Ocean Renewable Energy in South East Asia

Michael Lochinvar Sim Abundo (Dr)

Managing Director, OceanPixel Pte Ltd

OceanPixel Pte Ltd
#02-15 CleanTech One Bldg.,
1 CleanTech Loop, Singapore 637141

Unit 113B, Innovation Centre Block 2
18 Nanyang Drive, Singapore 637723

OceanPixel

www.oceanpixel.org

OceanPixel

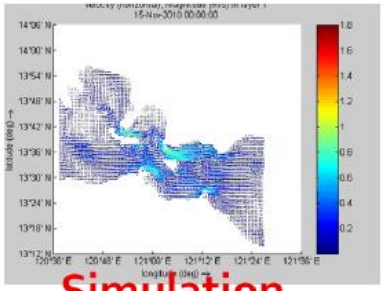
www.oceanpixel.org

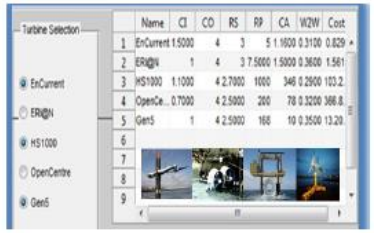
Making Marine Renewable Energy Happen in SEA!

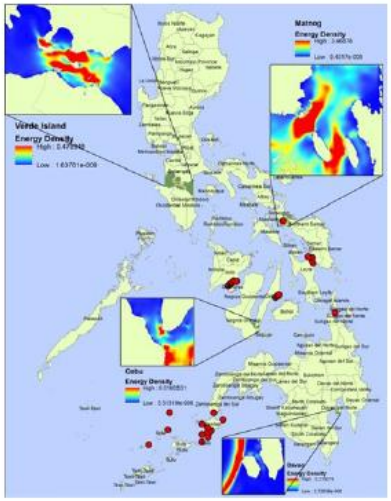
4 Directors | 8 Staff | 3 Associates

OceanPixel is a Singapore start-up company that spun off from the Nanyang Technological University's (NTU) Energy Research Institute. OP is currently engaged in ocean energy projects in Singapore, Indonesia, and the Philippines

With OceanPixel's capabilities, we provide *Multi-Site, Multi-Device, Multi-Criteria GIS Decision Approach* to project development.







- **Resource Data**
  - ◊ Integration
  - ◊ Processing
  - ◊ Analysis
- **Device Database**
  - ◊ Mechanical Specs
  - ◊ Electrical Specs
  - ◊ Cost
- **Installation**
  - ◊ Distance to Port
  - ◊ Distance to Shore (Grid)
- **Constraints**
  - ◊ Navigation & Shipping
  - ◊ Marine Protected Areas
  - ◊ Depth Constraints
- **Suitability Scoring**
  - ◊ "Best Site" Nomination
  - ◊ "Best Technology"
  - ◊ "Best Device"
  - ◊ Least Cost Analysis

Partners & Collaborators

aquatera
environmental services and products

NANYANG TECHNOLOGICAL UNIVERSITY
Energy Research Institute @ NTU

SCHOTTEL HYDRO

itp DHI VOS

seacore
southeast asian collaboration for ocean renewable energy

Orkney's renewable energy resources

Total = > 5,000 MW deliverable capacity

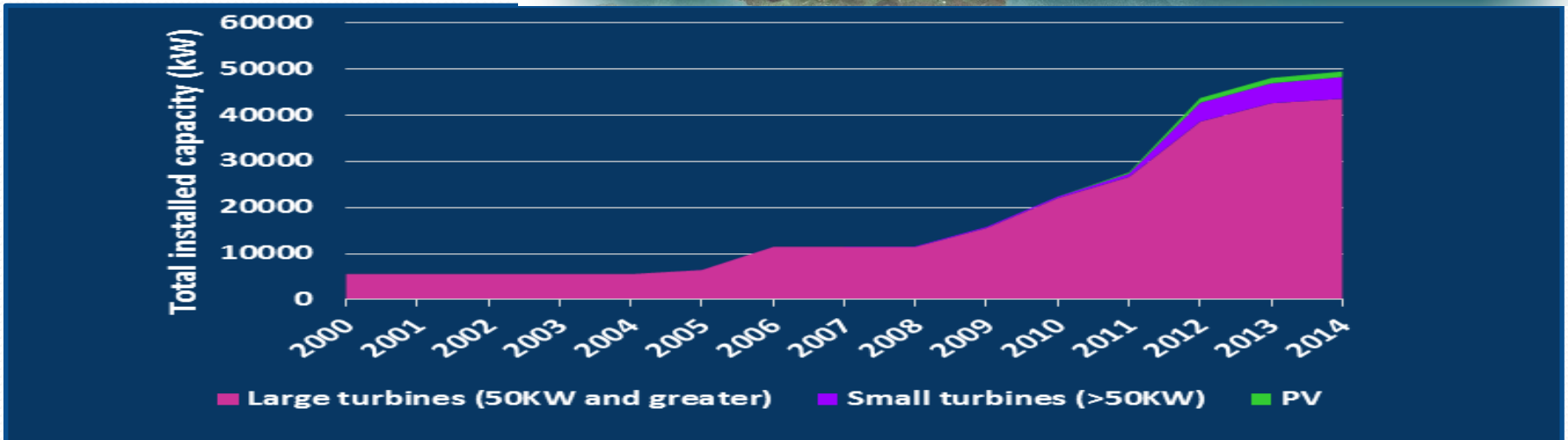
Key

Onshore wind	40 MW existing/planned
New onshore wind	100-200 MW
Wave	500-1000 MW
Tidal	500-2,500 MW
Offshore wind	1000 MW
Wave leases	550 MW
Tidal leases	500 MW
Mirco & other	2.5 MW
Gas & other	20 MW
EMEC sites	5 + 7 MW

