USP

THE UNIVERSITY OF THE SOUTH PACIFIC

Renewable Energy Research at the University of the South Pacific & Future Prospects

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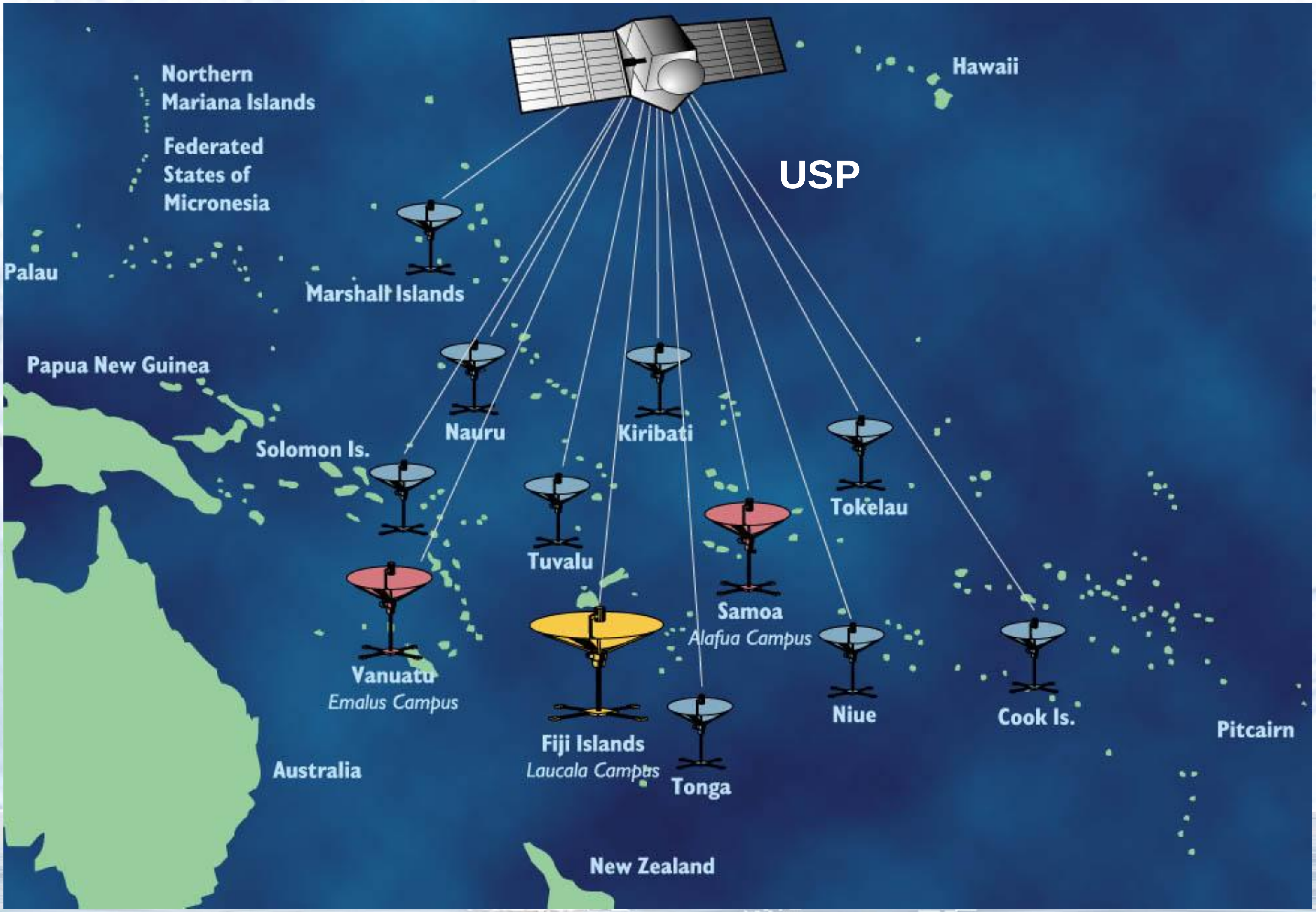
Renewable Energy Research at USP & Future Prospects

Background



The University of the South Pacific (USP) - a regional Univ owned by 12 countries & has 14 campuses in the South Pacific.

Background

- Geographical layout of Pacific (scattered islands and unavailability of power grid) needs tailor-made solutions that may differ from the rest of the world.
- USP covers 33 million sq. km of ocean, an area more than three times size of Europe.
- Total land mass is about equal to area of Denmark.
- A very high ratio of sea-area to land-area e.g. this ratio > 4000 for one country Kiribati.
- This unique nature of PICs makes offshore energy a clearly ATTRACTIVE OPTION and forces us to consider all options.

Background

Renewable Energy Group members are involved in a number of projects in many areas of RE including

- Resource assessment
- Design, development & testing of energy converters
- Installation of systems
- Capacity building at various levels

The Group has attracted external funding from donors such as EU, KOICA, Korean Govt, USAid, AUSAid, Taiwan etc. since 2010. Total cost of projects > F$15m.

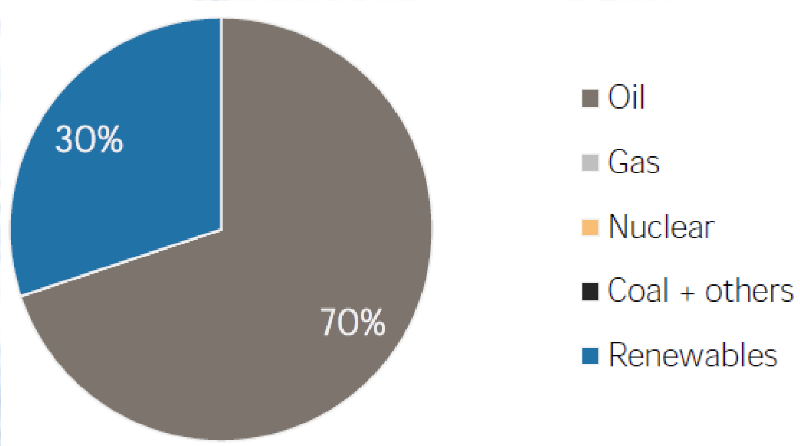
Types of work

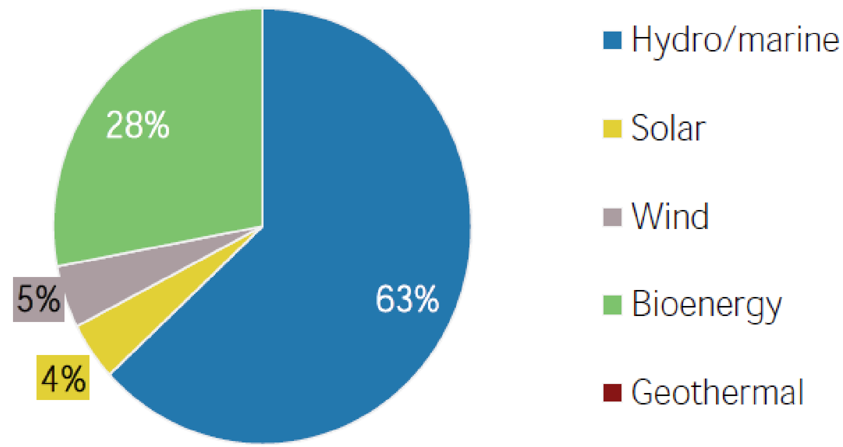
- Field work
  - Site survey
  - Initial (short-term) assessment of RE potential
  - Long-term measurements and analyses
  - Bathymetry and Geotechnical survey
  - Field testing of energy extraction devices.

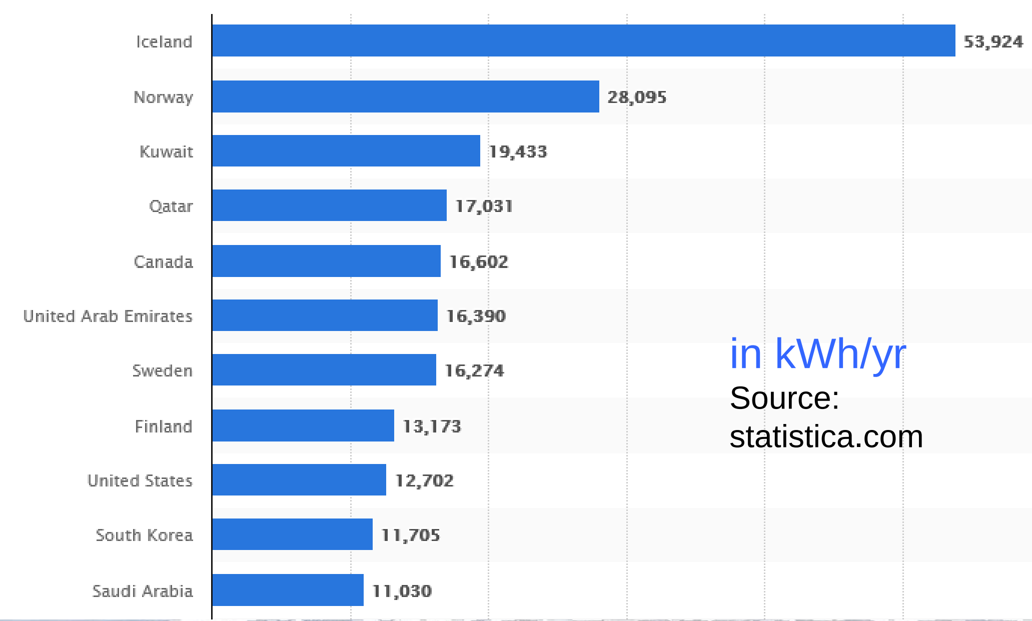
- Lab-based work
  - Numerical work (computational fluid dynamics)
  - Experimental work
  - Design and testing of new devices.

Some Statistics

Total (L) and RE (R) energy supply in Fiji. Source: IRENA







in kWh/yr
Source: statistica.com

- The RE share as of now is 30%. As of now, most of the RE in Fiji is generated from Hydro.
- Per capita electricity consumption (2022): top consumers. For Fiji, it is about 1,000 kWh.

Wind Energy

- Wind speeds on-land not high in PICs, except for some locations. However, power requirements also not large.
- Small WTs will be appropriate for most of the islands/ communities.
- Assessment of wind resources (short-term and long-term) at about 30 locations in PICs completed/underway.
- Ongoing work includes design of blades/sections for low Re applications, fabrication & testing of small WTs.

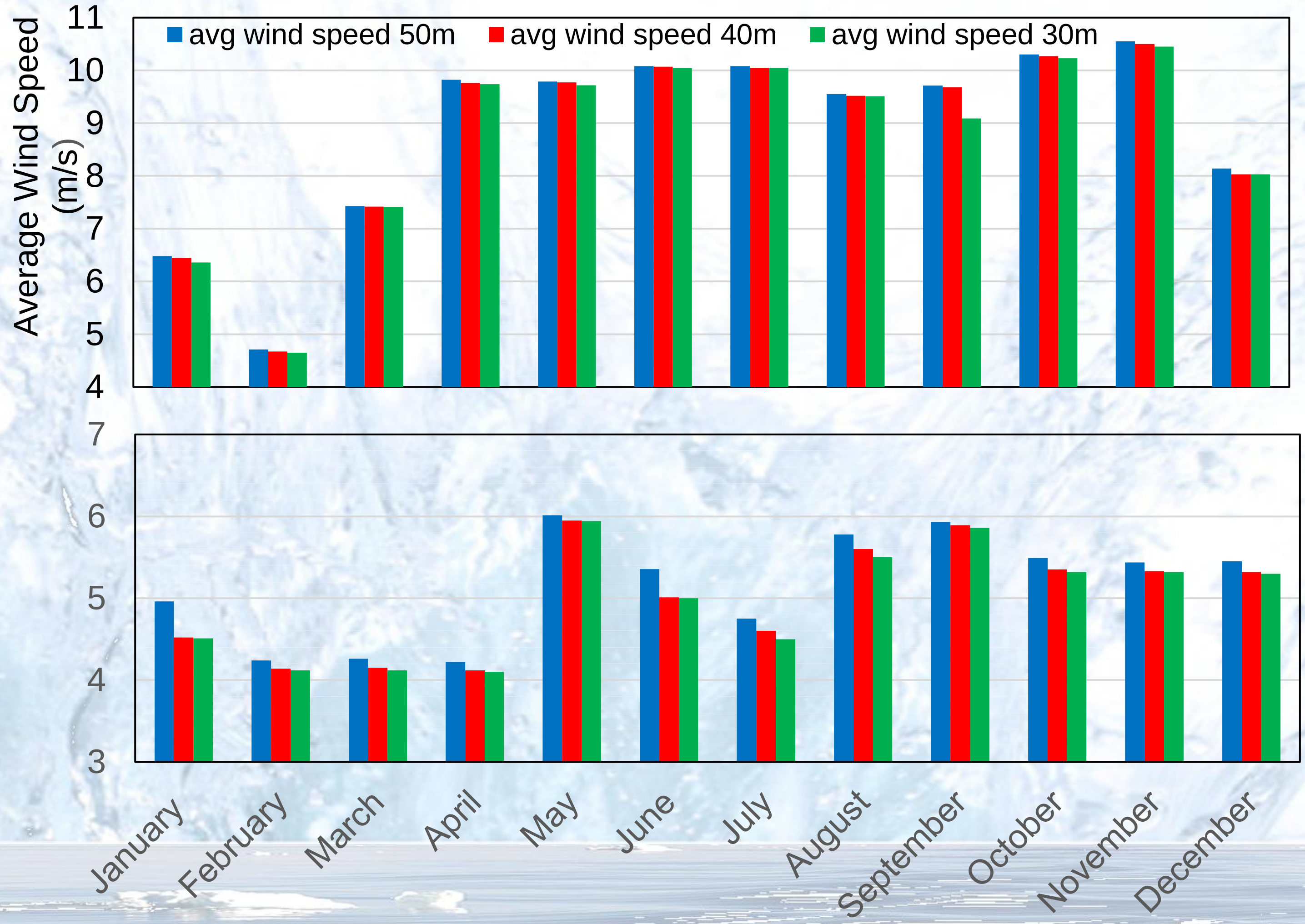
Wind Energy - IRERAS

Integrated Renewable Energy Resource Assessment Systems (IRERAS)
Details of Sensors

1	34m NRG TallTower - with anchors and ginpole
2	NRG SymphoniePLUS™ 15 channel Logger with Shelterbox
3	3 x NRG #40C Anemometer, Calibrated
4	1 x NRG #200P Wind Direction Vane, 10K, With Boot
5	1 x NRG #110S Temperature Sensor with Radiation Shield
6	1 x Guy Guard Kit - Single Unit (x17)
7	1 x Datakit4
8	1 x 4415 Relative Humidity Sensor RH5Xr
9	1 x 2046 NRG #BP20 Barometric Pressure Sensor
10	1 x 1948 Li-Cor #LI-200SZ Pyranometer
11	1 x Rain Guage - Tipping bucket
12	Symphonie SCM Sensor Cards as required
13	Cabling, mounting booms, lightning spikes and earthing as required
14	4033 Symphonie iPack for Iridium Satellite Phone, W/400 Minutes, w/PV

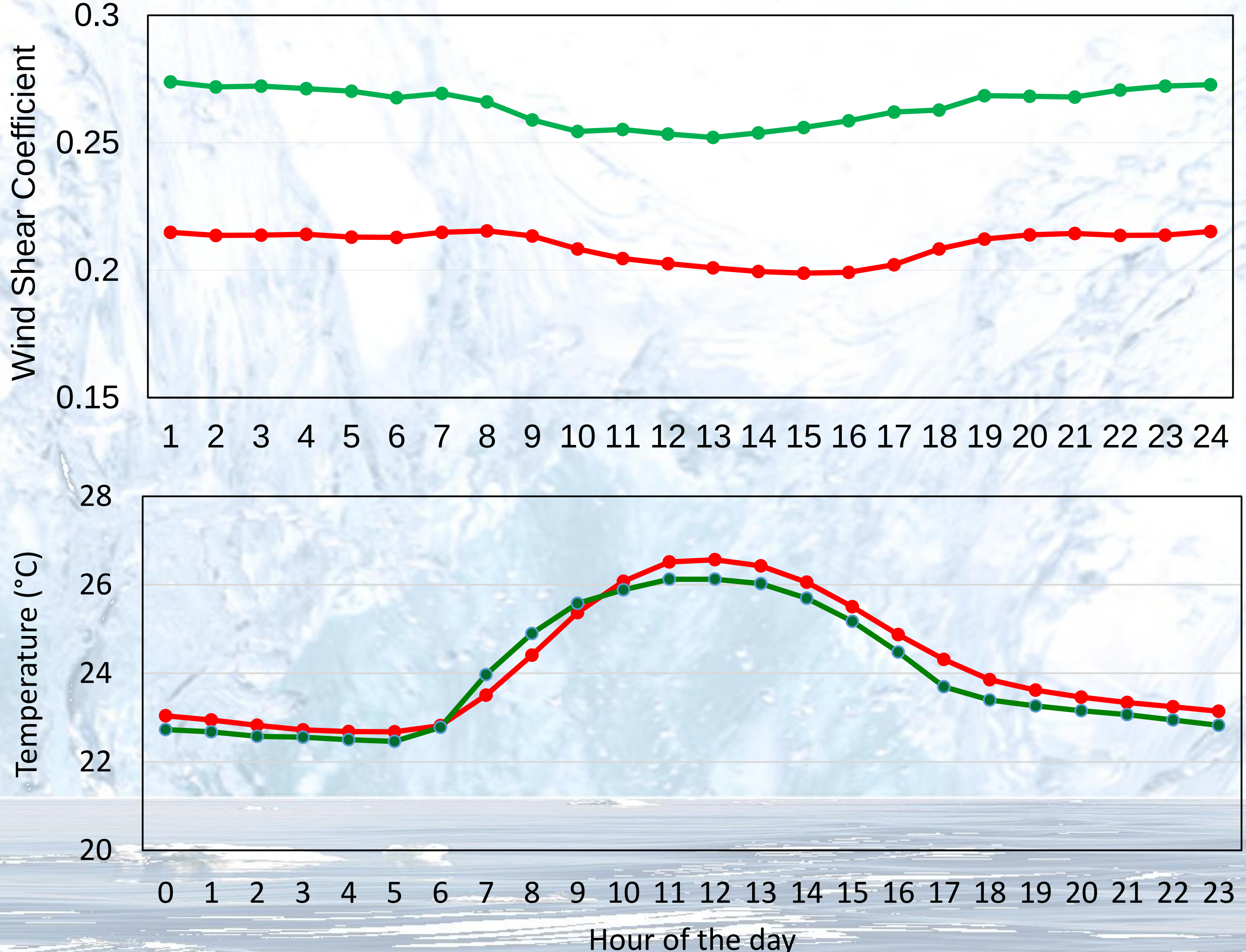
Renewable Energy Research at USP & Future Prospects

Wind Energy



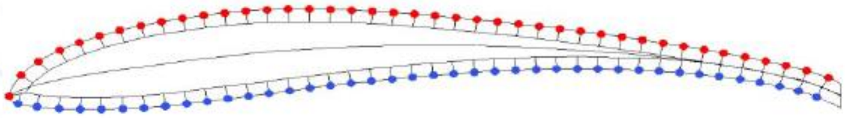
Monthly avg wind speeds at two locations – North-eastern Viti Levu

