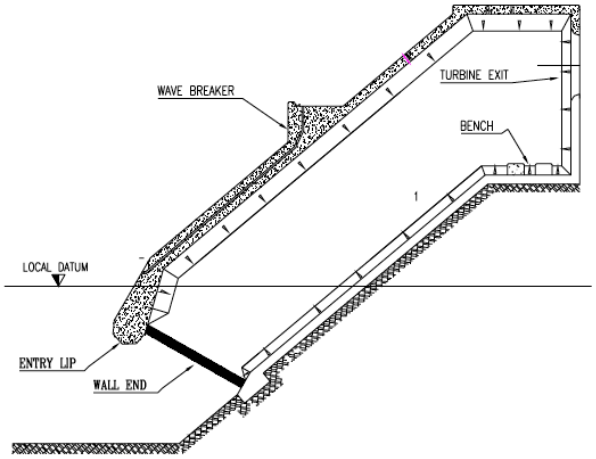
Modelled the annual average wave power using hindcast wave data

Centre for Renewable and Sustainable Energy Studies

OWC: Wavegen's Limpet

Land **I**nstalled **M**arine **P**ower **T**ransformer (**L**IMPET)

- Oldest surviving, grid connected WEC
- Built on Isle of Islay, Scotland
- Started off as project of Queens University Belfast
- Commercialised as a company: Wavegen LLC
- Sold Wavegen to Voith Hydro AG
- Developed Well's turbine and used Limpet as a test facility for Wells' turbines
- Other projects Mutriku (installed) and Isle of Lewis (terminated)
- March 2013 Wavegen scaled down
- April 2014, Oceanlinx floating OWCs sank, again!

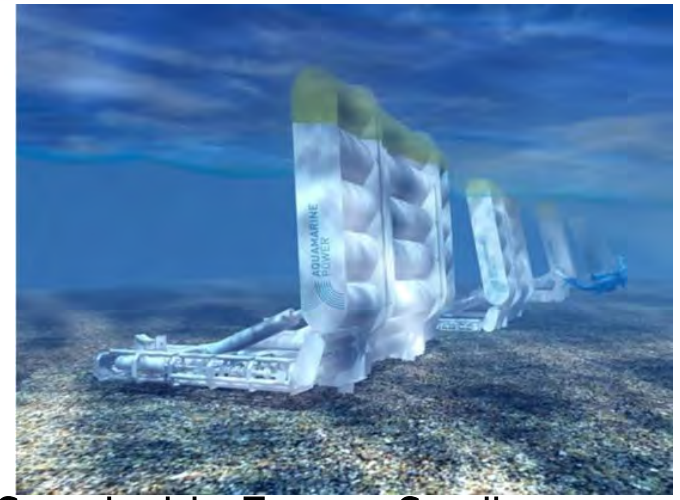


Attenuators: Pelamis

- Pelamis Wave Power is one of the most advanced commercial wave energy companies
- Makes us of a hydraulic PTO consisting of four rams at each node that drives two hydraulic motors and electric generators
- Followed a long development cycle since 1998
- Full-scale P1 machine tested at EMEC
- Three full-scale P1 machines delivered to a project in Portugal, failure?
- Two full-scale P2 machines delivered to clients for testing at EMEC, successful to date
- Still needs to prove survivability at sea
- Cost remains an issue and further development will take place to reduce this

Oscillating Wave-Surge Converter: Aquamarine Power

- Well-established wave energy company, since 2005
- Developed the Oyster oscillating flap
- Full scale prototypes, Oyster 1 (315 kW) and Oyster 800 (800 kW) deployed at EMEC
- Pump pressurised water to shore to drive a Pelton wheel turbine and generator
- Many component failures to date, even of equipment proven in the marine environment
- Next step is single hinged flap, made from composite with vertical cylinder
- Still developing their technology