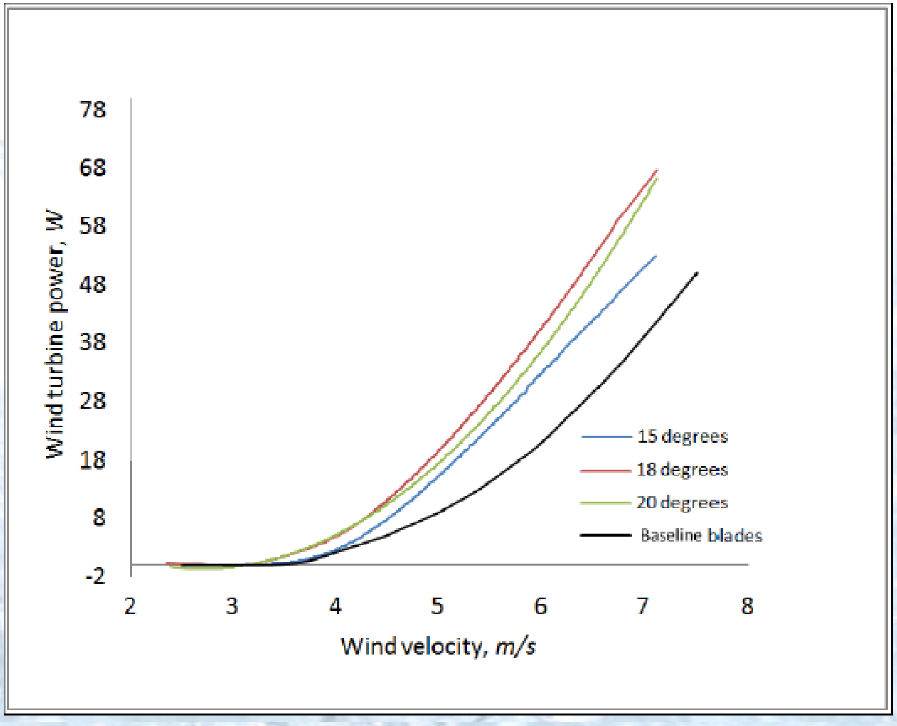
Wind Energy

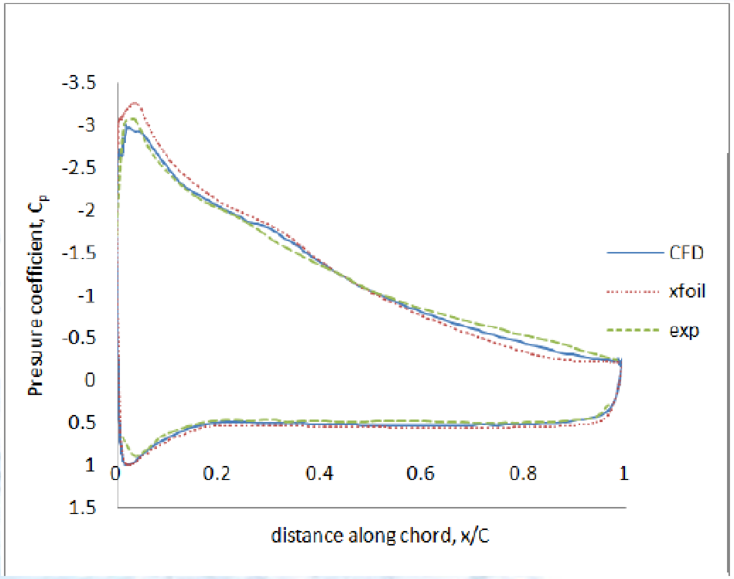


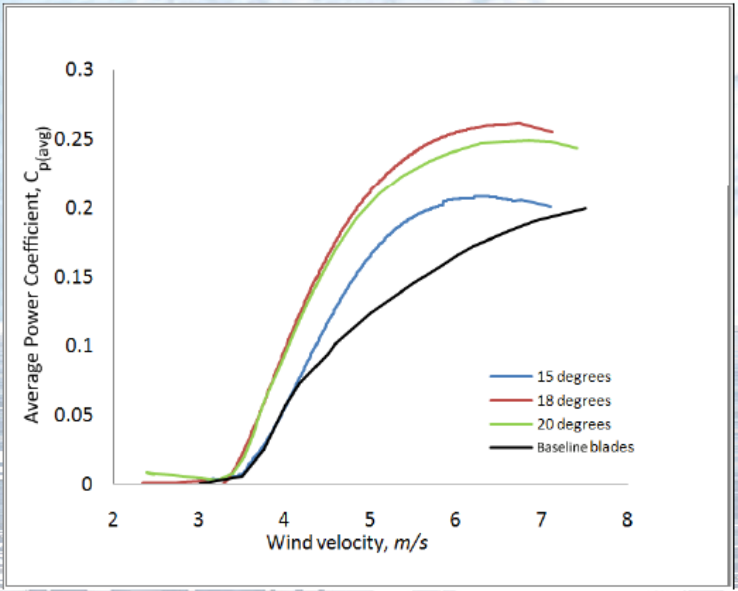
Diurnal var of WSC & Temp at two locations – North-eastern Viti Levu

Wind Energy



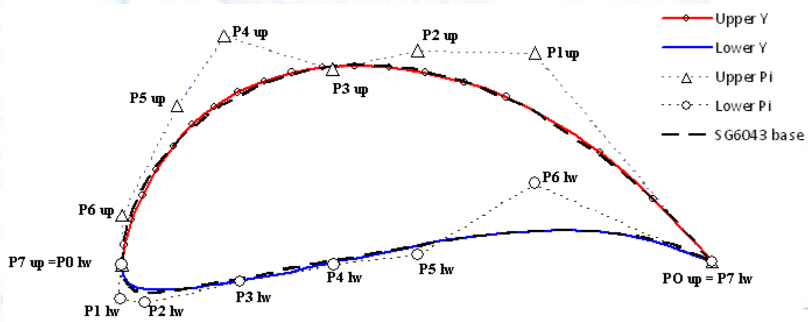


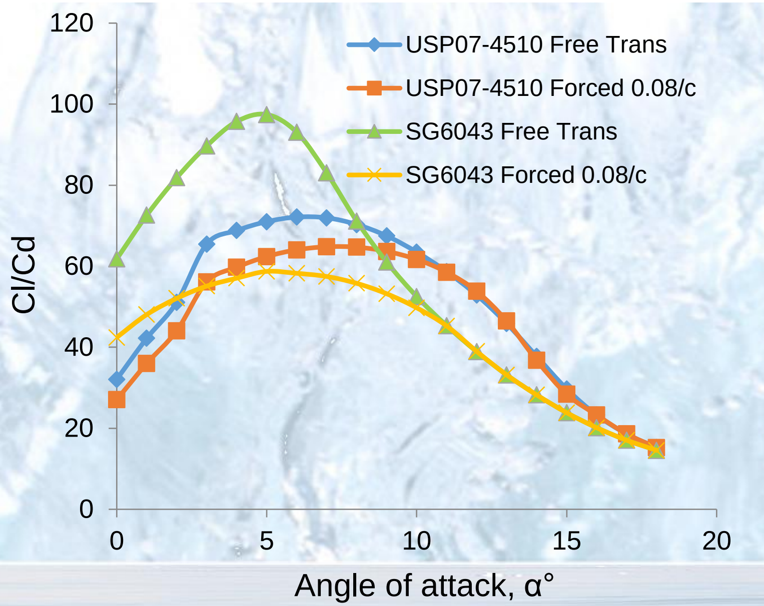


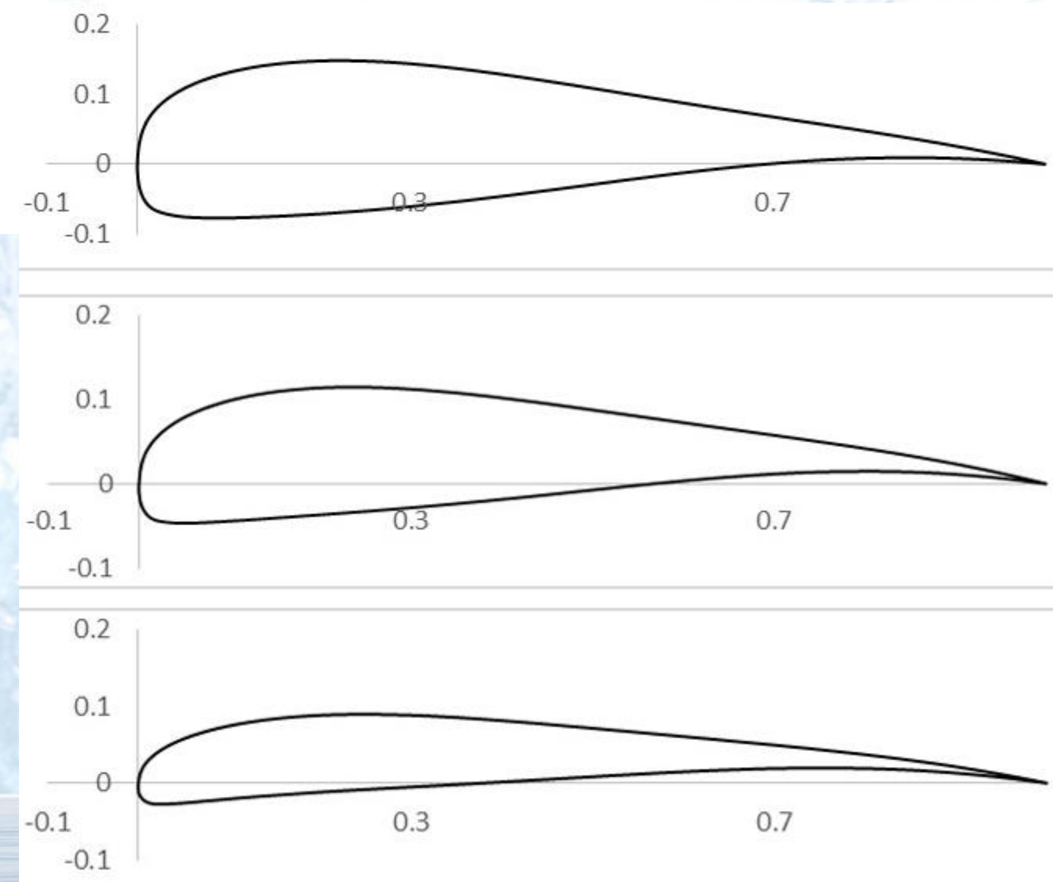


A blade section developed at USP. Pressure dist at Re = 205k & α = 10°, power o/p and Cp at diff wind speeds.

Wind Energy







Use of Multi-Objective Genetic Algorithm (MOGA) for design of blade sections for wind turbines is another work going on - being done in collaboration with CS staff.

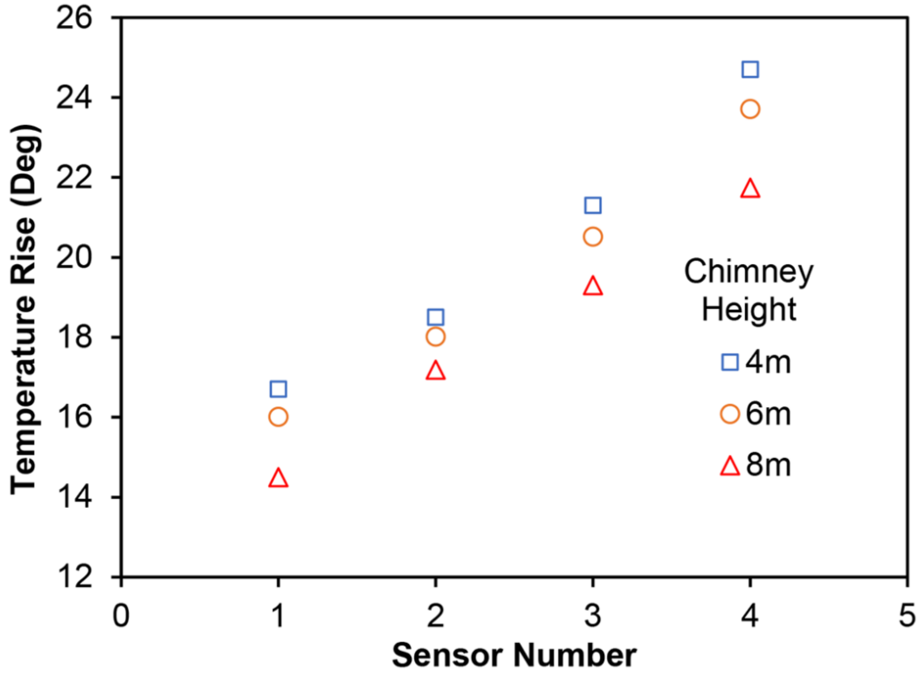
Solar Energy

- A variety of devices have been built to harness solar energy; most commonly used globally are solar panels & also used extensively in the South Pacific. However, maintenance/repair issues persist.
- Some of the solar energy technologies are expensive to build and maintain. This is one of the major issues in developing countries. The solar energy device must be simple, reliable and cheap to build and maintain.
- The Pacific Island Countries (PICs) have limited raw material resources and it is expensive to import specialized materials. So, the preference is for technologies that require cheaper and easily available resources.

Solar to Wind Energy

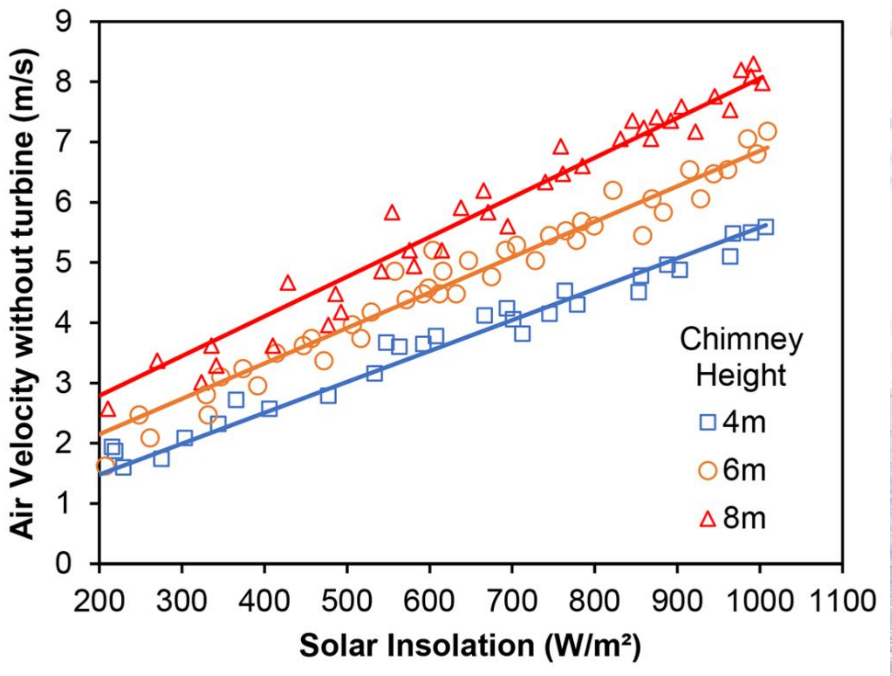
The solar chimney power plant (SCPP) meets these conditions very well. It is simple and reliable (fewer rotating parts compared to other thermal power plants), inexpensive since raw materials needed to build an SCPP are readily available in most of developing countries.

Solar to Wind Energy



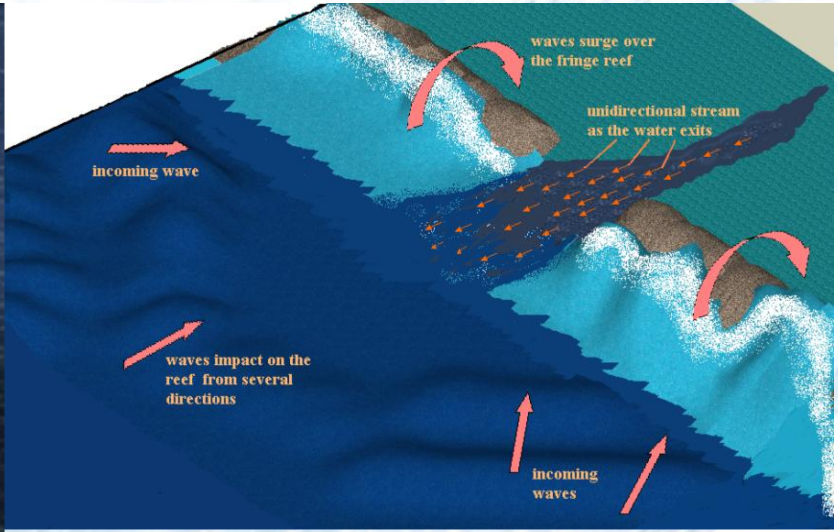
Temperature rise in the collector at 1.00 pm for the three chimney heights.

Variation of air velocity at the turbine section with solar insolation for the three chimney heights.



Tidal Current Energy

- A number of sites in Fiji and PICs have good tidal currents. We are working on two projects – one at national level and the other at regional level to do tidal current assessment in PICs.

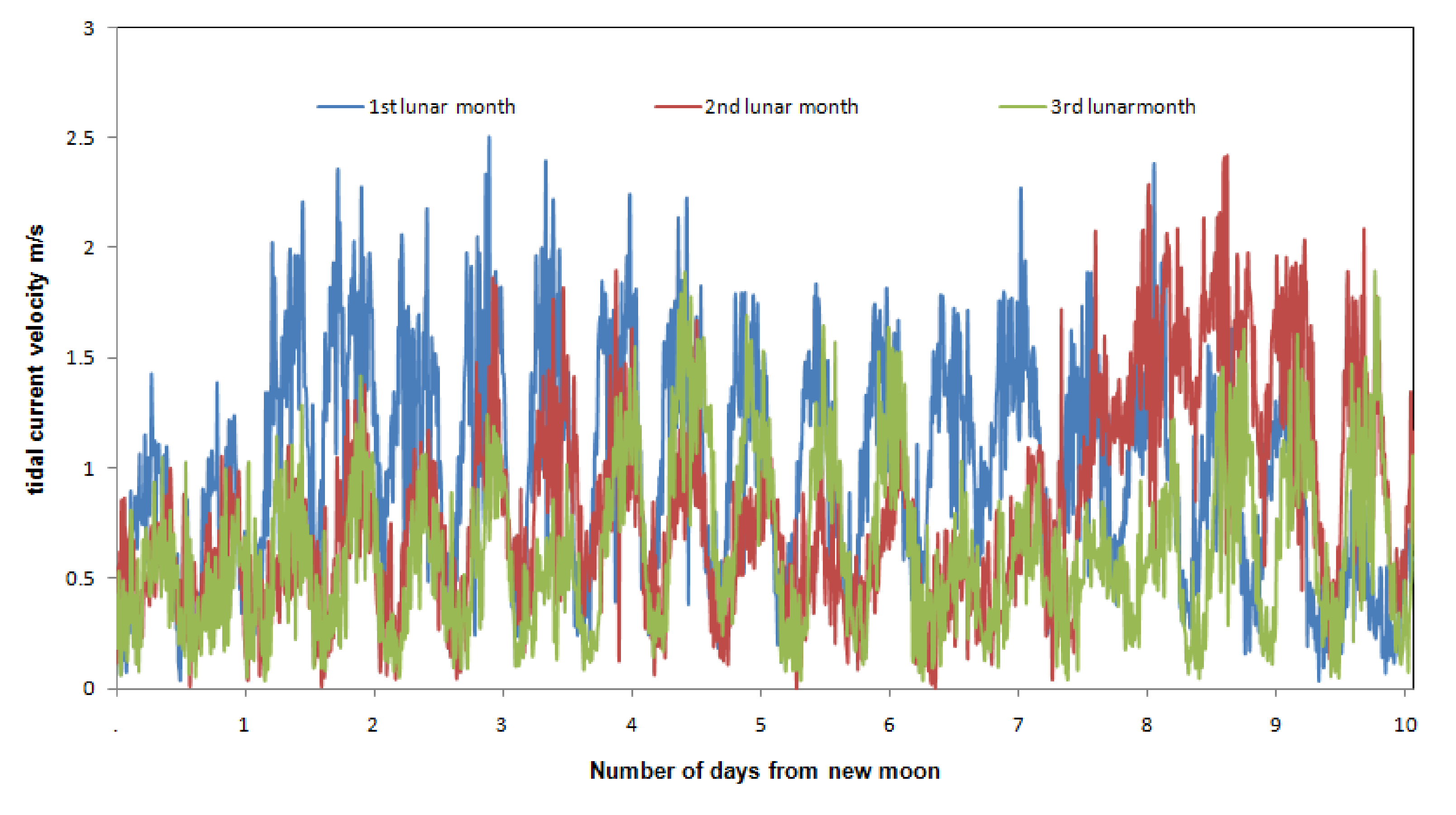


Some interesting sites where we did assessment.

Tidal Current Energy

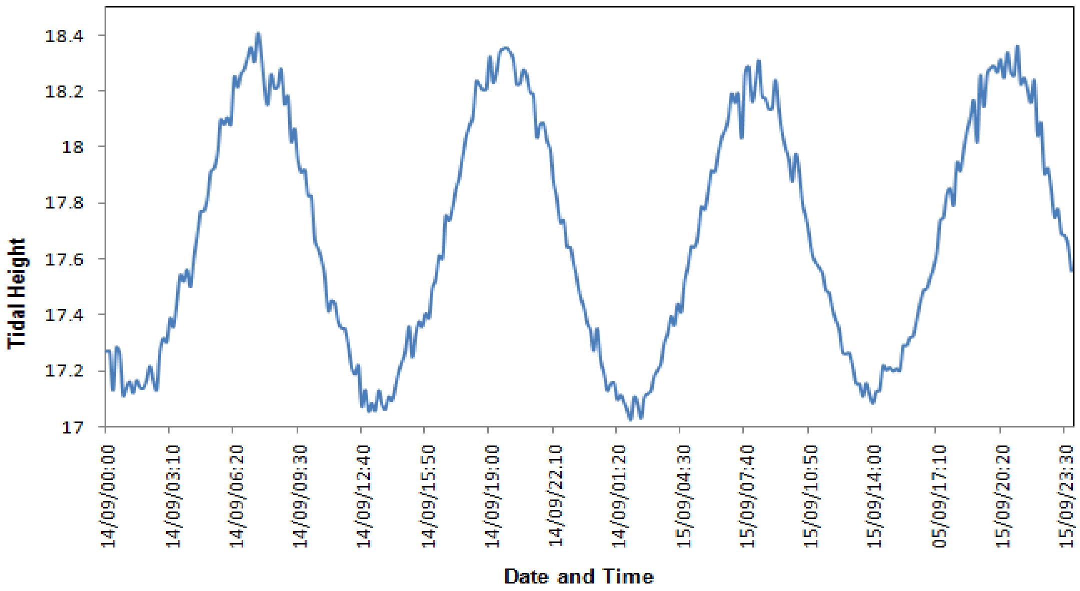
- Normally, if peak current speed exceeds 2 m/s, site is considered good for tidal current power generation. From the initial assessment, we have already identified more than 25 locations in PICs with good potential.
- Measurements are completed at 8 locations and currently underway at 2 more.