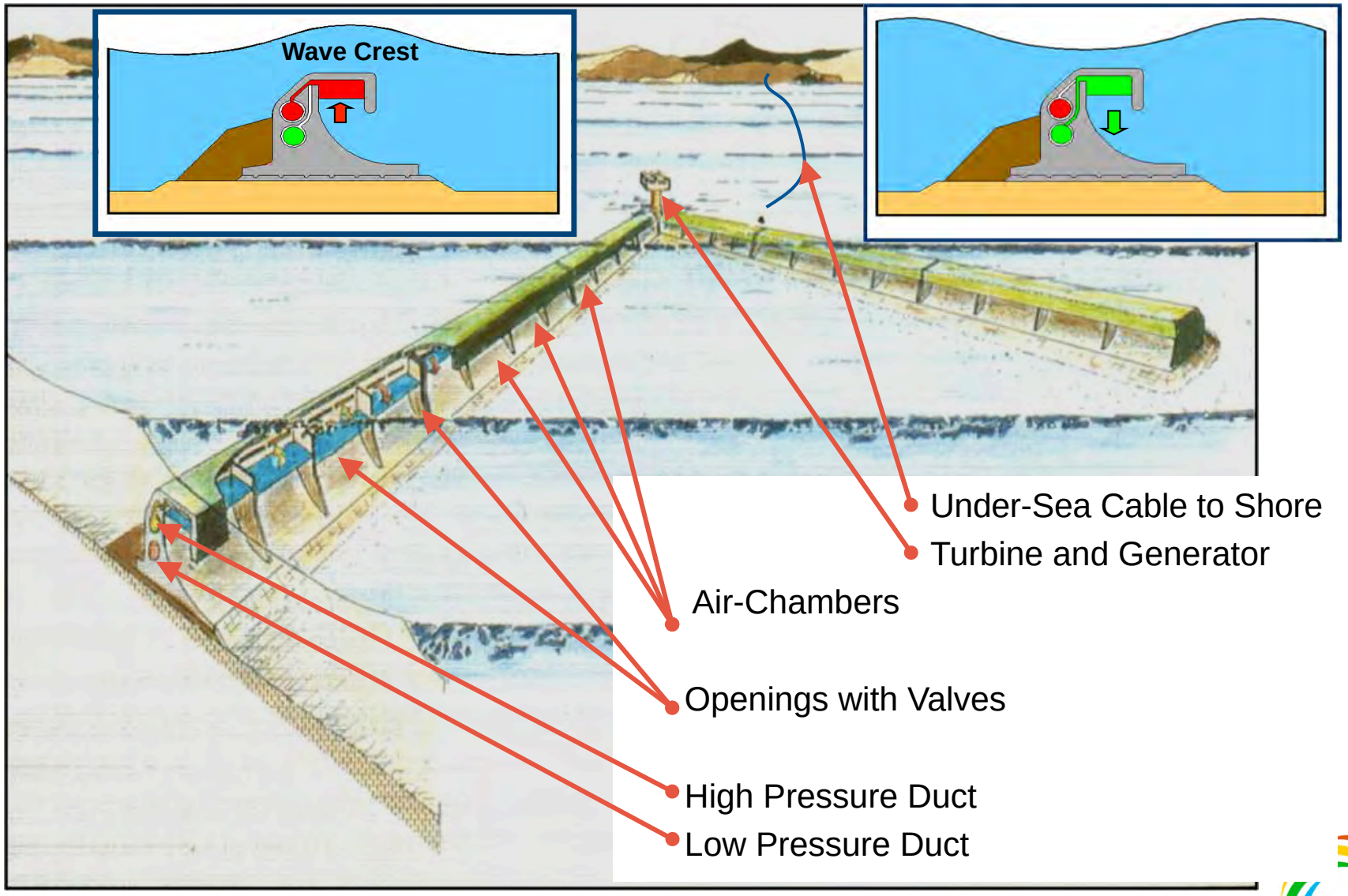
Others: Wavestar

- Bottom-standing device with articulating arms driving a hydraulic system
- Started in 2000 and has tested 1:10 and 1:2 scale models in the sea
- Currently upgrading 1:2 scale model with two more pontoons

Wave Energy Projects in South Africa

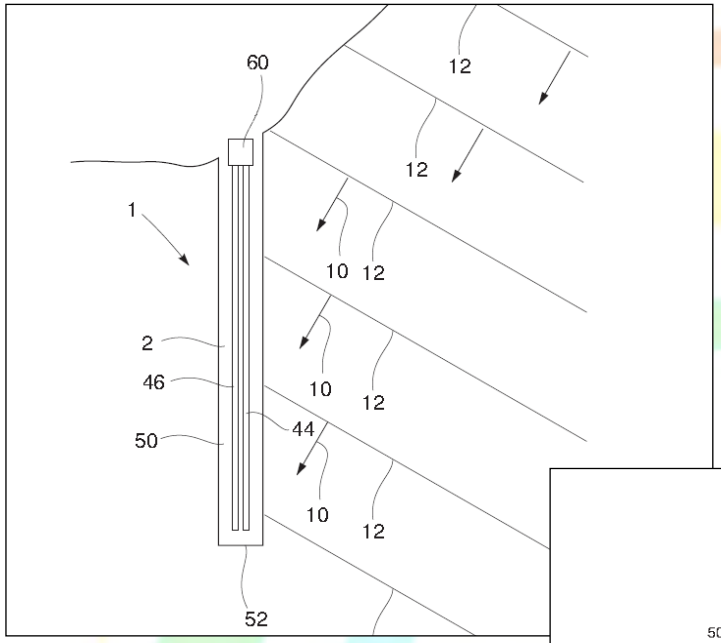
- SWEC
  - Stellenbosch Wave Energy Convertor
  - Developed in 1980's at Stellenbosch University's Ocean Energy Research Group (OERG)
- ShoreSWEC
  - One "arm" of the SWEC incorporated into a new breakwater
  - V&A Waterfront, Granger Bay identified as suitable deployment site
- Pelamis
  - Pursued a SA project in 2006-07 but that did not come off
- AquaBuoy
  - Vinafera's hose-pump buoy looked at a project off Hout Bay
  - Project sank with AquaBuoy and Finavera's ocean energy business
- Resolute
  - A technology developer from the USA is in discussions with stakeholders in SA on a possible wave energy plant, possibly for desalination
- Hermanus (Mean Sea Level (Pty) Ltd
  - Private developer looking at an overtopping device to provide electricity for abalone farming operations
- Others? WAPU; Impact-Free Water (Pty) Ltd; ??

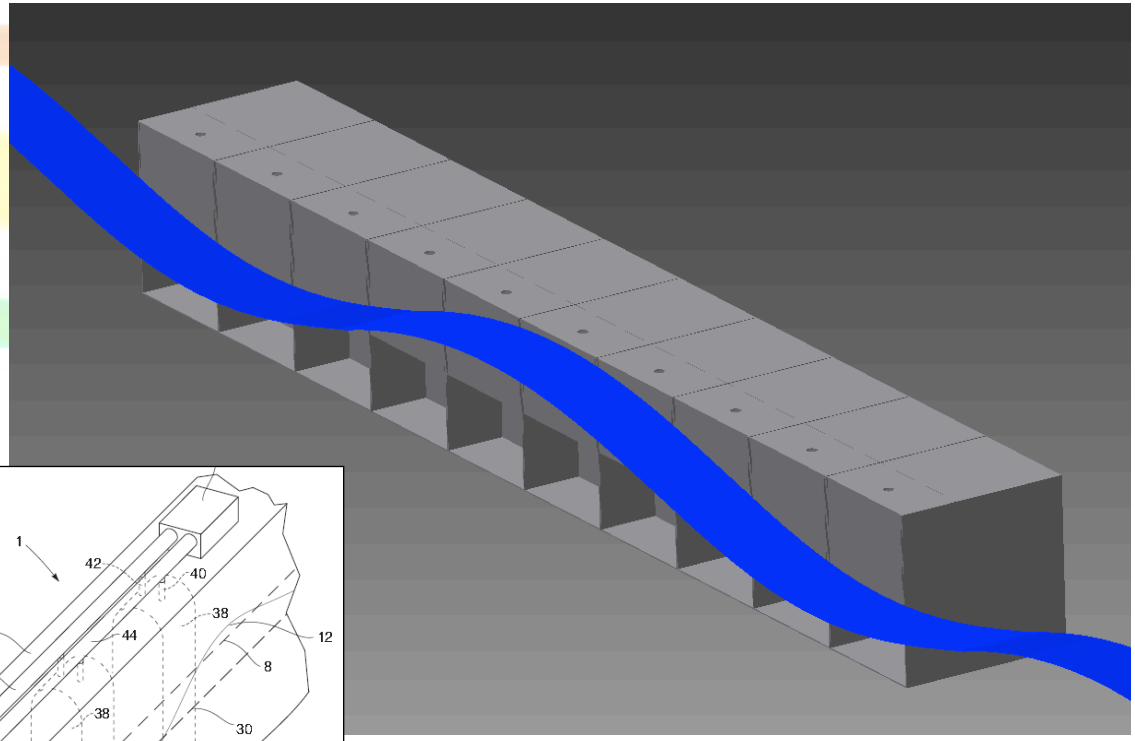
Stellenbosch Wave Energy Converter

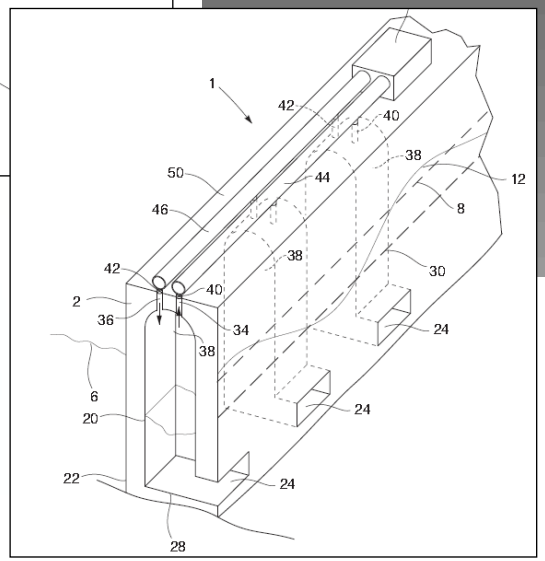


Centre for Renewable and Sustainable Energy Studies

ShoreSWEC





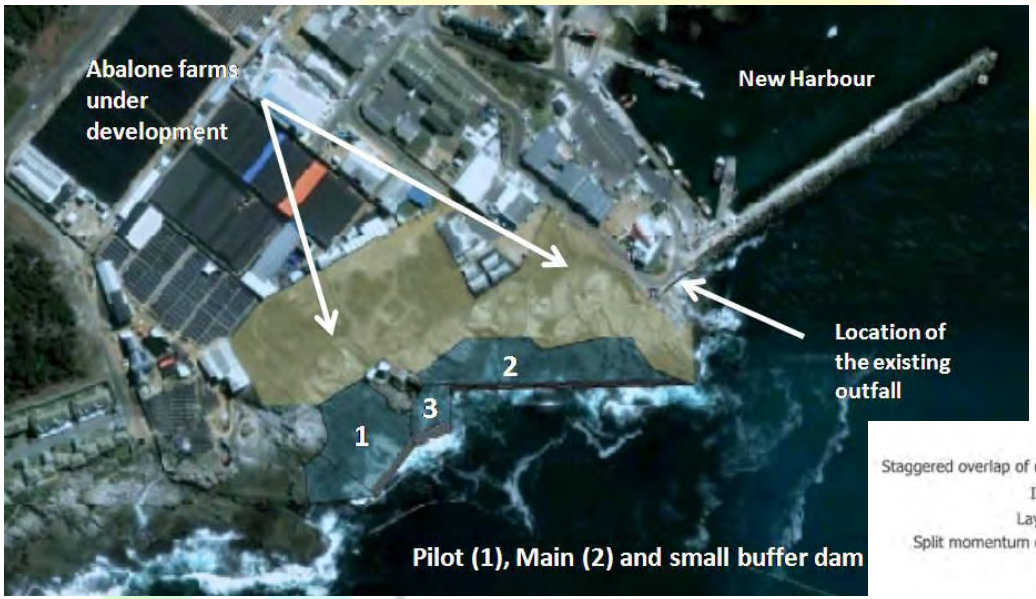


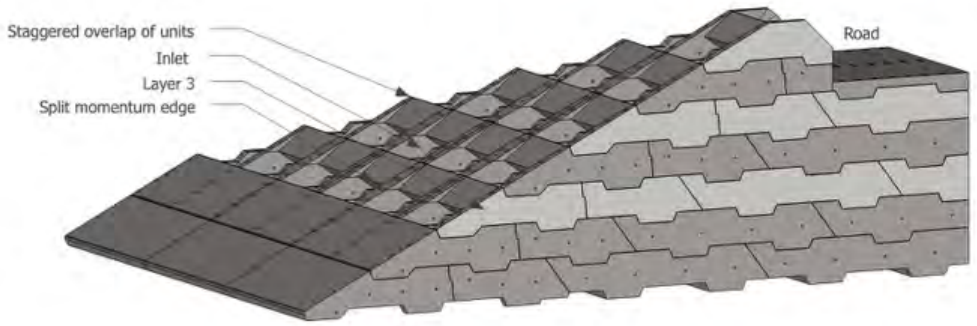
Centre for Renewable and Sustainable Energy Studies