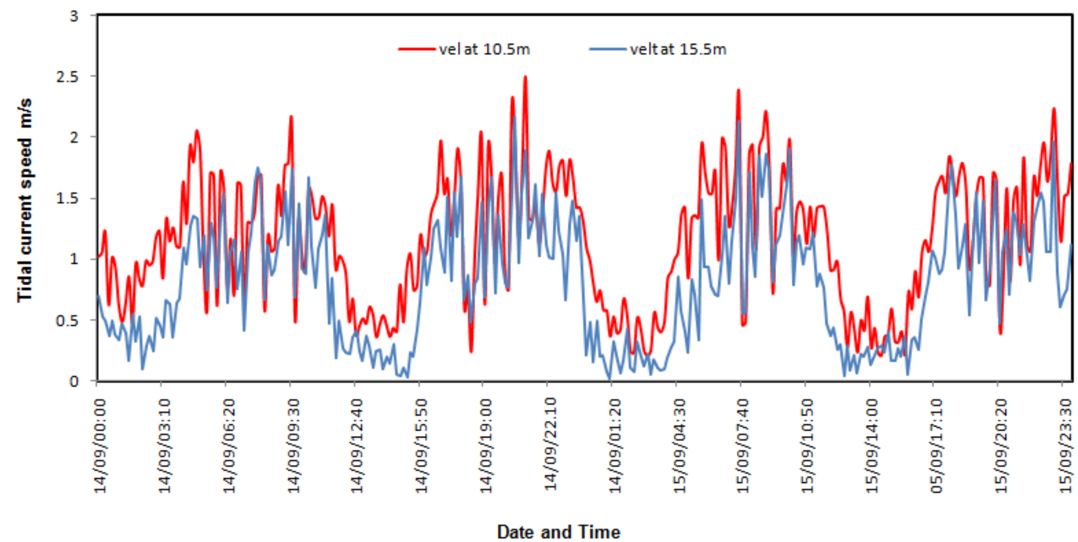
Tidal Current Energy



Current velocities for first 10 days of lunar month at a location in Fiji.

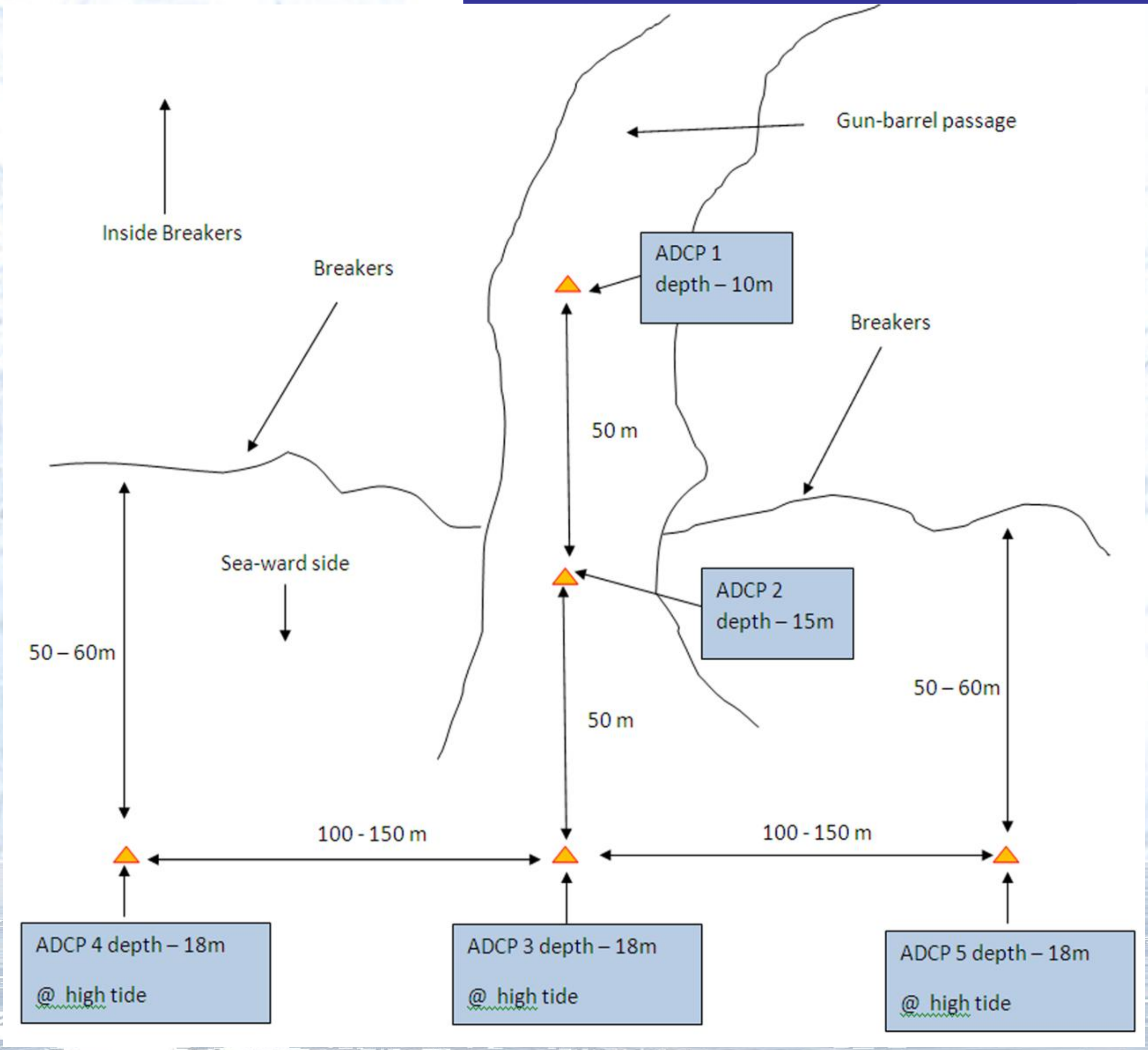
Tidal Current Energy





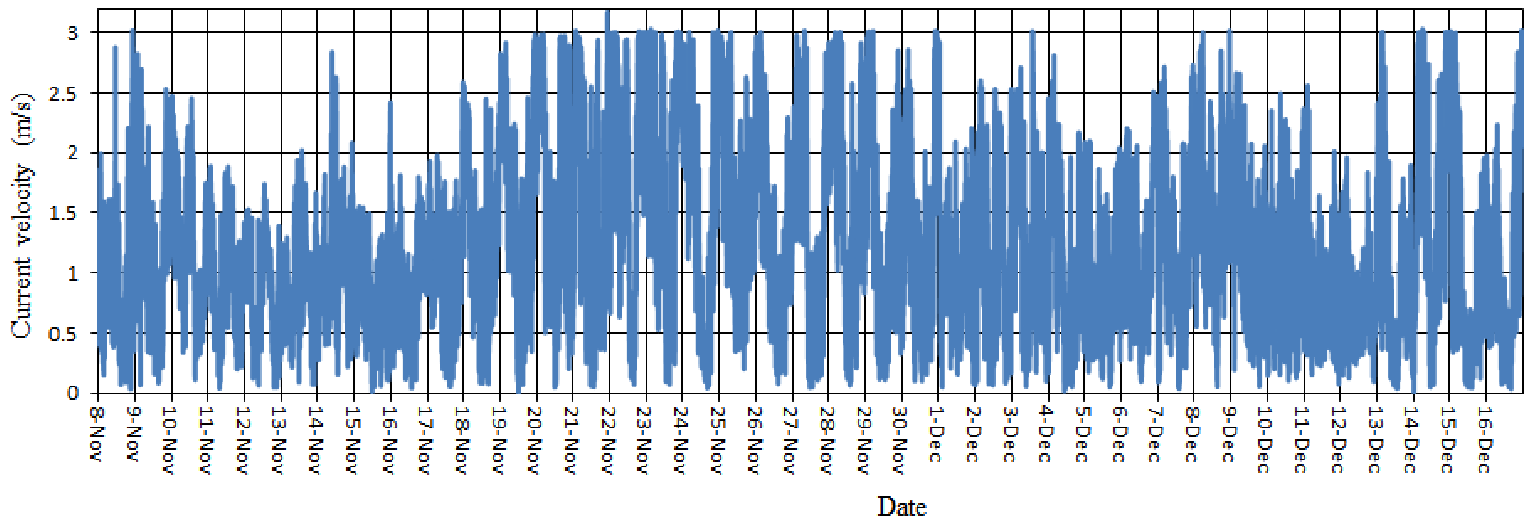
Relation between tide height and tidal current velocities for a couple of days.

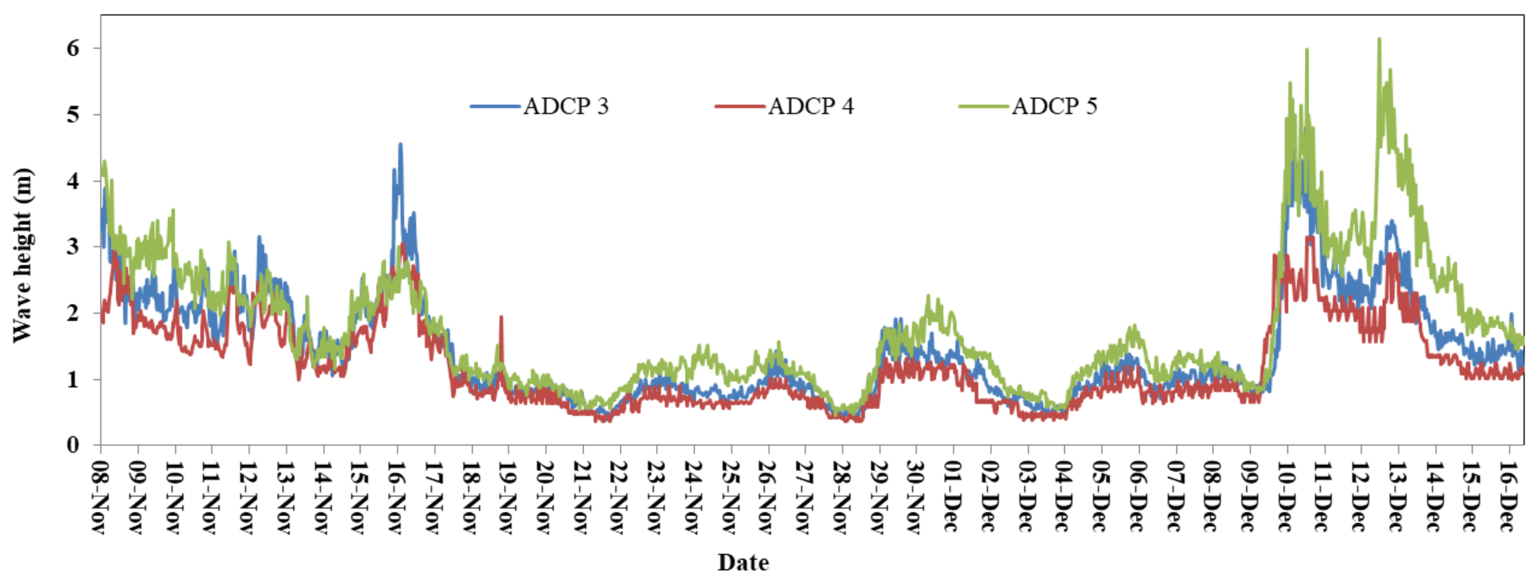
Tidal Current Energy



Set-up of 5 ADCPs for detailed study of flowfield of a rip current.

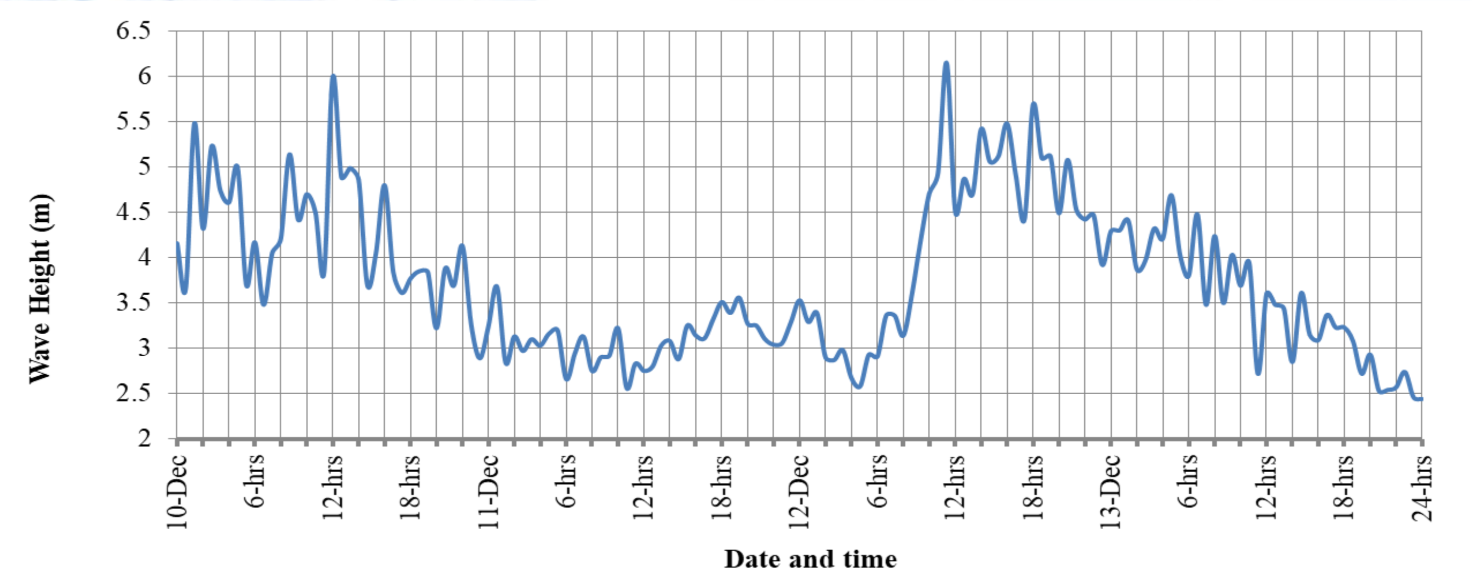
Tidal Current Energy

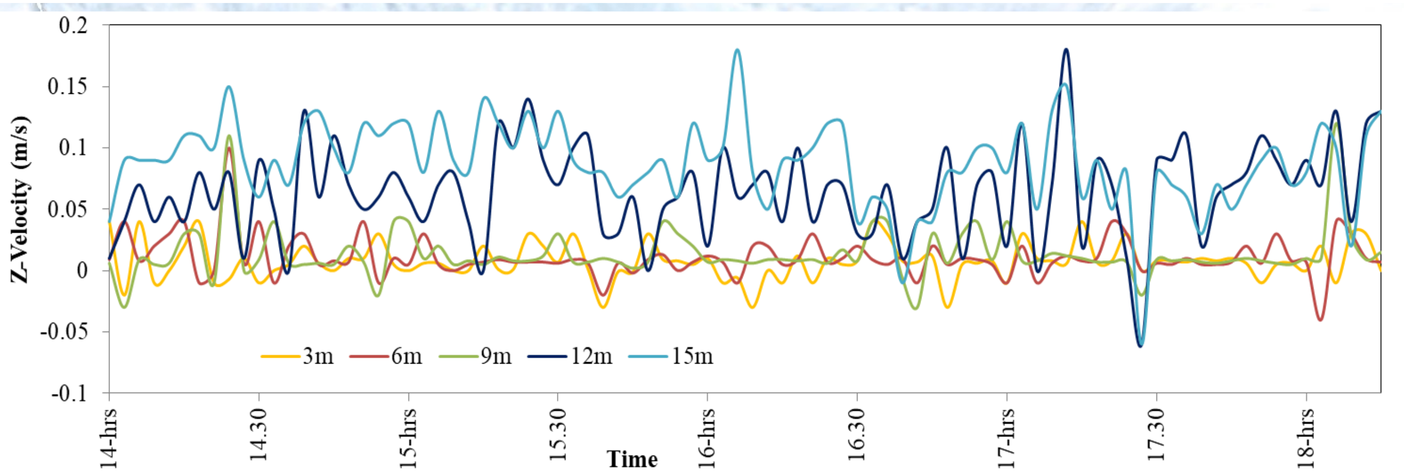




Current speed from ADCP1 and wave height from 3 ADCPs.

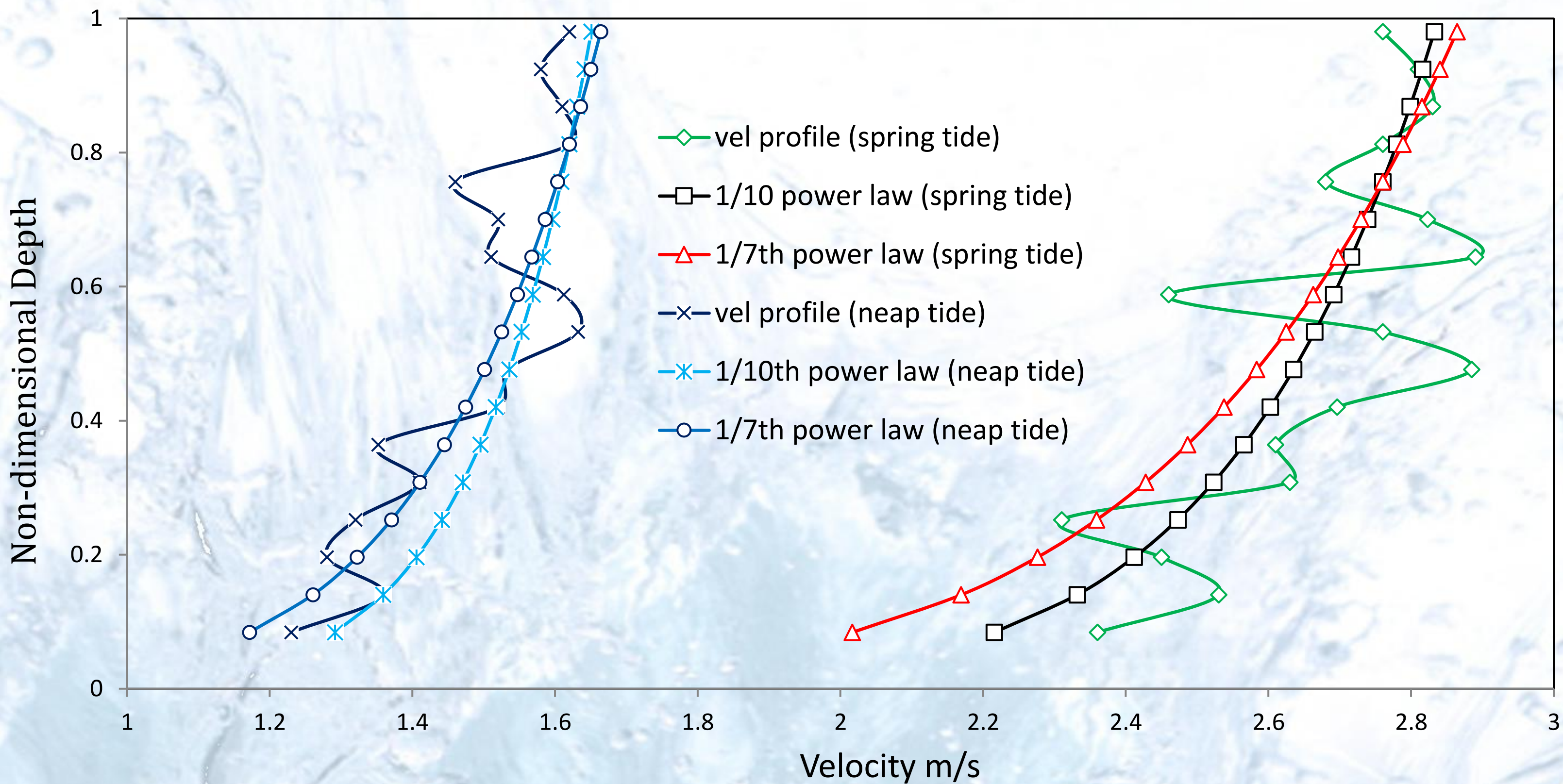
Tidal Current Energy





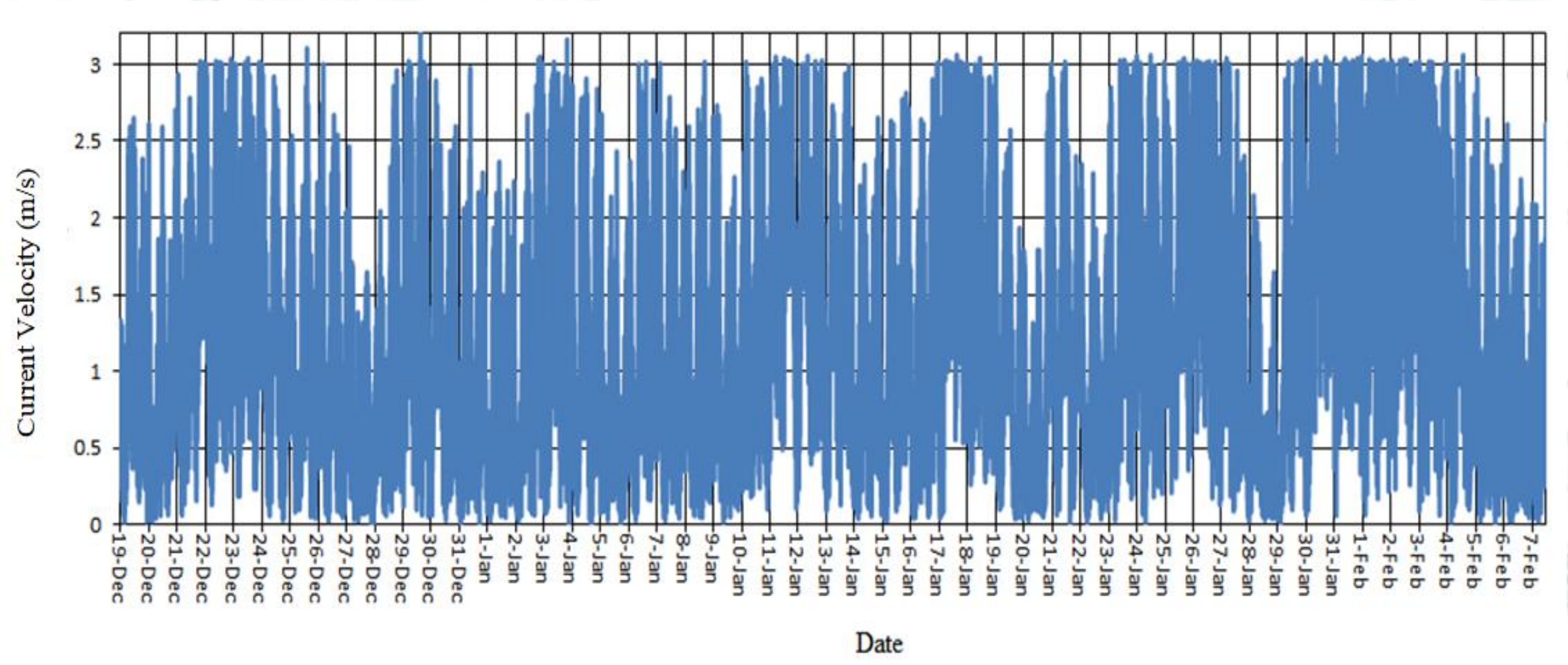
Wave height from ADCP 5 and effect on Z-comp of current speed.