ShoreSWEC

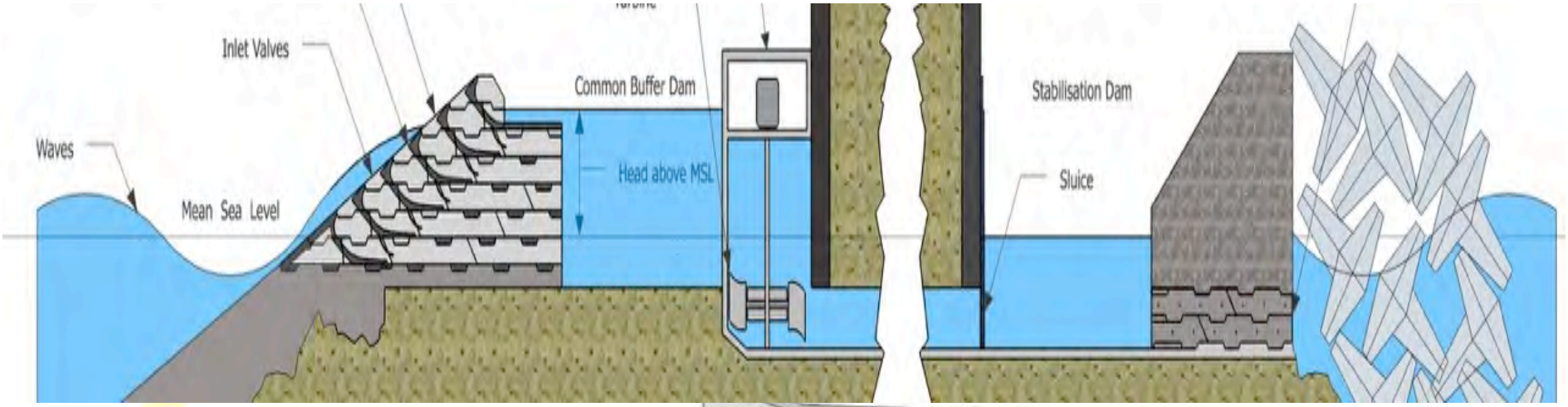
Hermanus Overtopping Device

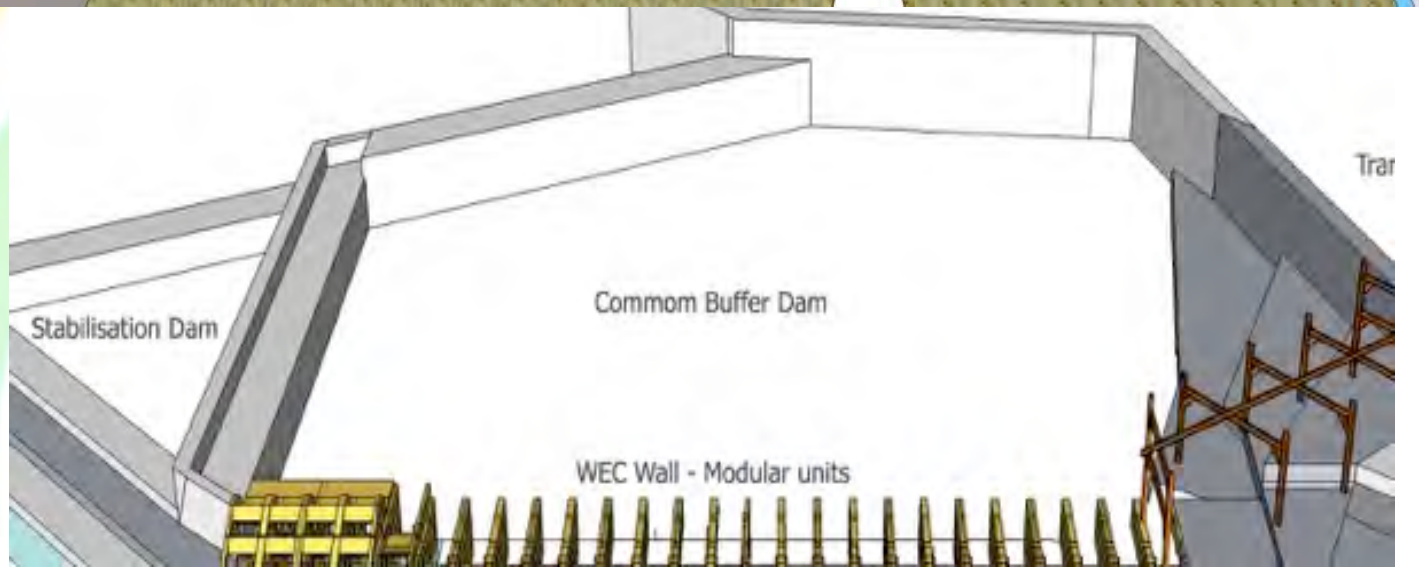
- Overtopping device(s), up to 5.25 MW (?) from low-head turbines by Mean Sea Level (Pty) Ltd
- First project 1 MW @ R 1,20/kWh ?



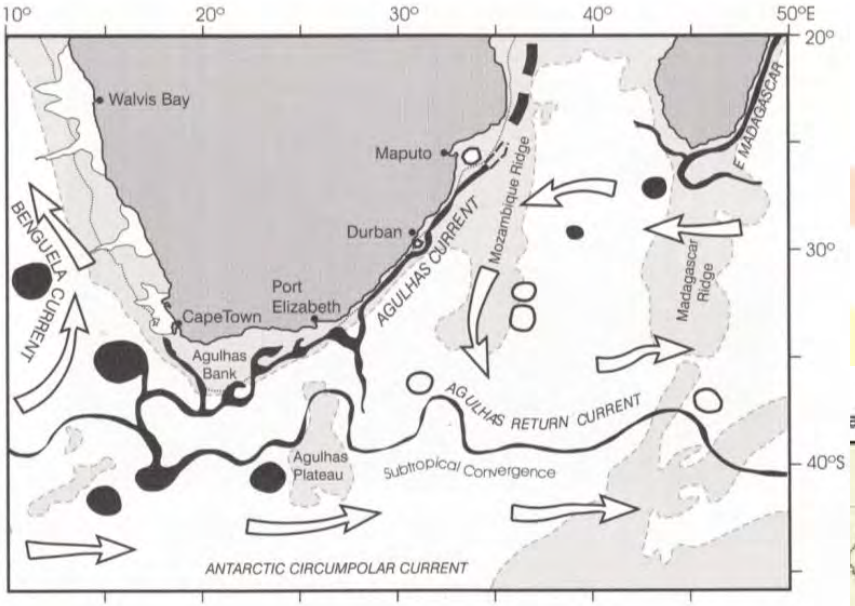


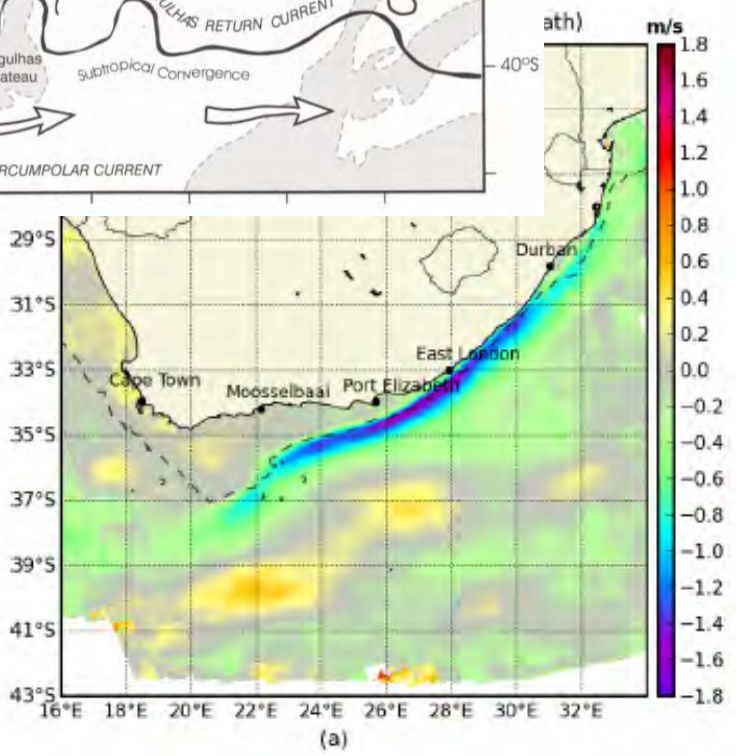
Hermanus Overtopping Device





Agulhas Ocean Current

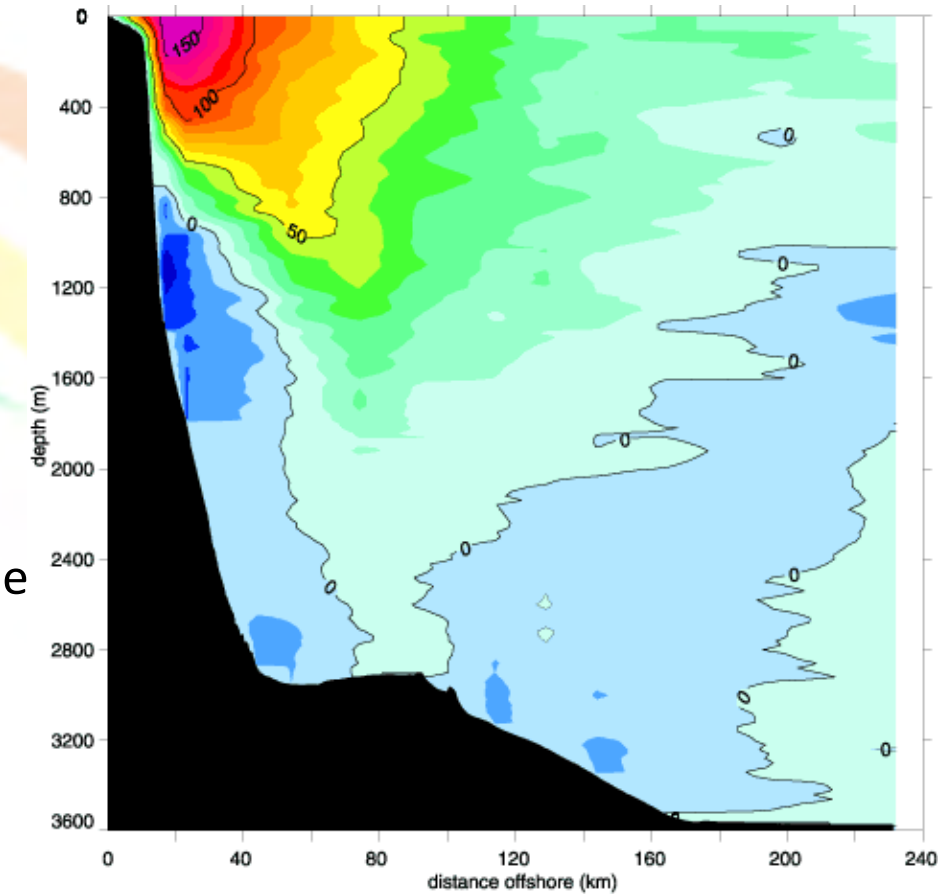




- Introduction (Origin)
  - The Agulhas current is an energetic wind driven current that transports warm salty water from the Indian Ocean to the Atlantic Ocean.
  - Formed by the combination of the Mozambique and East Madagascar Currents.
  - It is a surface current that is stabilised by the shallow shelf and steep continental slope on the southeast coast of South Africa.