Tidal Current Energy



Velocity Profile from ADCP 2 during neap and Spring tides.

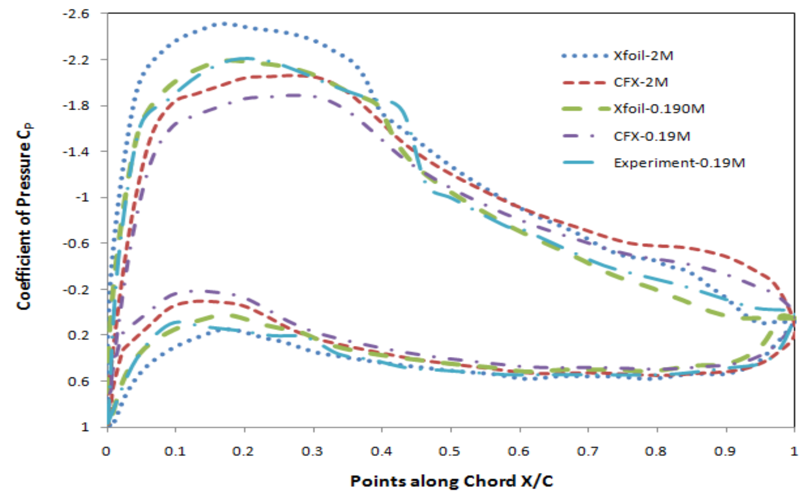
Tidal Current Energy

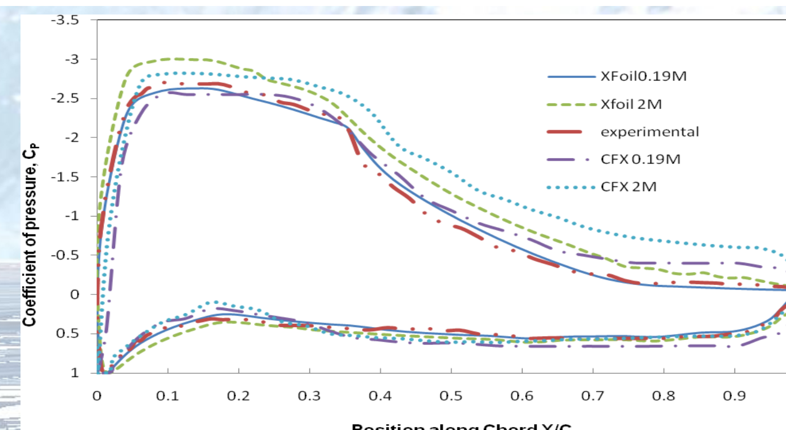


Marine current velocities for about 50 days at Gun-barrel passage (Sigatoka).

Tidal Current Energy

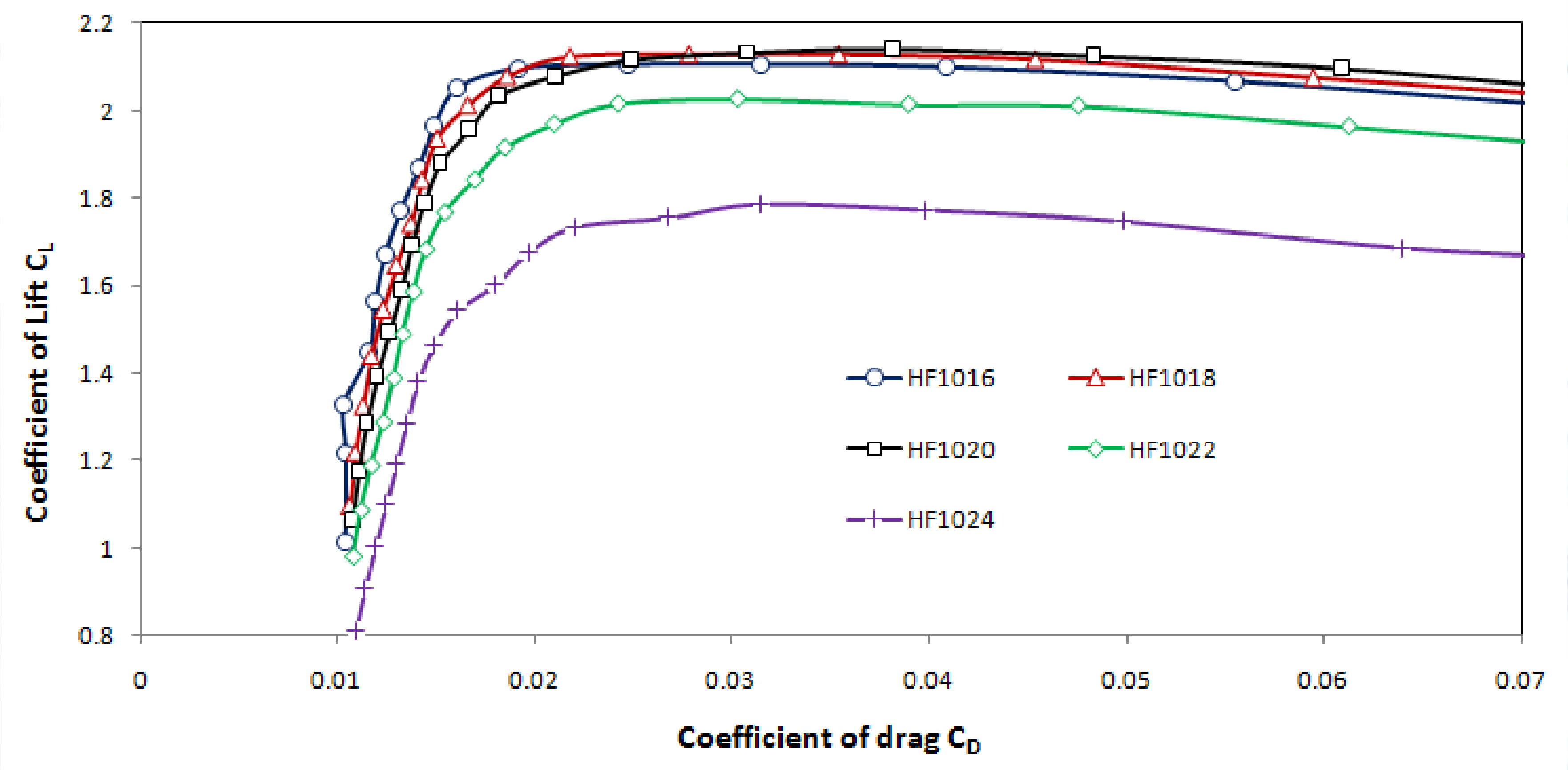
A HATCT is designed with varying thickness from tip to root region and optimized profiles.





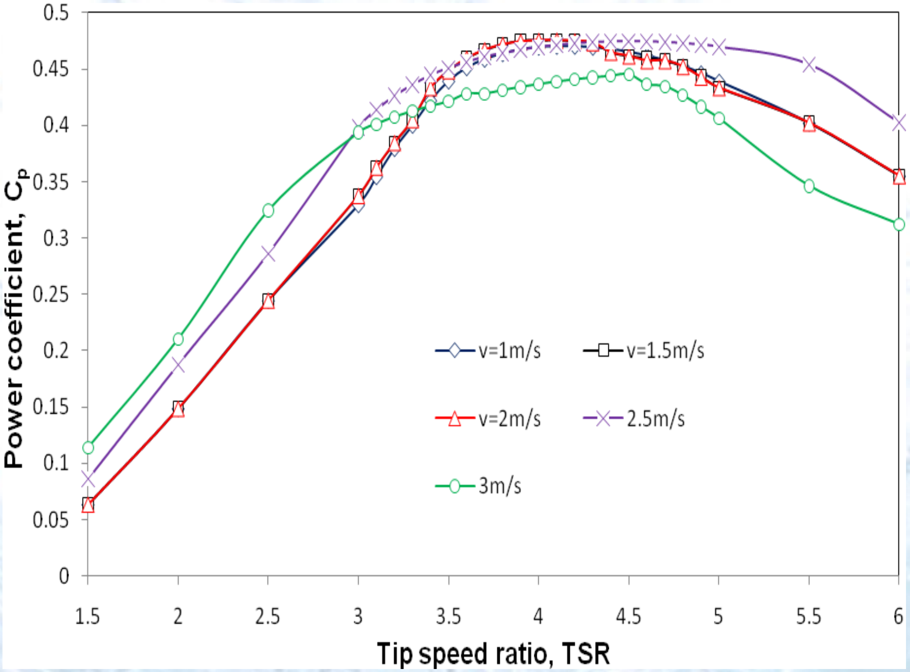
Profiles of the 5 sections (above) and pressure distributions of the 20% thick section at 6º and 10º AOA. It was ensured that there is no cavitation inception.

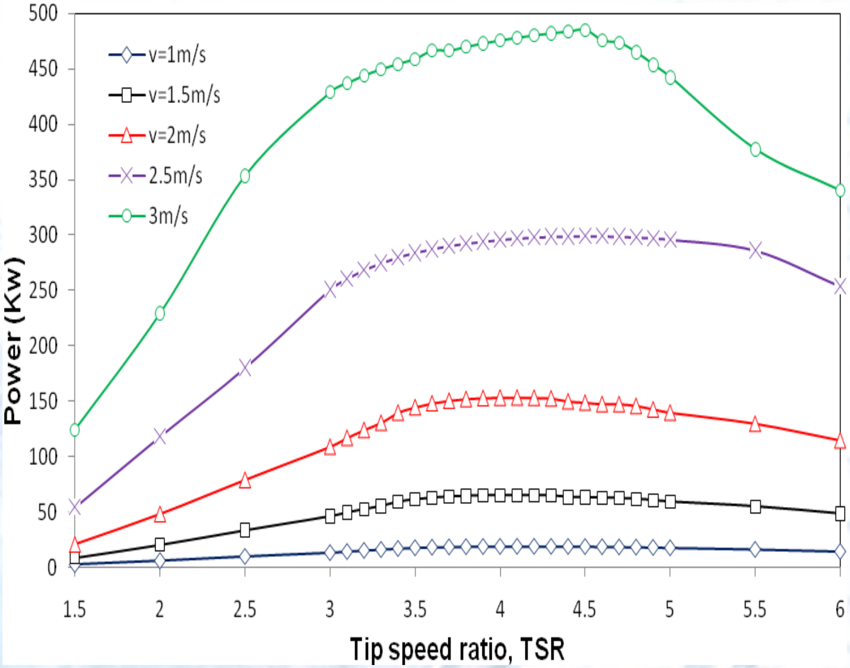
Tidal Current Energy

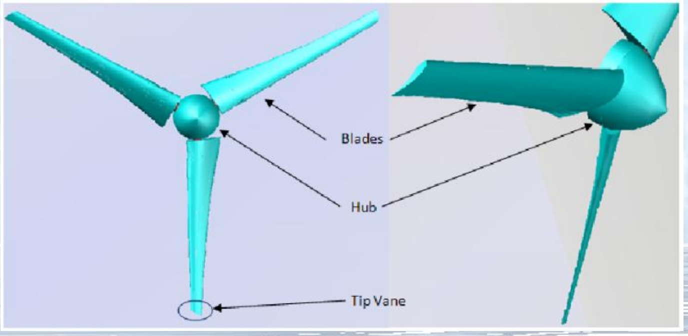


Drag polars for the five blade sections.

Tidal Current Energy

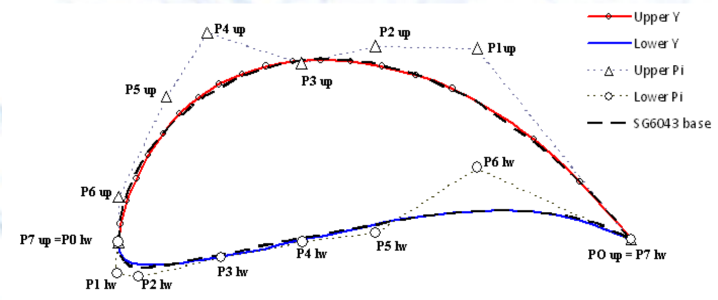




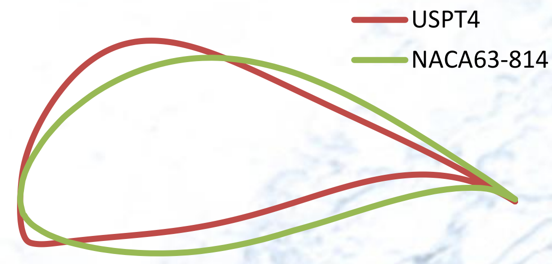


Power coefficient & power output of HATCT at diff TSR.

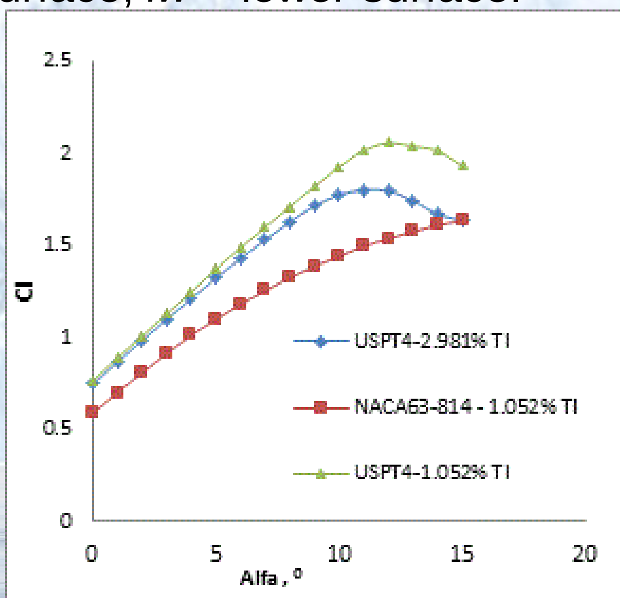
Tidal Current Energy



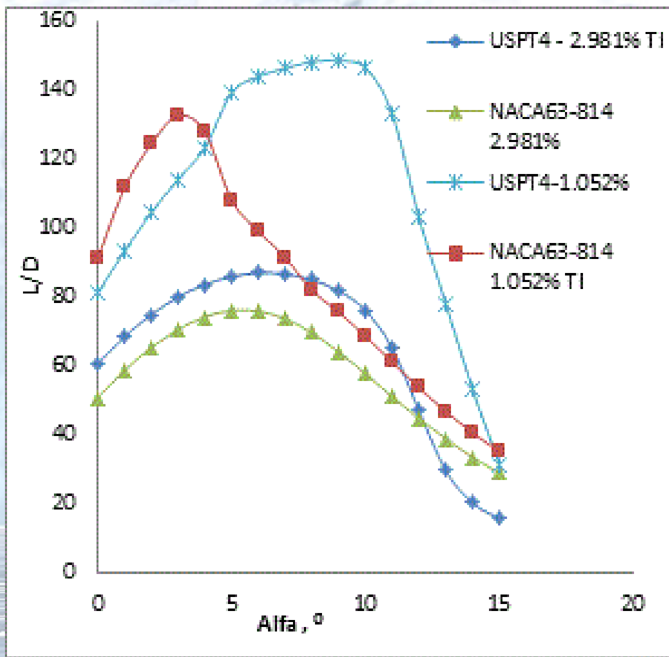
Bezier curve parameterization of seed foil using composite Bezier curves , *up* = upper surface, *lw* = lower surface.



Hydrofoil USPT4 compared to NACA63-814.

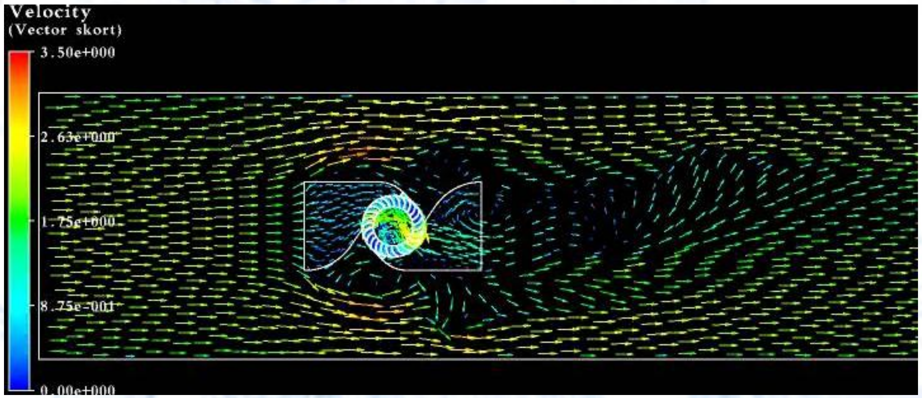


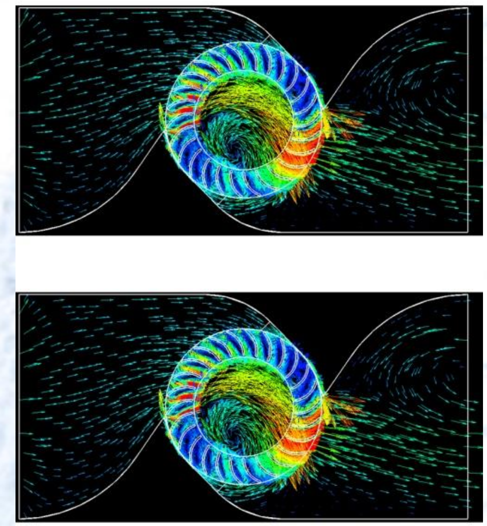
Lift and drag characteristics of an optimized hydrofoil



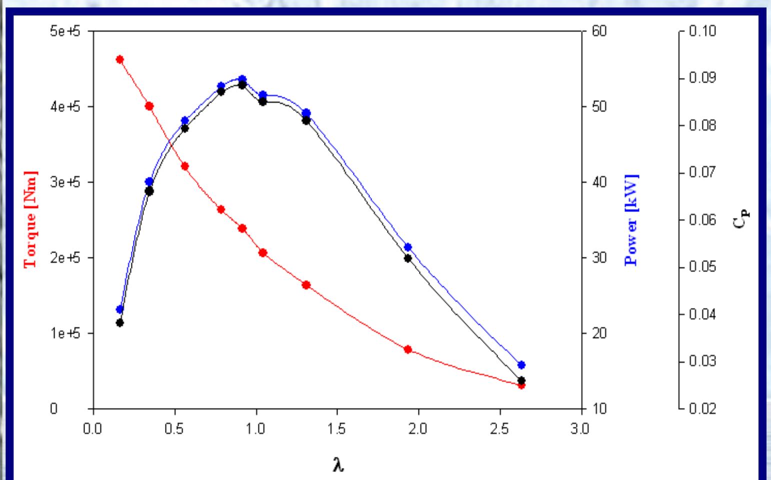
Use of Multi-Objective Genetic Algorithm (MOGA) for design of blade sections for TCTs (and also for WTs).