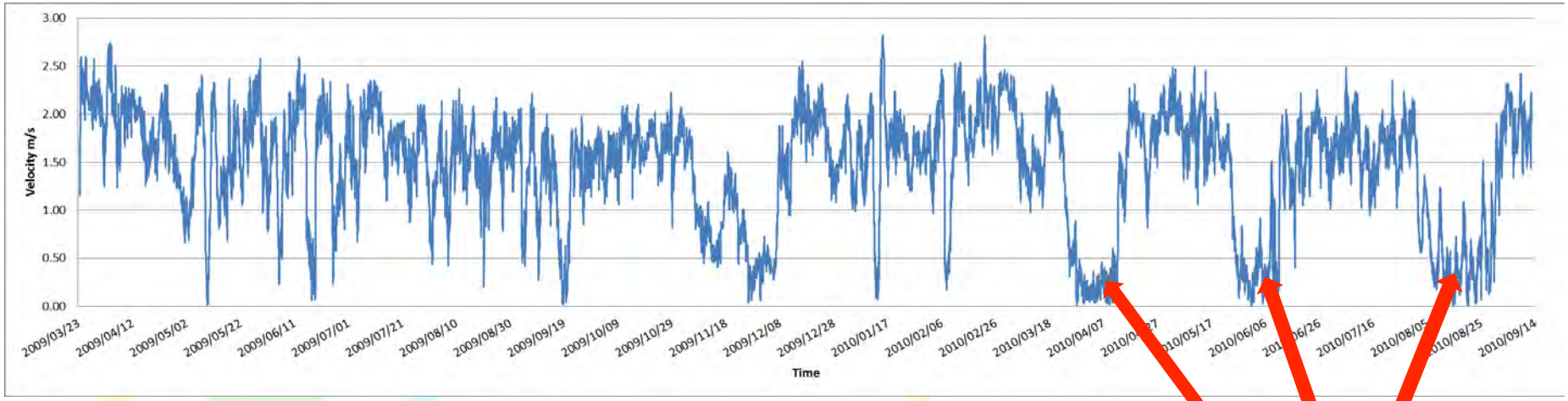
Agulhas Current Profile

- Surface current with a V-shape.
- Challenges:
  - Ships drift down the current to conserve fuel and reduce journey time.
  - Interaction between current, tides and storm system cause large rogue waves.
  - “Natal pulses” are eddies that break off main current and swirls back while moving south west with the current.
  - Undercurrent traveling in the opposite direction also present indicated by the blue shaded areas



Agulhas Current Measurements

Data capture through the use of ADCP's deployed by Eskom
Data captured at 32.507S, 28.831E (just off the coast of Cape Morgan)



- The presence of a Natal Pulse is seen as:
  - the sharp decrease in velocity of the current
  - the direction of the current reversing as the current passes over a specific point
- Interestingly it has been found that the pulses are not present when the minima and maxima in overall transport are studied