Tidal Current Energy

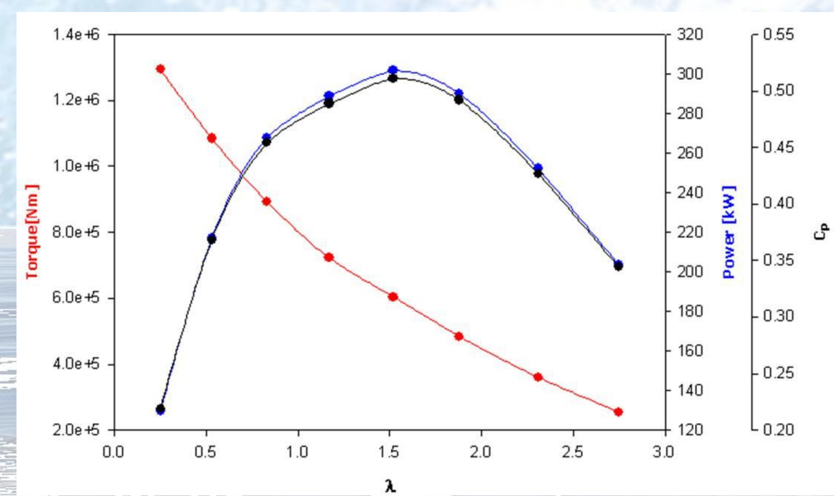




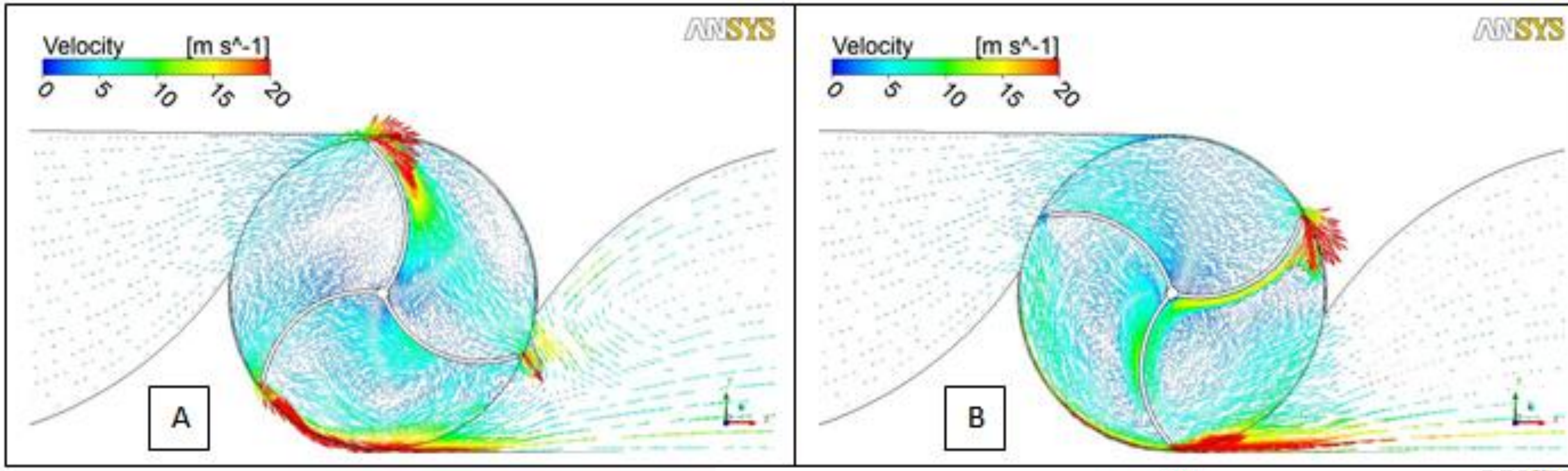
Performance of multiple cross-flow turbines occupying the channel width



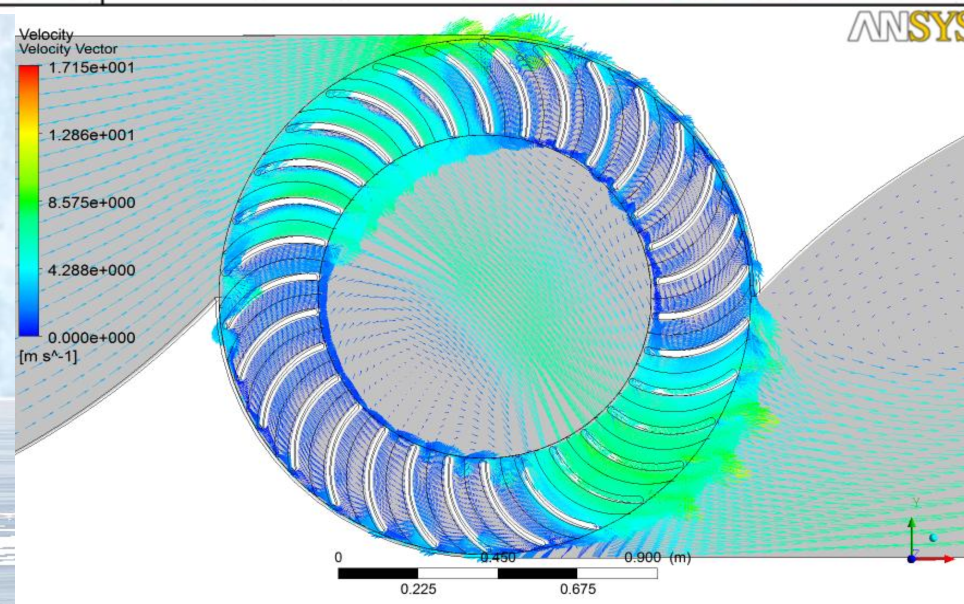
Performance of a single cross-flow turbine in a wide channel



Tidal Current Energy



Velocity vectors in the Savonius rotor at 2 different positions (top) and through the blades of a cross-flow turbine.

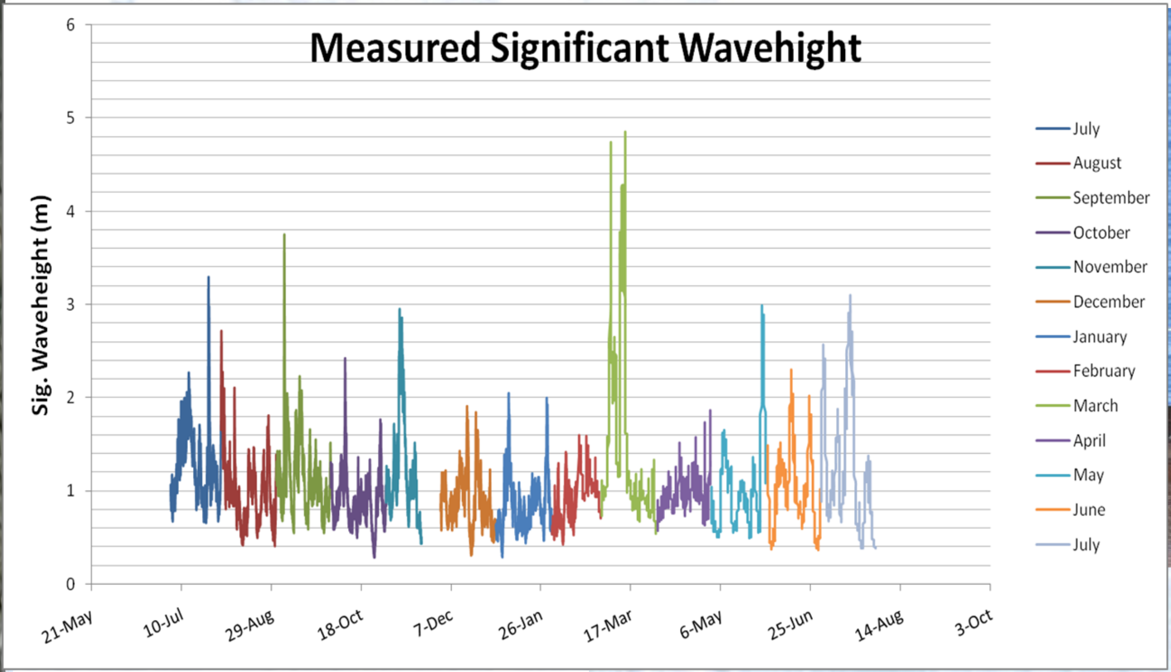


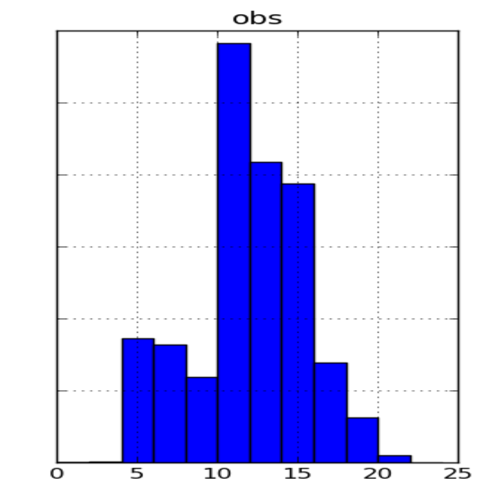
Wave Energy

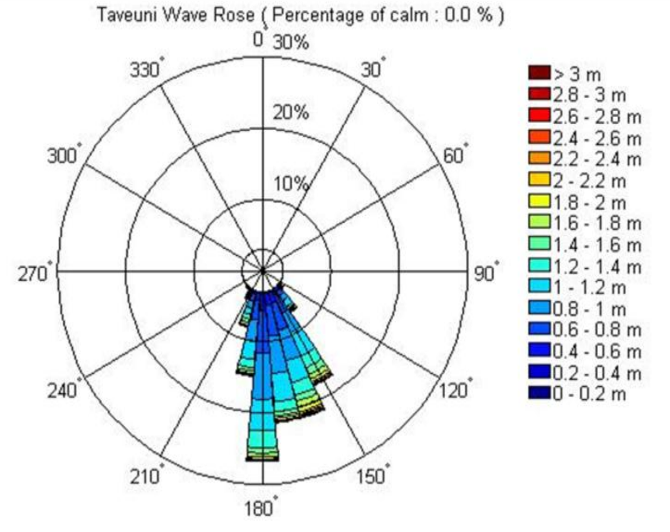
- Average potential of wave energy in PICs. Ongoing work includes assessment of wave energy potential at selected locations as well as development of WECs.
- Completed projects on measurement of wave characteristics at some near-shore locations in Fiji. Directional Wave Recorder (DWR) and AquaDopp Current Profilers (ADCP) were used.
- We have 3 waverider buoys (Datawell). On of them was deployed near Taveuni and more than one year of data collected and analyzed.
- Apart from wave energy extraction, wave powered desalination is also planned esp for some remote islands that don’t receive enough rain.

Renewable Energy Research at USP & Future Prospects

Wave Energy





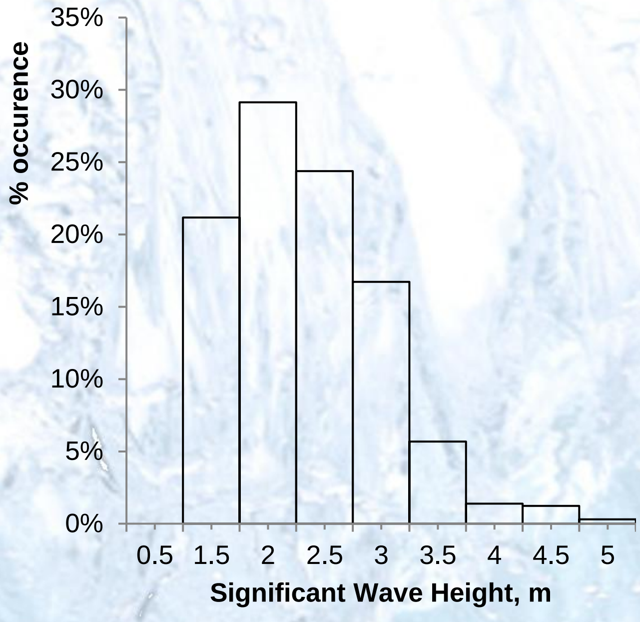


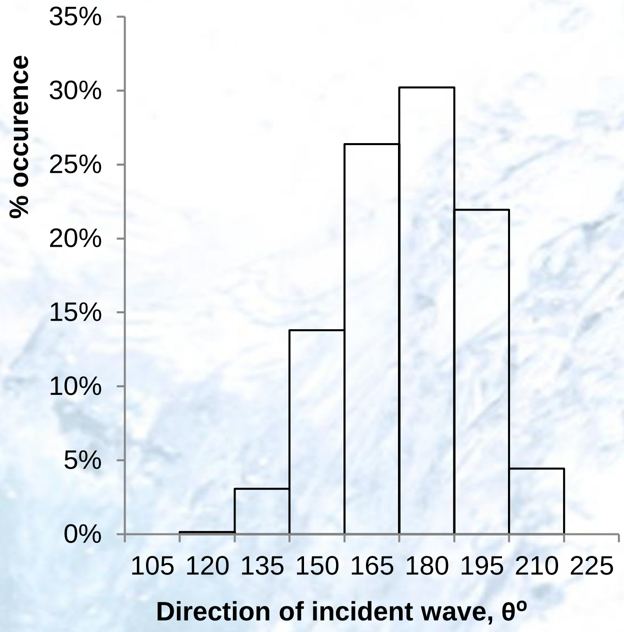
Top-left: Measured sig. waveheight in Taveuni (depth: 80 m)

Far-left: Histogram of peak period

Left: Wave rose plot

Wave Energy

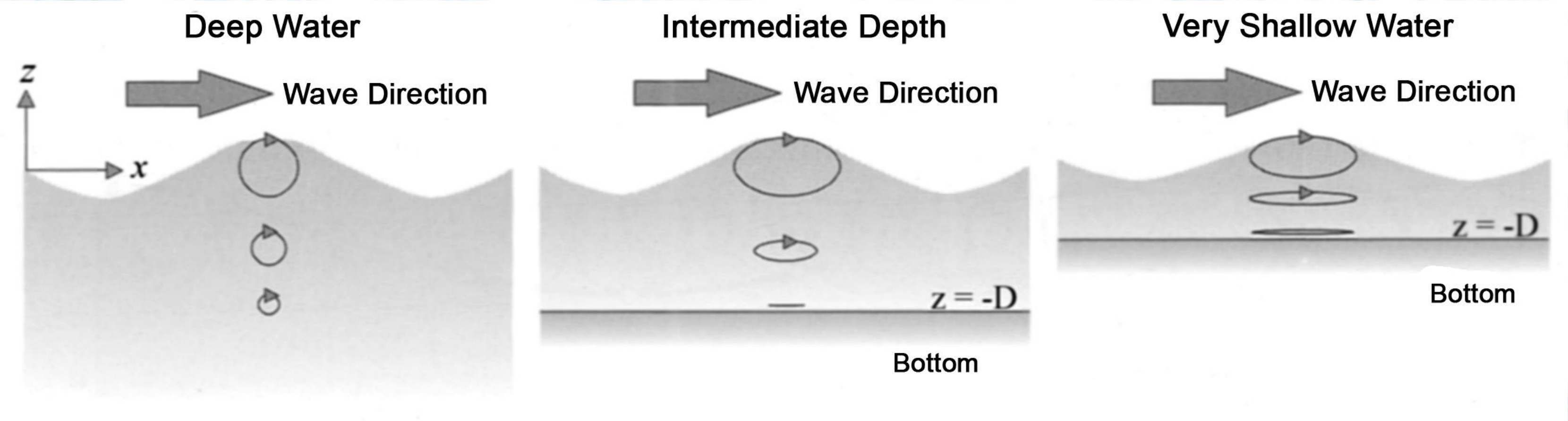




Wave measurement results at a depth of 18 m in the southern Fiji (Muani, Kadavu).

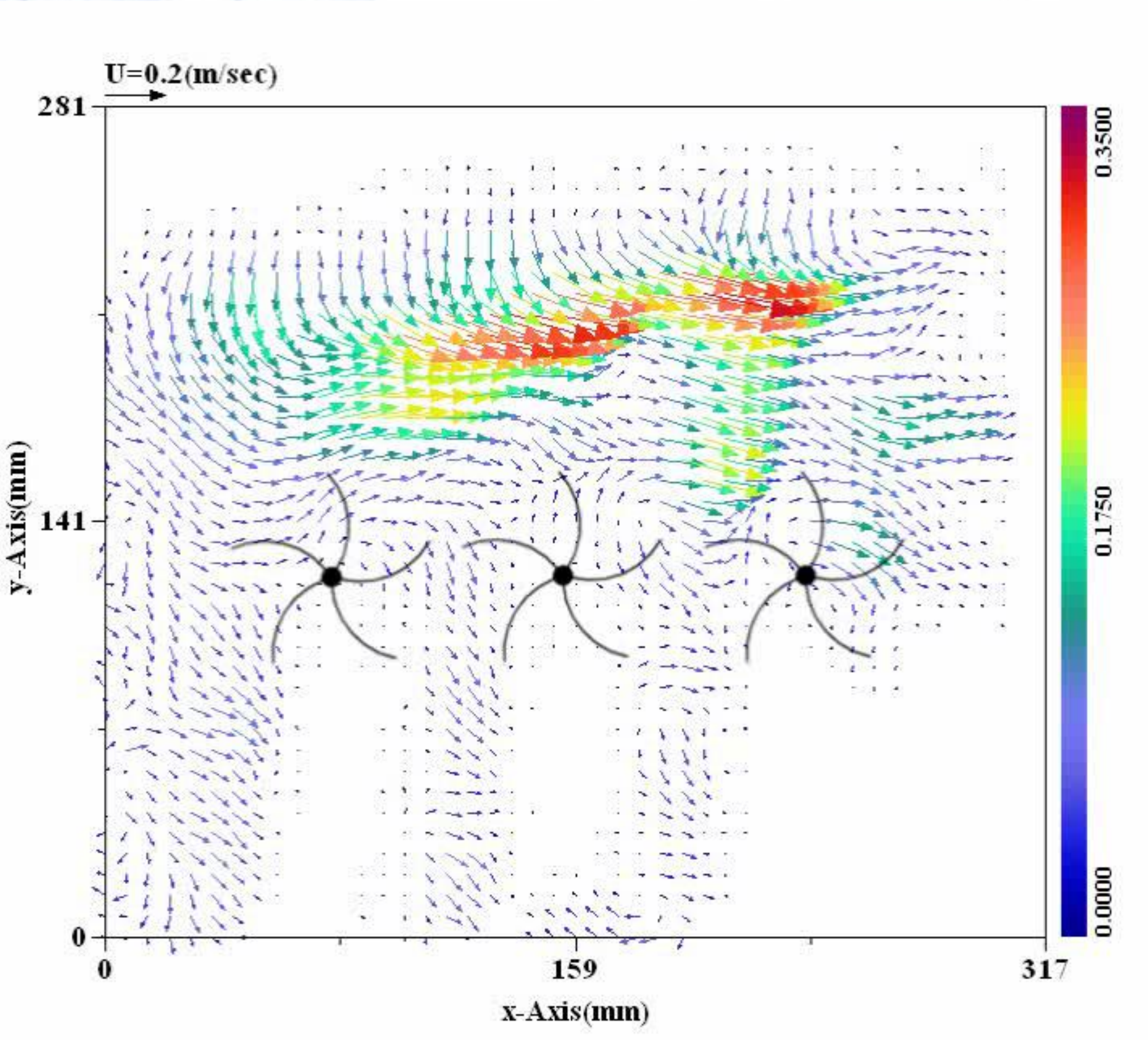
Wave Energy

- In wave motion, water particles are known to follow orbital paths. This orbital motion was studied and a number of Savonius rotors that extract energy from the orbiting particles were built.



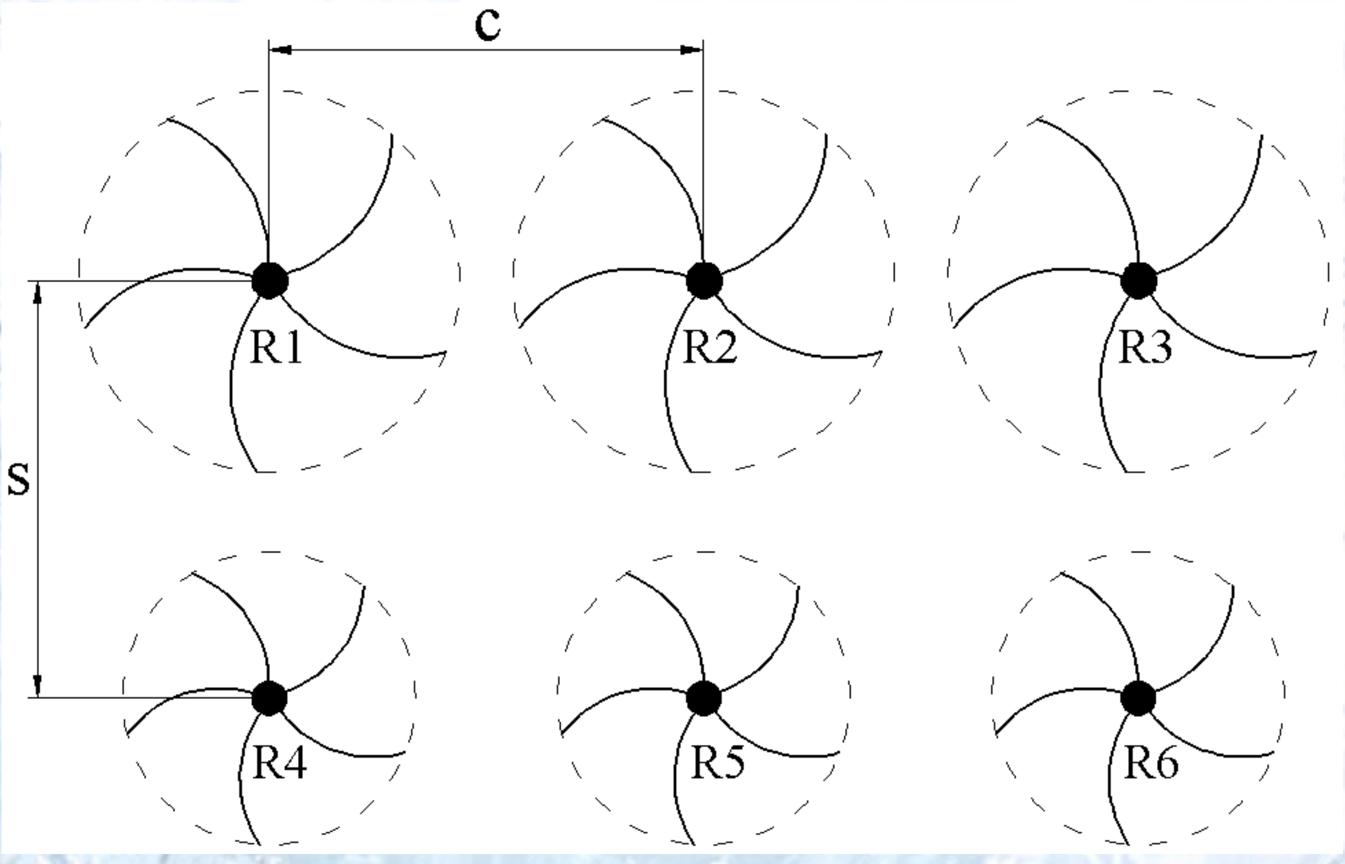
- Maximum energy extracted when rotor is placed close to water surface at minimum submergence. Many rotor configurations were tested experimentally and an optimum geometry obtained from the results.

Wave Energy



Rotors driven by the orbital motion of particles

Wave Energy

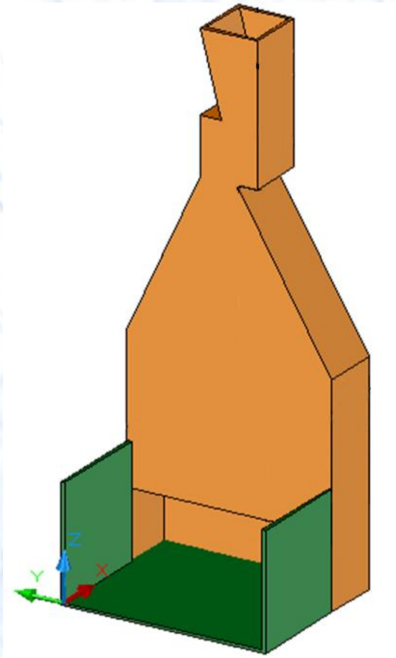


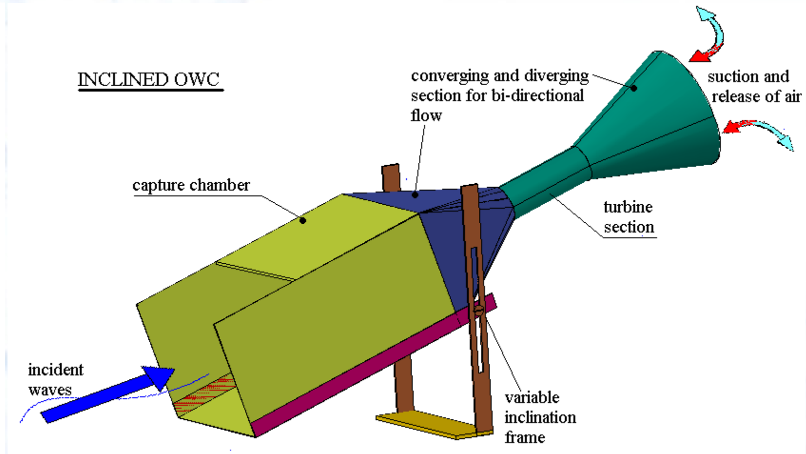
Effect of spacing on arrays of rotors.

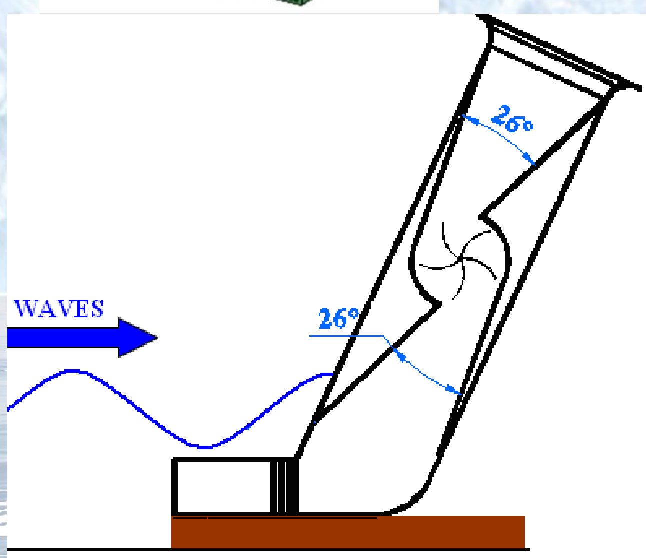
Wave Energy

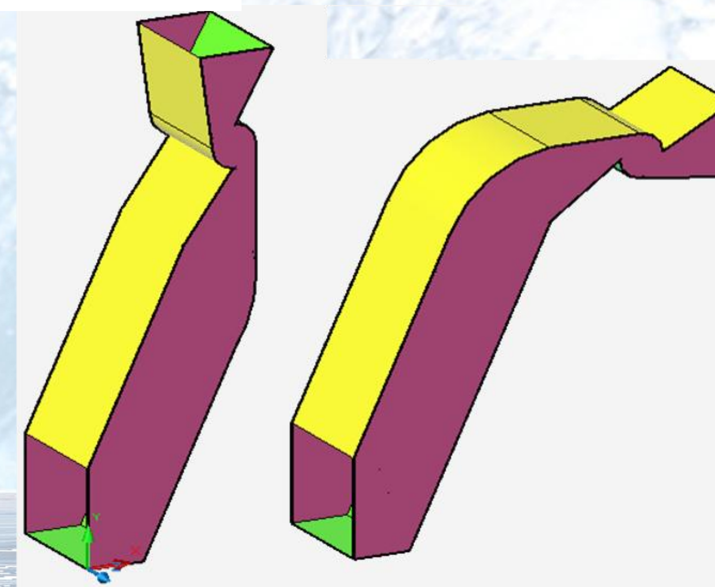
- Working on both direct-drive WECs and OWC devices.
- Focusing on rectangular OWCs designed to direct bi-directional flow onto the blades of Savonius rotor.
- This has advantage of provision to increase width of chamber and extract more power from waves by employing either a large rotor or a number of rotors in segments; this is not possible in circular OWC devices.
- Other advantage is ease of construction & operation of rectangular OWC as well as Savonius rotors.

Wave Energy



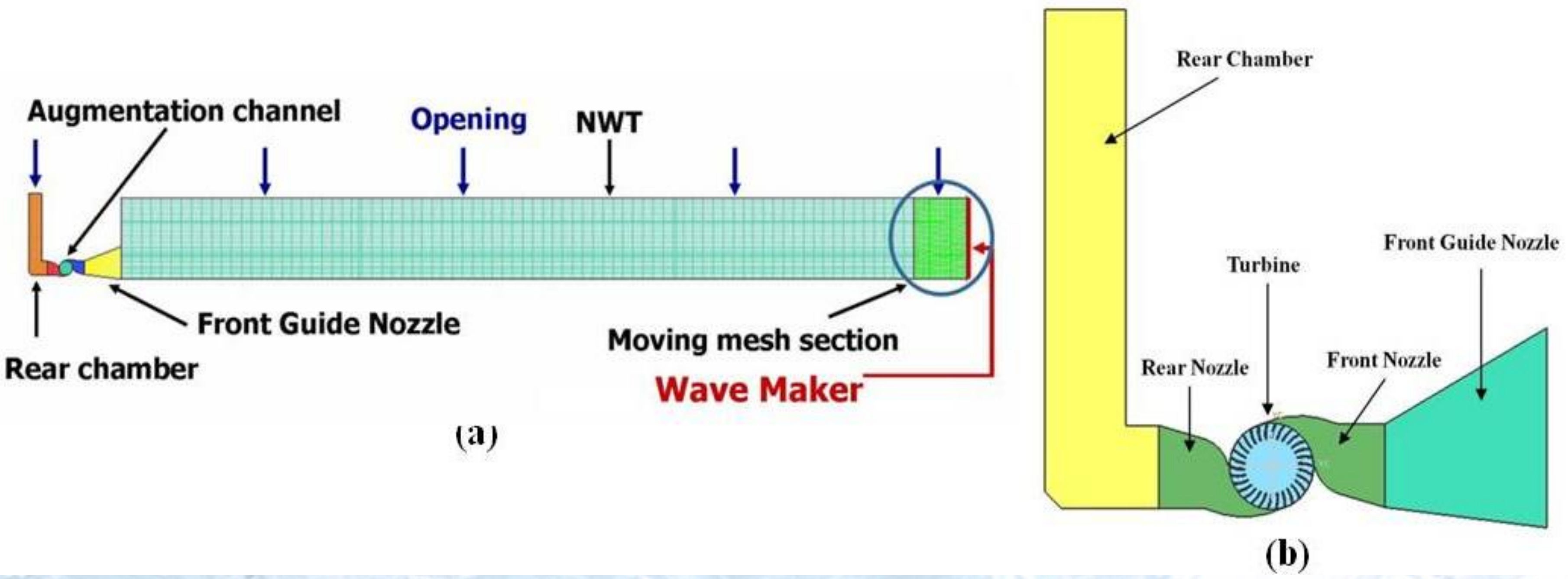






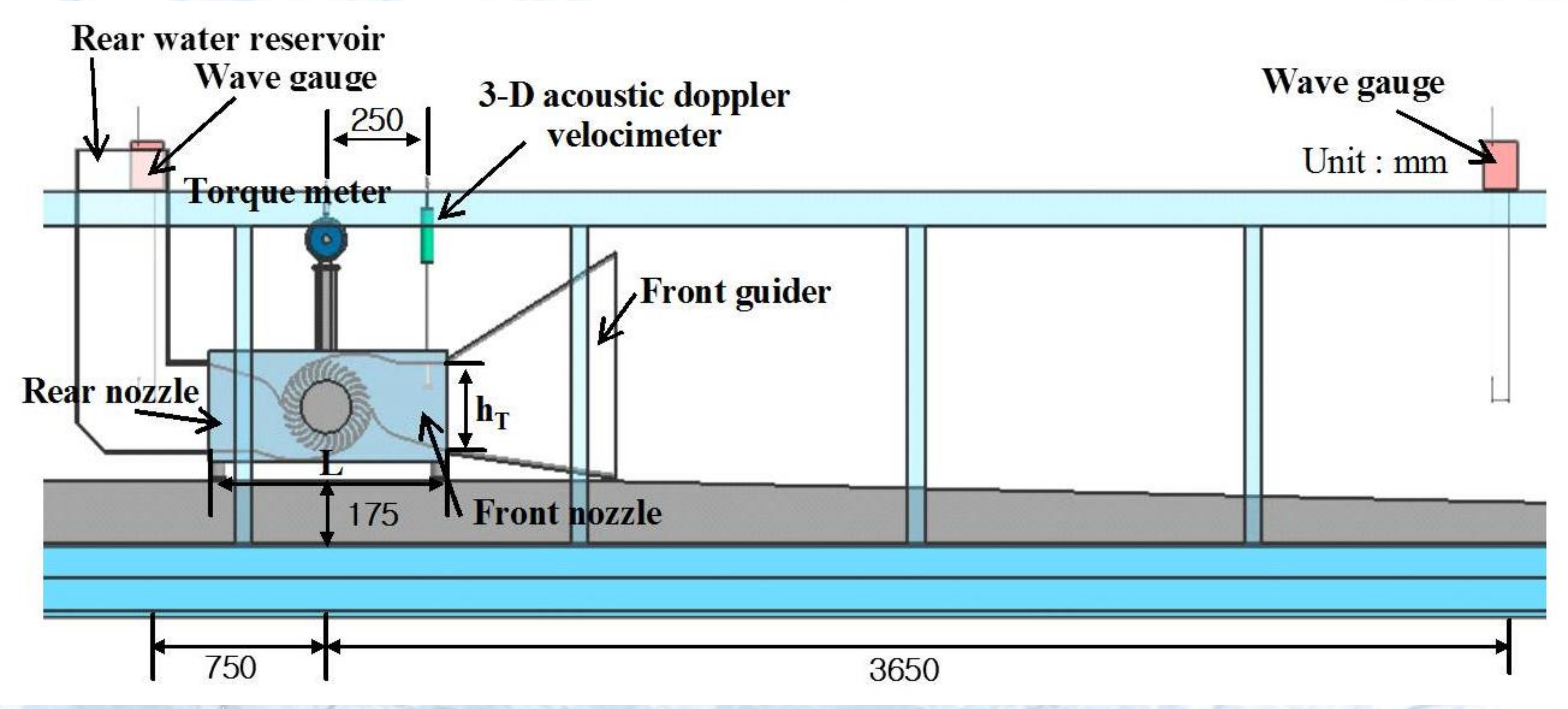
OWC devices tested in USP wave channel.

Wave Energy



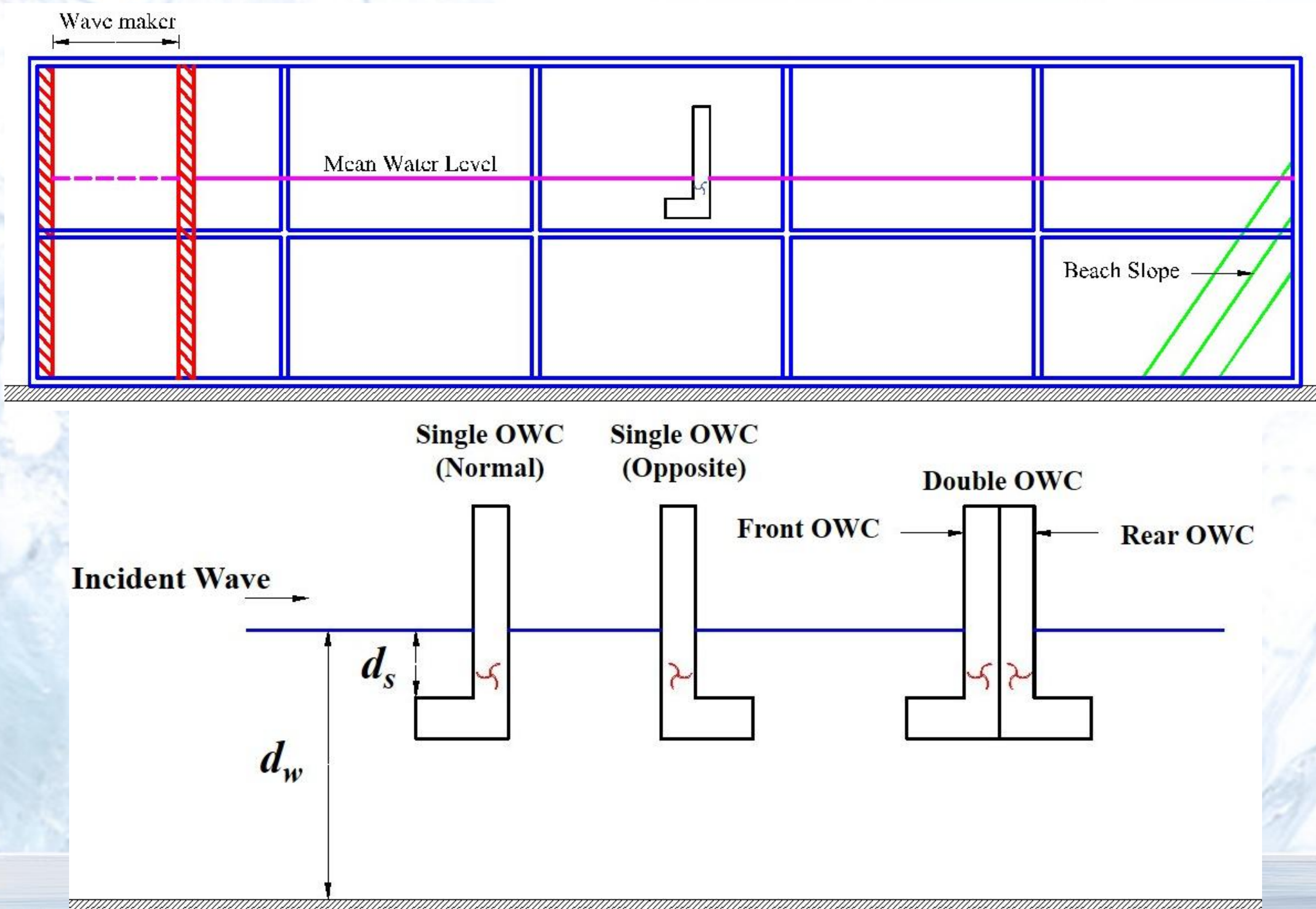
A NWT modeled and CFD studies conducted in it; the total length of NWT 700 m and height of 28 m.

Wave Energy



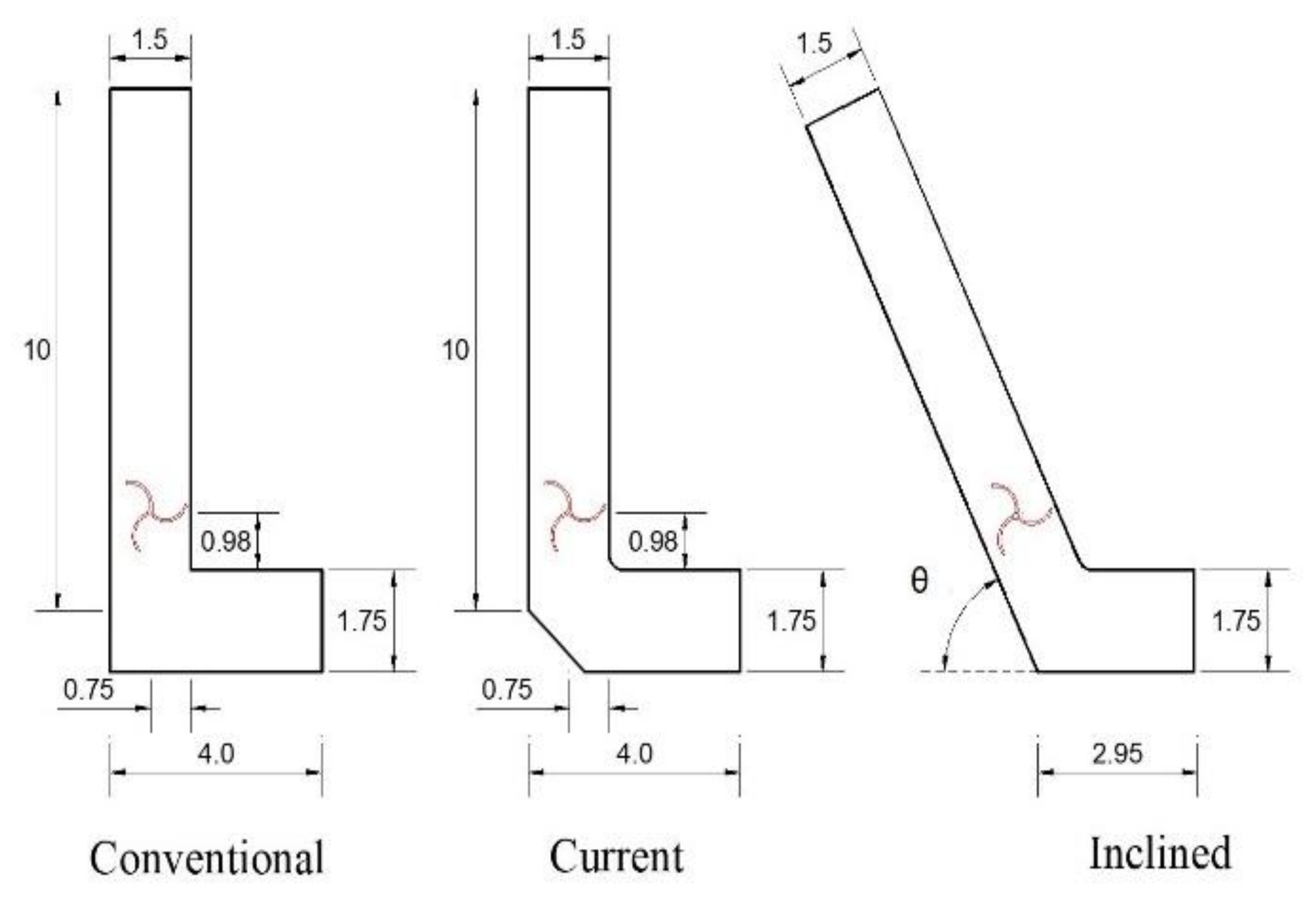
Schematic diagram of experimental setup. Wave channel has a length of 35 m, width and depth of 1 m each.