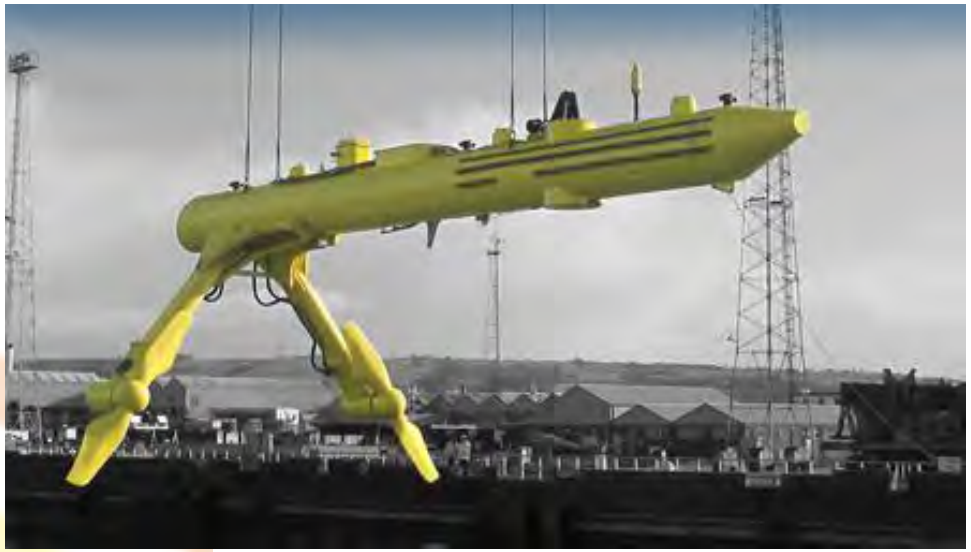
Horizontal Axis Turbine

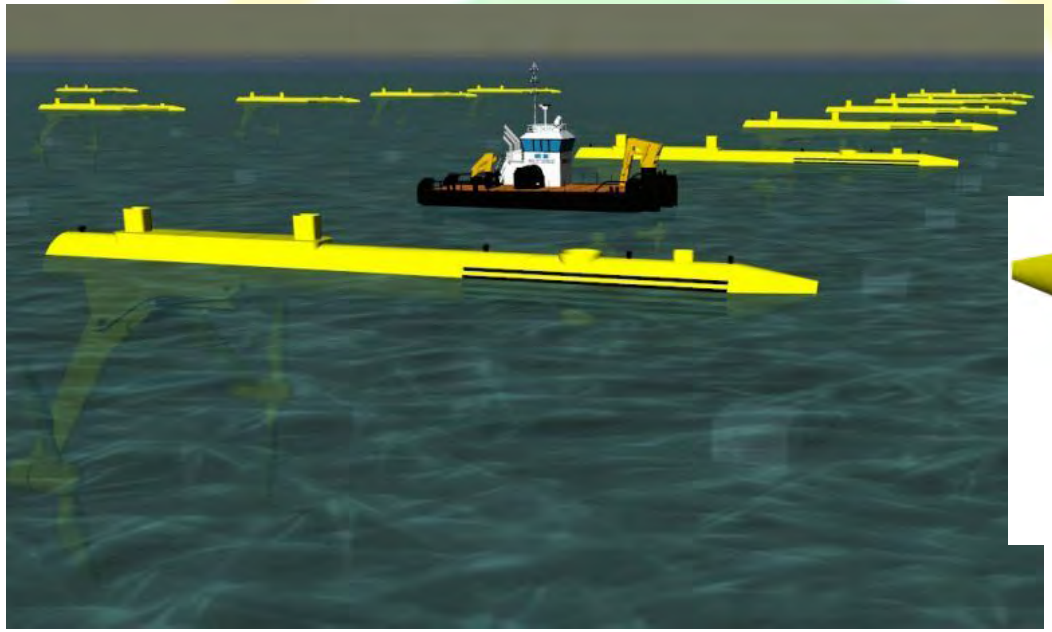
Marine Current Turbines Ltd (MCT) : SeaGen

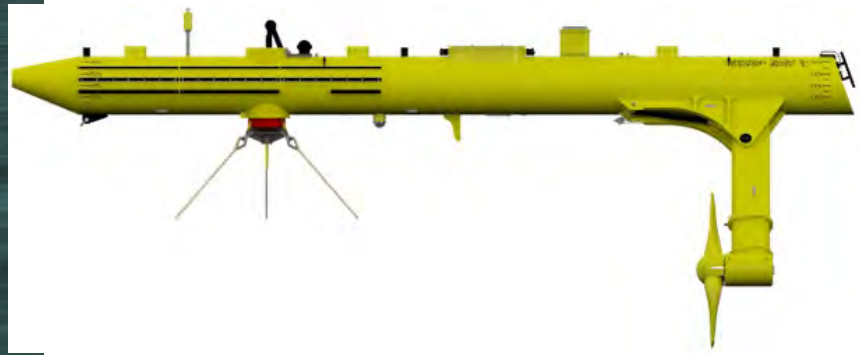
- Wholly owned by Siemens
- Turbines designed for tidal applications
- Been in this marine stream technology sphere for over 20 years
- Proven technology with commercial readiness
- Technology which has been deployed at Strangford Lough in 2008
- Specifications: 1.2 MW system which can generate 60 000 MWh per year

Scotrenewables

- Pre-commercial full-scale 250 kW prototype deployed in 2011

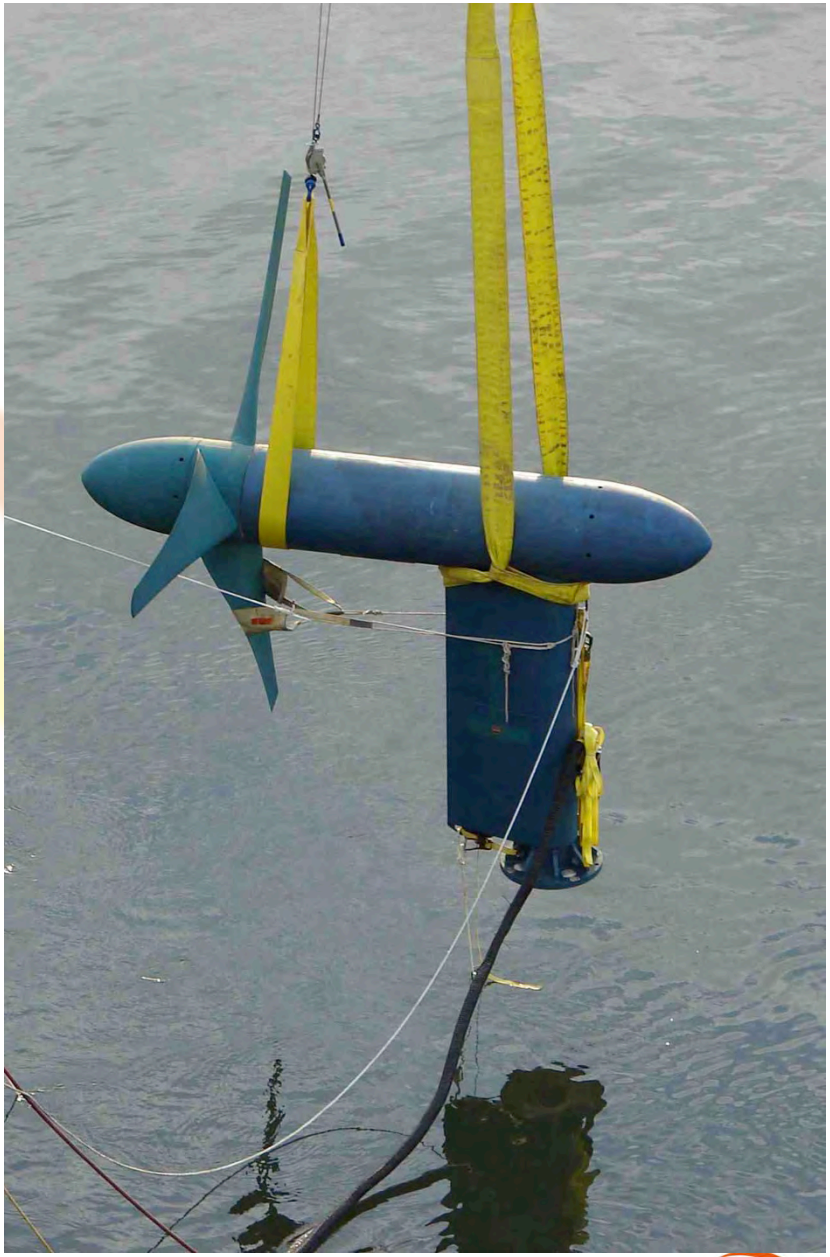


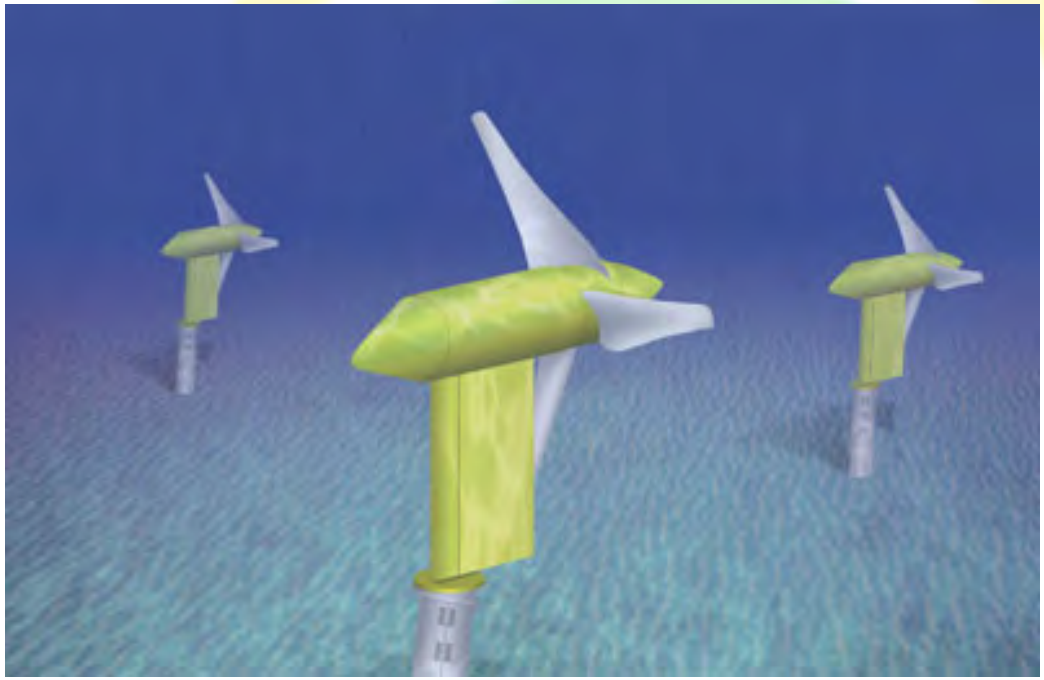




Verdant

- 3 phase project in progress for installation in the East River, New York
- Demonstration phase completed





Cost?

UK "Strike Price" 2012 prices published December 2013

	Strike Prices £/MWh (2012 prices)				
	2014/15	2015/16	2016/17	2017/18	2018/19
Advanced Conversion Technologies (with or without CHP)	155	155	150	140	140
Anaerobic Digestion (with or without CHP)	150	150	150	140	140
Dedicated Biomass (with CHP)	125	125	125	125	125
Energy from Waste (with CHP)	80	80	80	80	80
Geothermal (with or without CHP)	145	145	145	140	140
Hydro	100	100	100	100	100
Landfill Gas	55	55	55	55	55
Sewage Gas	75	75	75	75	75
Onshore Wind	95	95	95	90	90
Offshore Wind	155	155	150	140	140
Biomass Conversion	105	105	105	105	105
Wave	305	305	305	305	305
Tidal Stream	305	305	305	305	305
Large Solar Photo-Voltaic	120	120	115	110	100
Scottish Islands Onshore				115	115

Wind Energy:
£ 95/MWh
(R 1,71/kWh)

Ocean Energy:
£ 305/MWh
(R 5,50/kWh)

Large Scale PV:
£ 120/MWh
(R 2,16/kWh)

Cost?

- Technology harvesting energy from the ocean is still being developed with only a few pilot/demonstration plants built to date, hence accurate pricing information is difficult to obtain and still uncertain.
- In the **UK** the LCOE range will be **R 5,50/kWh** in the short to medium term, with the aim to compete with off-shore wind in the North Sea at **R 2,80/kWh**
- **Canada**: **R 3,75/kWh** to **R 6,50/kWh** for tidal current energy with subsidies
- In **South Africa**: **PV ≈ R 1/kWh** and **Wind ≈ R 0,74/kWh**
- Value of dispatchable power in South Africa **R 5/kWh** from OCGT, but ocean energy is not dispatchable

Conclusions

- South Africa
  - Has a reasonable wave energy resource and a strong ocean current, Agulhas Ocean Current, that can be harvested.
  - Stellenbosch University did some research and development work in the 1970's and -80's and again since 2007 on both ocean wave and ocean current resources and technologies.
  - Eskom has measured the Agulhas Current and sponsored some work/studies on wave energy, some new wave measurements are currently underway.
  - SANEDI sponsored some OE projects since 2007.
  - Ocean Energy converters are still too expensive for deployment in SA, especially when compared to other renewables, such as solar PV and wind energy.

Contact Details:

www.crses.sun.ac.za

wikus@sun.ac.za