Wave Energy



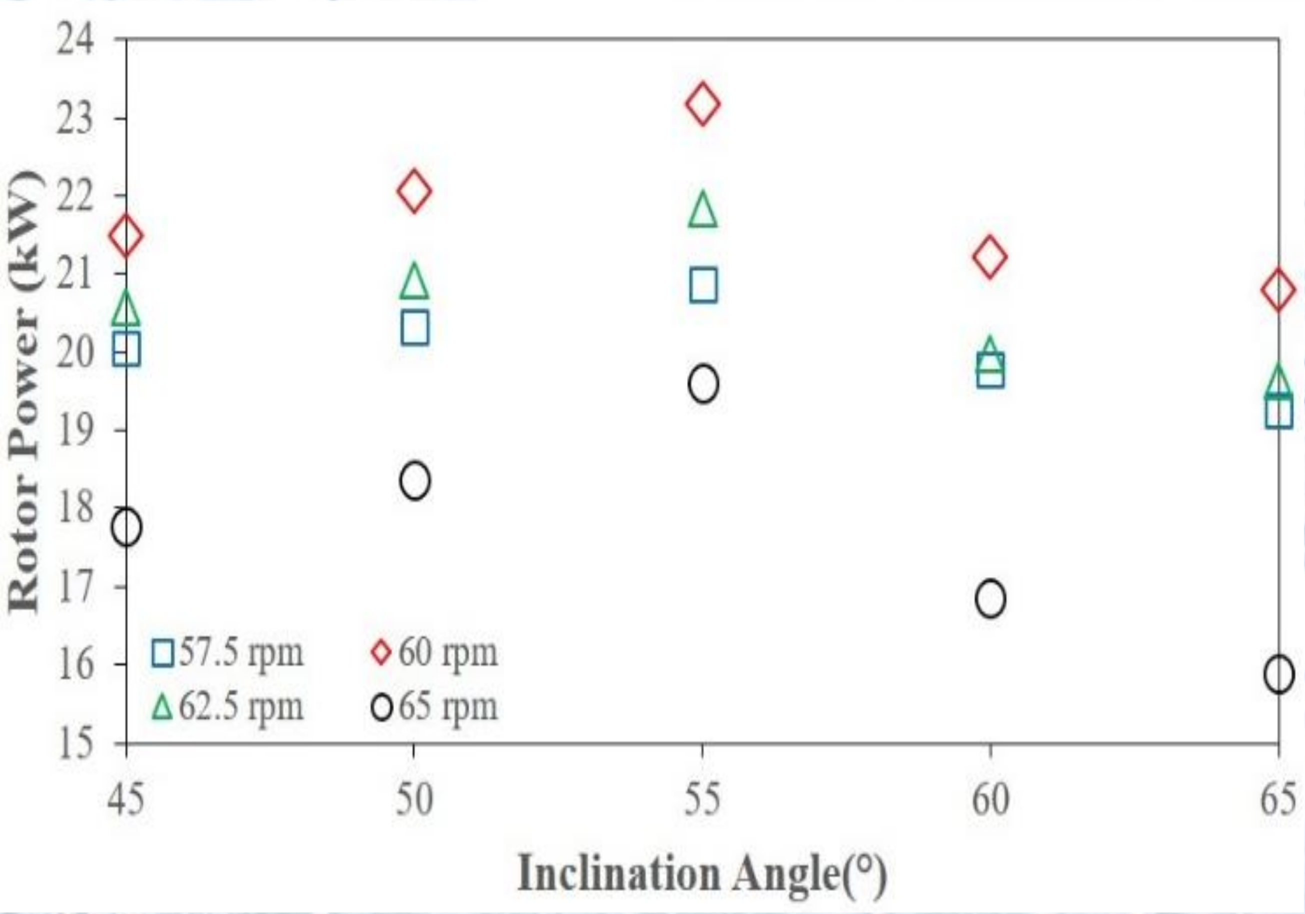
Rotor power and efficiency were studied for different OWC configurations

Wave Energy



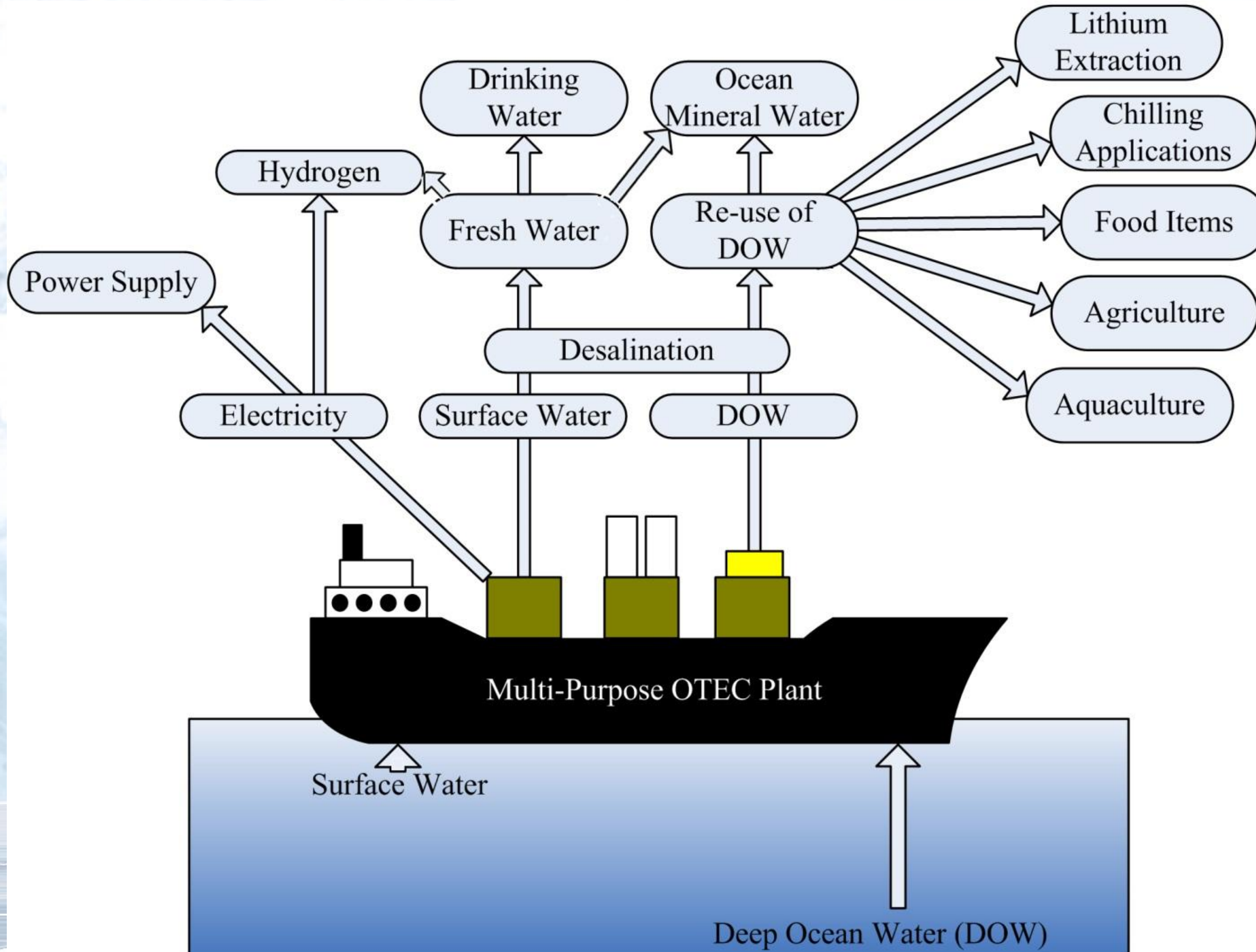
Conventional OWC, current OWC and inclined OWC

Wave Energy



Effect of OWC inclination angle on the rotor power at mean wave condition at different rotor rpms

Ocean Thermal Energy



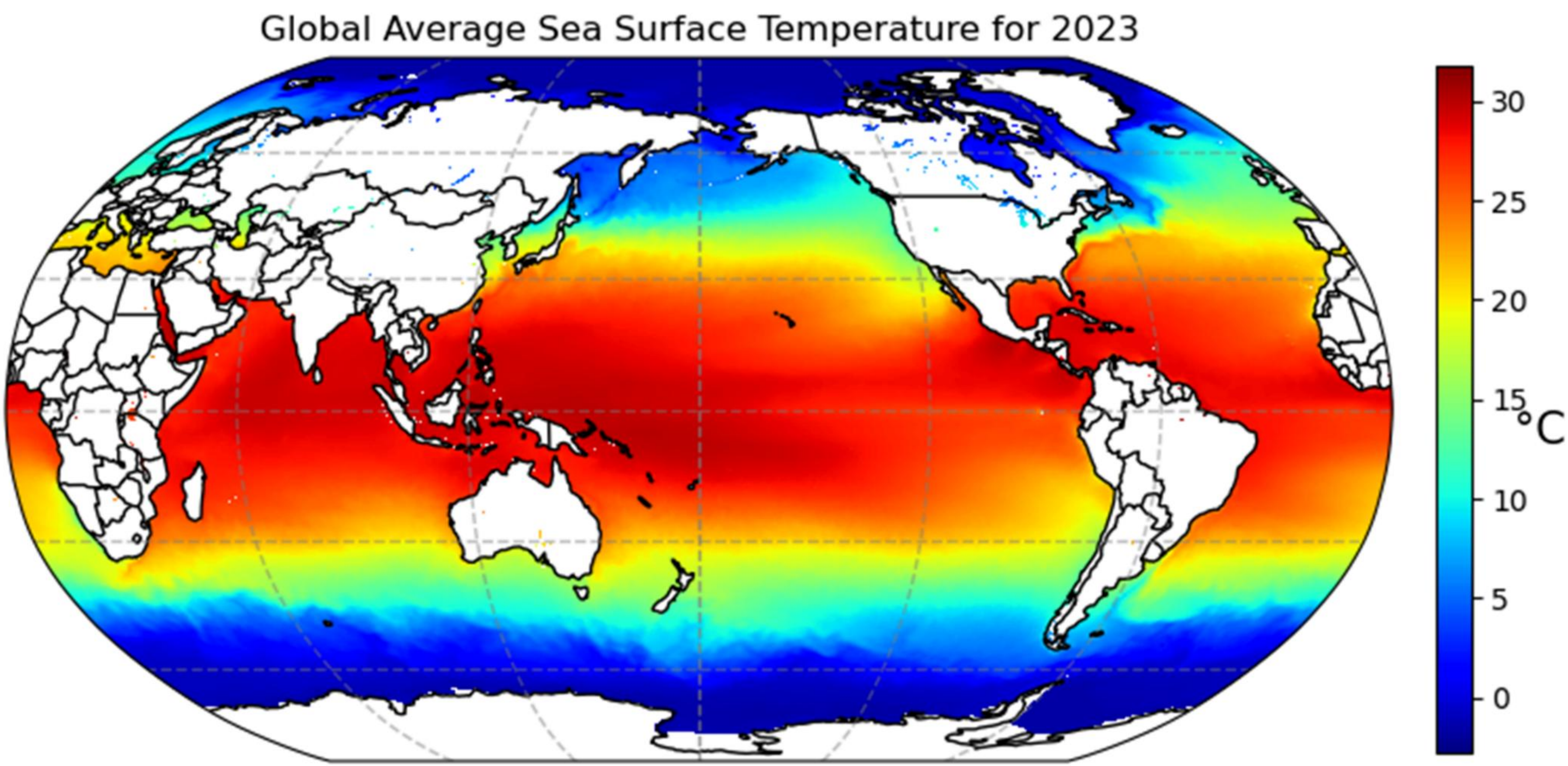
A multi-purpose OTEC plant will have a number of byproducts

Ocean Thermal Energy

- Power generation from the perpetually available temperature difference between the ocean surface and at a depth of about 1 km is only one of the benefits of an ocean thermal energy conversion (OTEC) plant.

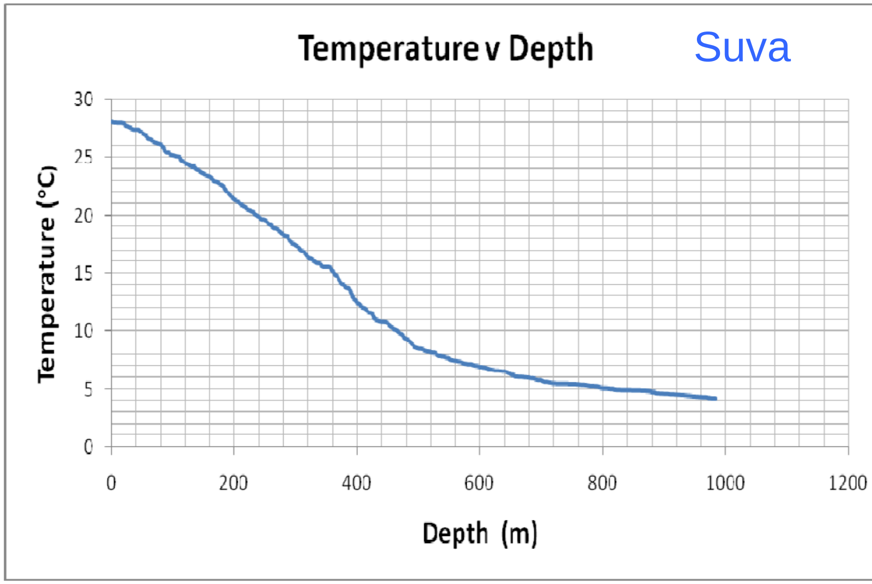
- Imagine getting an **inexhaustible supply of Hydrogen** for powering our future cars (no harm to environment) OR getting **unlimited quantity of ocean mineral water** for daily consumption OR exporting **huge quantities of lithium** for earning the precious foreign exchange OR being able to **cool our buildings without installing air-conditioners** OR **farming salmon in Fiji**. All this is possible with the modern OTEC plants.

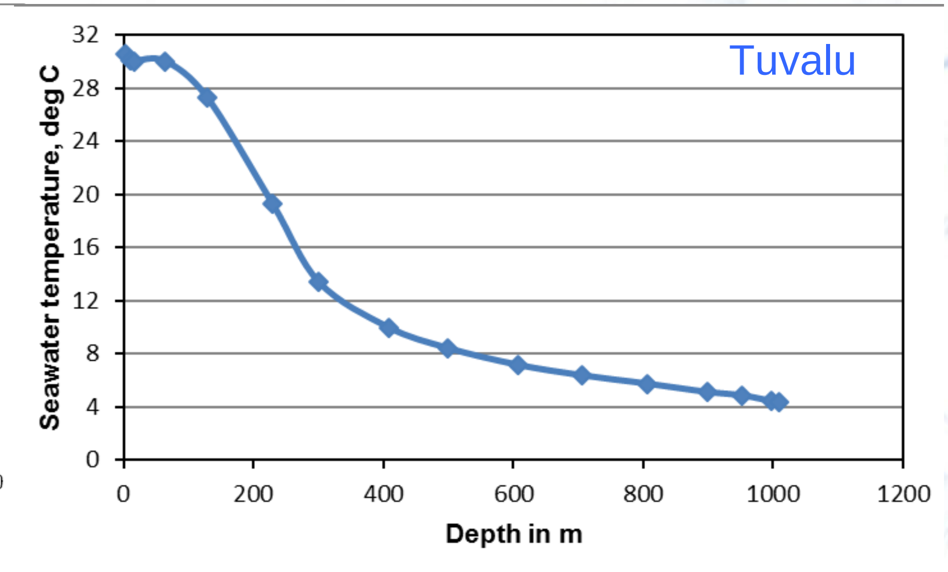
Ocean Thermal Energy



Source: AIMS, South Africa & Stellenbosch University

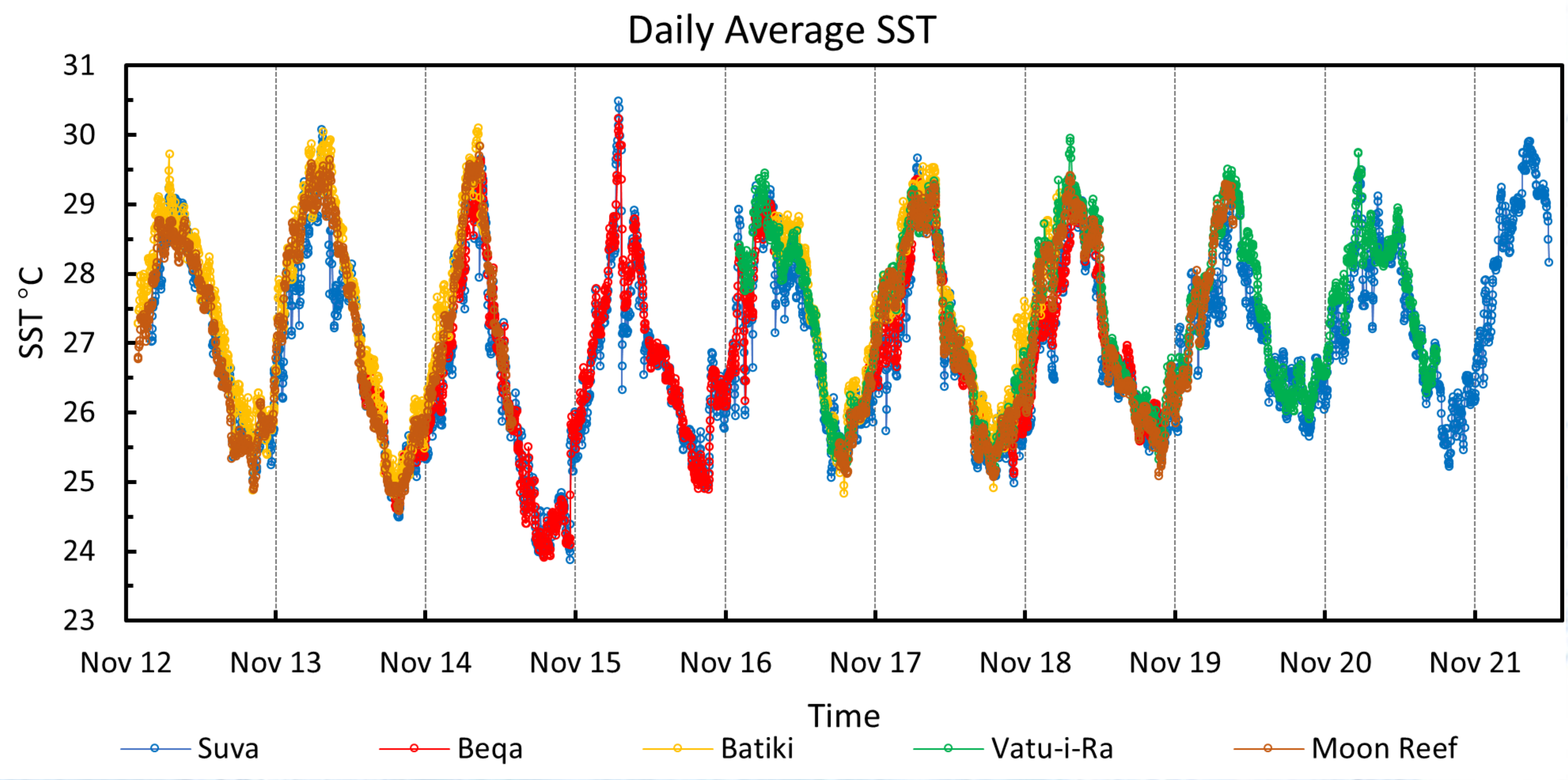
Ocean Thermal Energy





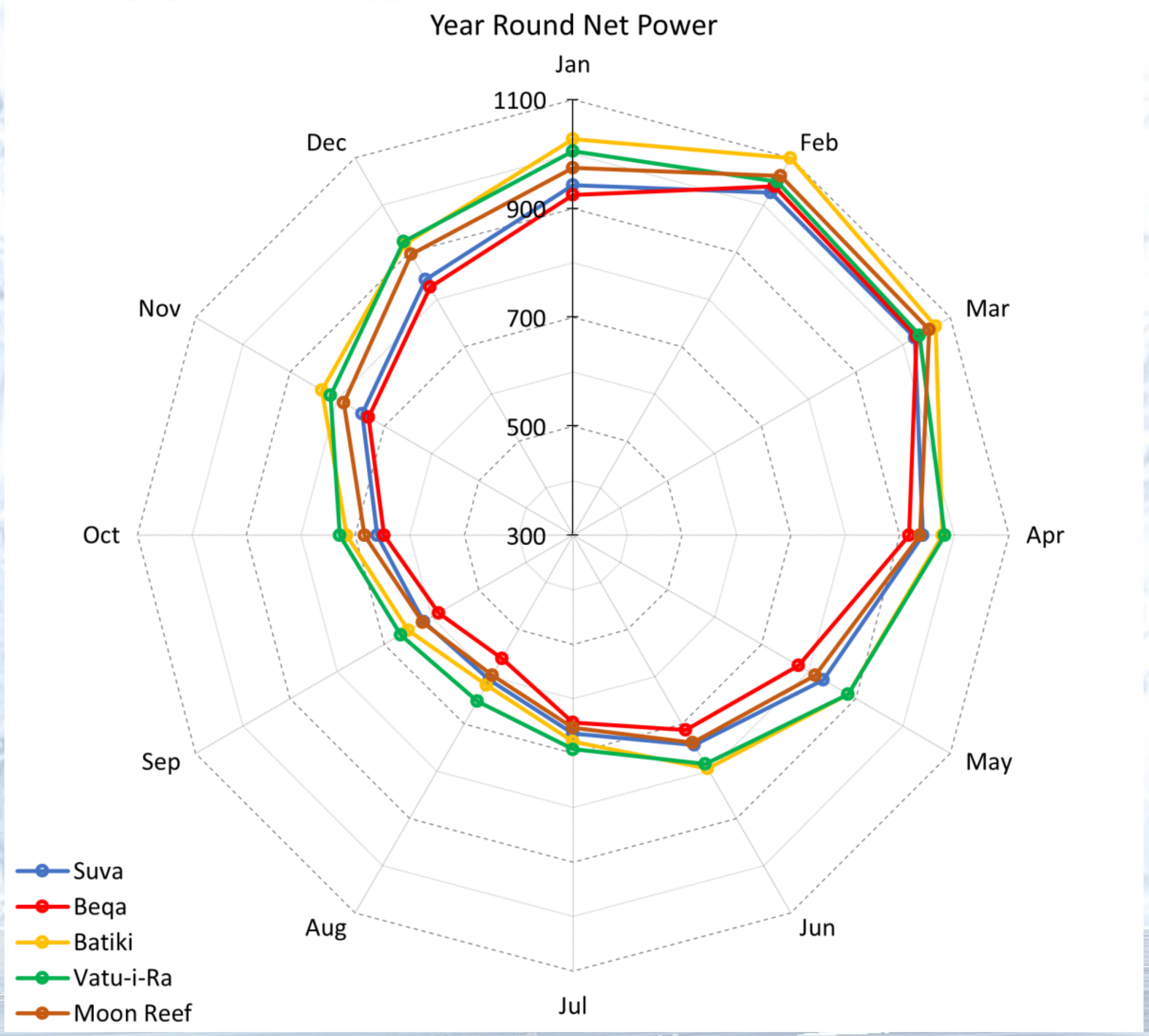
Measurements are performed at a number of places in the South Pacific and the surface temperature is observed to be increasing.

Ocean Thermal Energy



Daily average sea surface temperatures from 2012 to 2021 at five locations in Fiji.

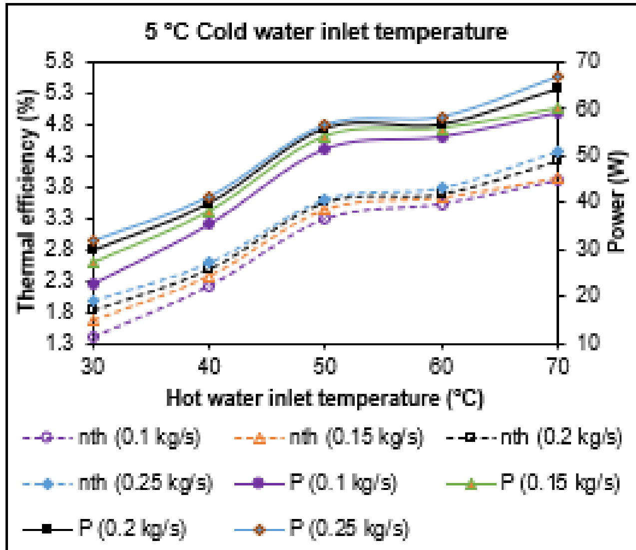
Ocean Thermal Energy

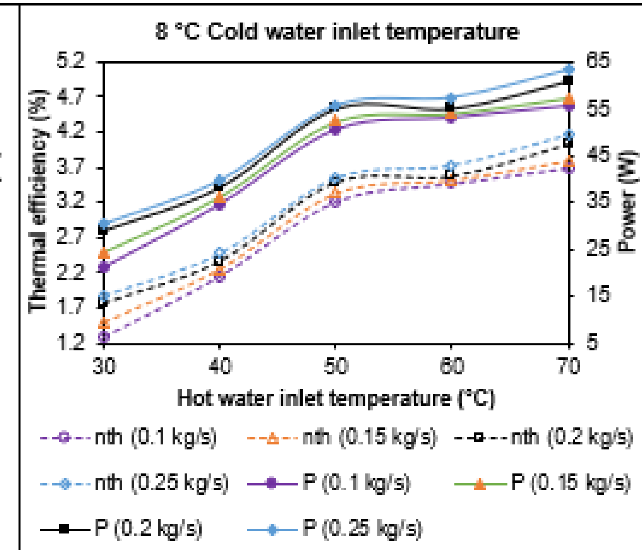


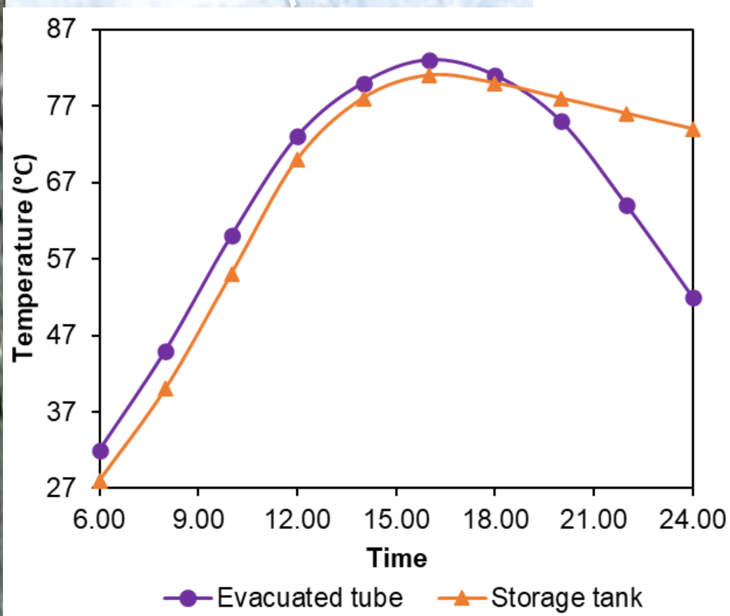
For a Gross power of 1.7-2.4 MW, the net power ranged from 430 kW to 1.15 MW (Tmax & Tmin of 29.7^{o}C & 24.1^{o}C.

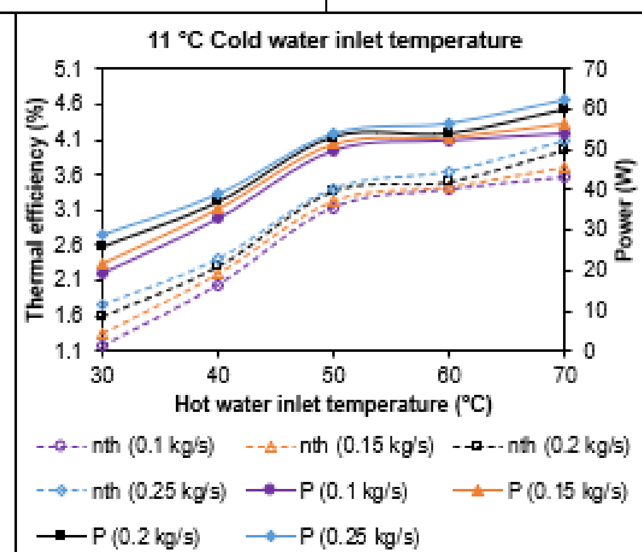
Ocean Thermal Energy

A solar-boosted OTEC system recently designed and tested. The temp in the tubes and in storage tank (below).







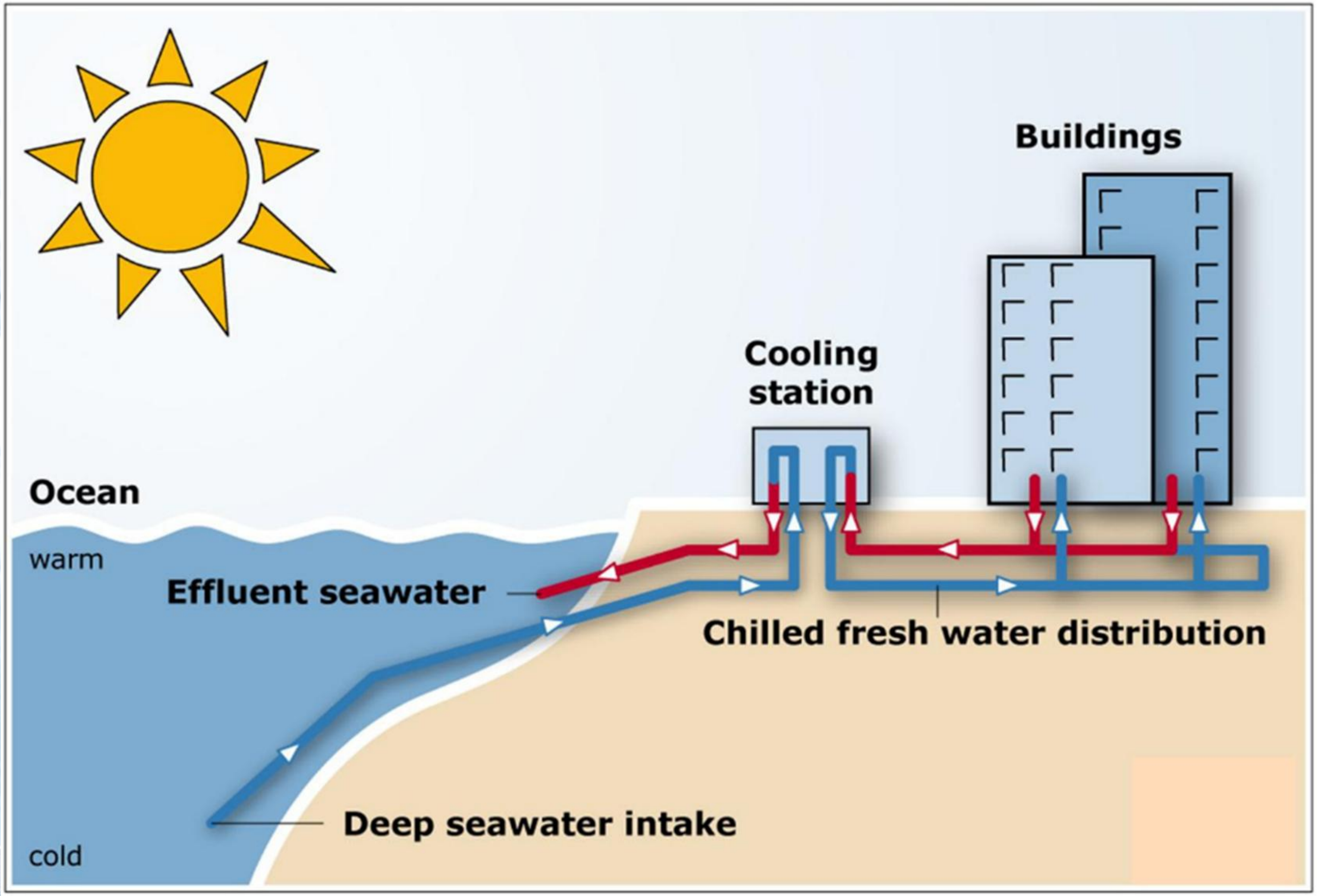


Power output and thermal efficiency (above).

Seawater Air Conditioning

- Seawater air conditioning (SWAC) - a non-polluting economical alternative to conventional air conditioning.
- PICs are surrounded by ocean; large quantities of cold deep seawater can be extracted with little energy consumption. SWAC is an ideal alternative for these countries.
- We have now completed two projects:
  - Feasibility study of SWAC of USP Tuvalu campus and design of components of a suitable SWAC system.
  - Feasibility study of SWAC of USP Marine campus and design of components of a suitable SWAC system.

Seawater Air Conditioning

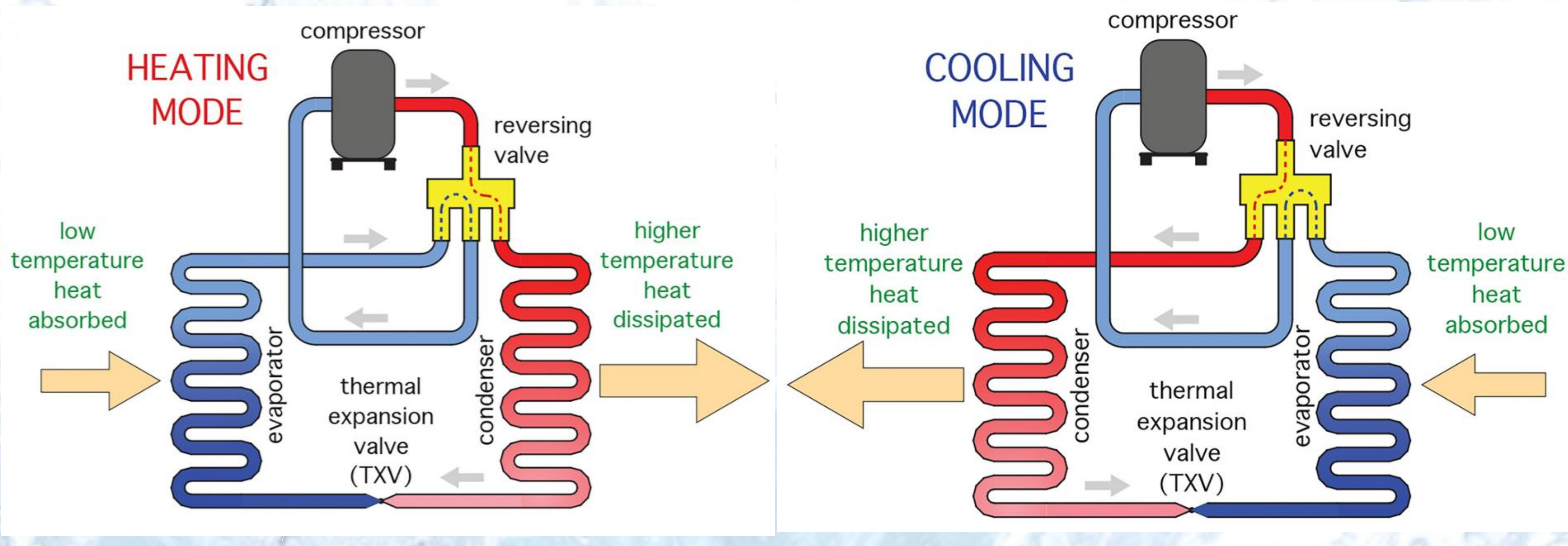


A DSWAC system uses cold, deep seawater to provide energy-efficient air conditioning; best option if cold water is available close to the shoreline.

Seawater Air Conditioning

A model of a USP building made and cooled by cold water.

Seawater Air Conditioning



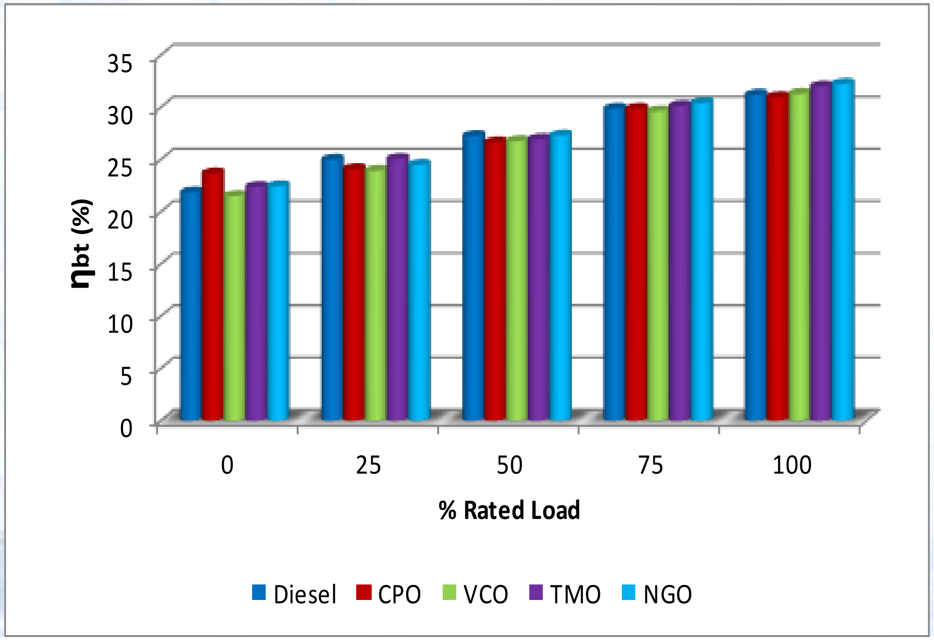
Source: Flexiheat UK Ltd.

Seawater based heating and cooling with a reversible valve.

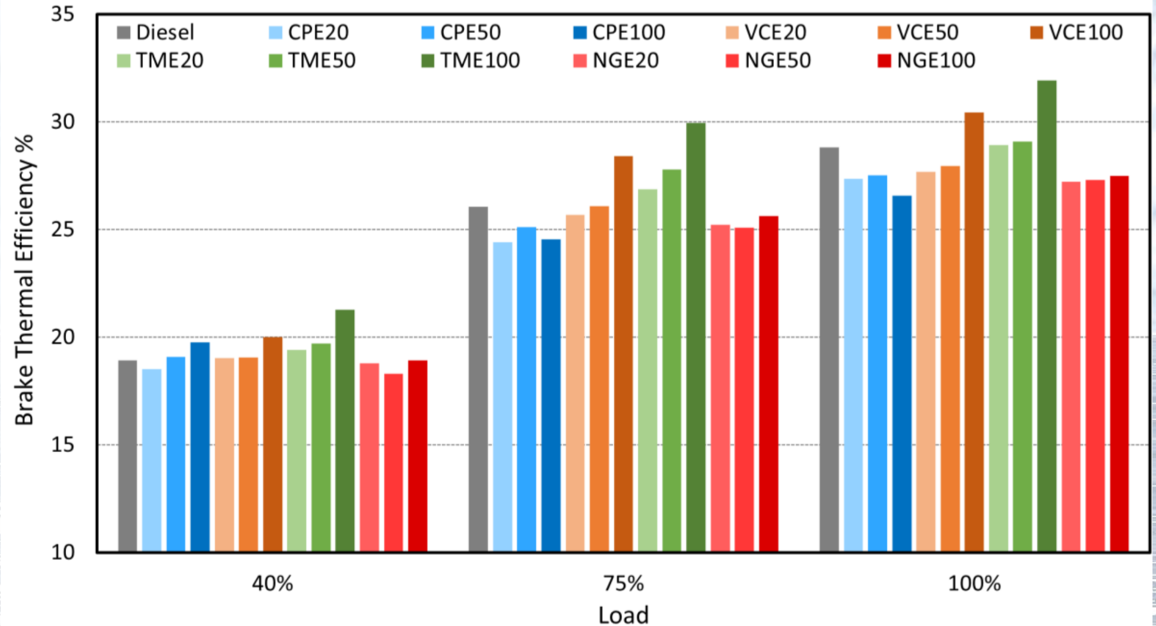
SVOs & Biodiesel

- PICs have no indigenous sources of fossil fuels to support their economy; end up spending millions on importing oil.
- Attention is also paid on SVOs and Biodiesel for achieving sustainable economic development and promoting ‘clean and green energy’.
- Virgin coconut (cocos nucifera), Copra, Tamanu (calaphyllum inophyllum), and Nangae (canarium indicum) are some of the sources of oils tested for use in engines (SVOs and biodiesel).

SVOs & Biodiesel



Brake thermal efficiencies with SVOs and with biodiesel – oils from Vanuatu.



Rocket Stove Design and Testing

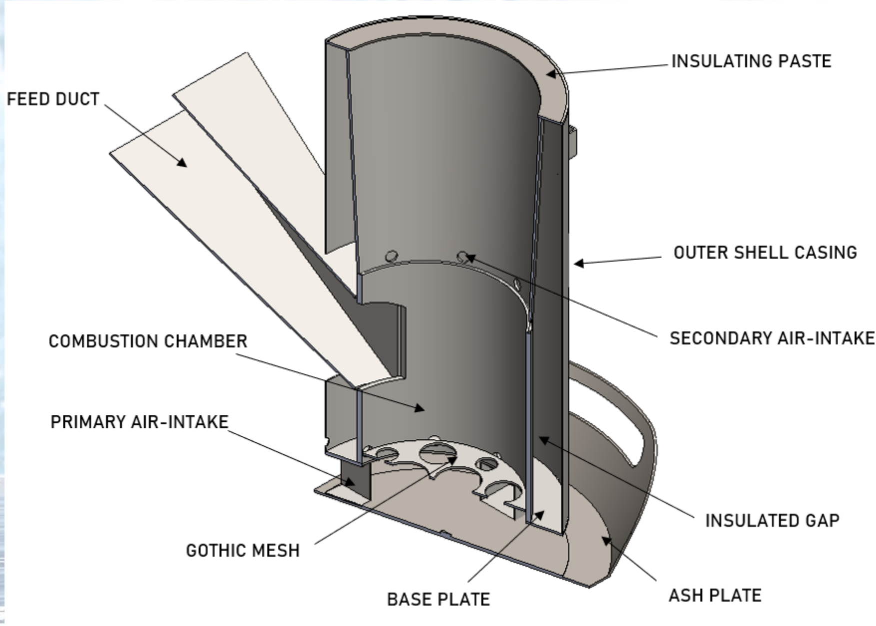
Efficient, well-designed rocket stoves not in widespread use in the region providing motivation for the present work.

- **Key Design Considerations:**
  - Handling
  - Heat transfer
  - Ash collection
  - Improved combustion
  - Effect of wind
  - Aesthetics.

Rocket Stove Design and Testing

Features of the New Stove

- Cylindrical shape for even flow of air around stove
- Secondary air inlets for improved combustion
- Divergent combustion chamber for reduced airflow (enhanced mixing)
- Double-walled cover for reduced heat losses
- Base air intake design; burning fuel is supplied with fresh air that is directed from the combustion chamber (at the base) towards the top of stove.



Rocket Stove Design and Testing

Four types of local wood tested in the stove under different indoor and outdoor conditions. A max efficiency of 36% was obtained.

Future Work and Collaboration

- The group has done a lot of resource assessment work involving extensive measurements of wind, waves, tidal currents and temperature difference (OTEC).

- A lot of work on design and testing of lab scale energy harvesting devices is also completed. CFD analysis of full-scale prototypes is also completed.

- The group would now like to focus on the installation of actual energy harvesting devices and this is where we HAVE TO COLLABORATE with bigger countries. Along with energy, safe water is another major issue in PICs.

Collaboration with UNSW

- MoU between UNSW and USP signed in April 2024.
- Exploring joint funding opportunities – lots of calls for proposals with millions of $$$ available for Energy, Water and Environment research esp for developing countries.
- Any of the Australian companies that work with UNSW willing to install actual energy harvesting devices as pilot projects?
- Along with Energy issue, PICs also face water supply issues – including some remote islands that don't receive enough rainfall to flooding of low-lying areas in the major cities, seawater getting mixed with fresh water and water treatment issues.

Summary

- Enormous potential of renewable extraction in the PICs. Available energy density not as high as in some European countries, but requirement also not large.
- Government considering wave-powered desalination as a viable option for some remote islands. Another priority is wind turbines of about 100 kW to be installed at a number of locations.
- Work on modeling and forecasting of wind, waves and tidal currents is also initiated apart from extensive resource assessment work by *in situ* measurements.
- Many PICs are now thinking beyond solar PV systems for power generation – after the last Pacific Energy Leaders' Meeting, OTEC & SCPP are being considered.

How Different is This?

A location where the depth is about 40 m.

Renewable Energy Research at USP & Future Prospects

Thank You!!

Vinaka!!

QUESTIONS & Comments???