Dispersed

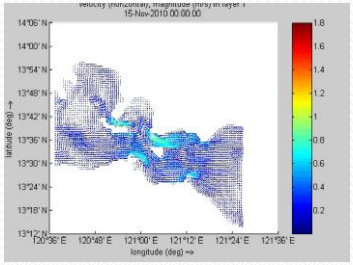
Dispersed and

107% of electrical demand in Orkney met by renewables in 2014



South East Asia RD&D

Simulation Studies

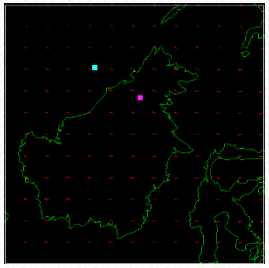


Myanmar
Tidal Barrage

Indonesia
Tidal Current Test

Europe, N. America, Australia

Brunei
Offshore Wind



Vietnam
Tidal Turbine Drive Train

Malaysia
OWC Test

Tow Tanks
(eg UTM, MMU, NTU)

Philippines
Tidal Barrage

Singapore
Tidal Turbine Testing

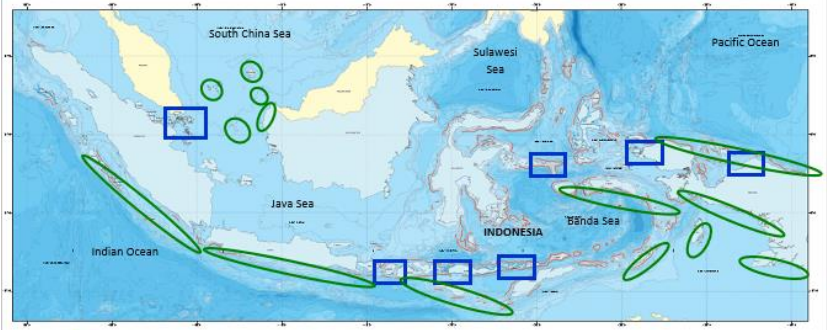
Source: SEAcORE 2013

Ocean/Marine Renewable Energy Resource in SEA

OceanPixel
Fluid. Intelligence.

* ORE Potential: Indonesia[1]

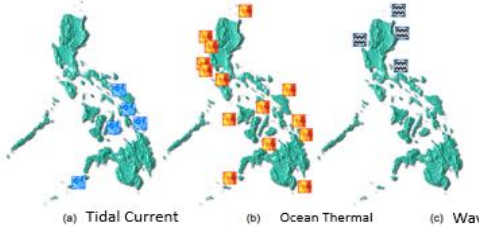
Potential	Tidal Current	Ocean Wave	Ocean Thermal
Theoretical	160 GW	510 GW	57 GW
Practical	4.8 GW	1.2 GW	43 GW



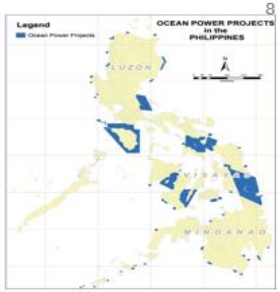
Tidal Current Energy Reserves
Wave Energy Reserves
Contour showing water depth having > 20 °C Temp. Gradient

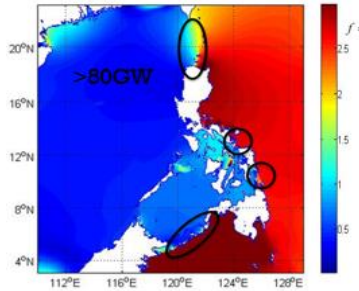
[1]INOCEAN 2013

* ORE Potential: Philippines (170 GW)

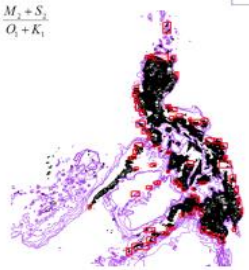


(a) Tidal Current (b) Ocean Thermal (c) Wave





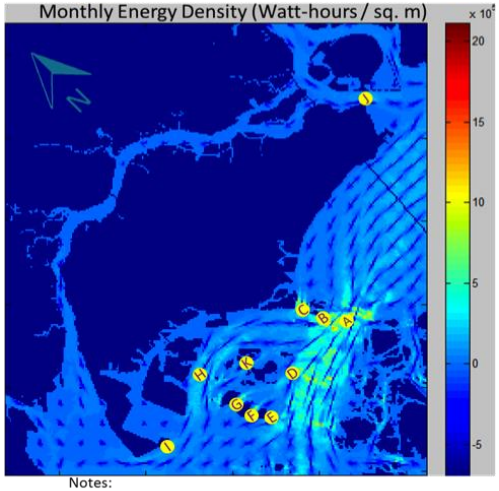
Tidal In-Stream Energy Potential Sites



Wave Energy Potential Sites

OTEC Route to Grid Parity

Singapore Tidal In-Stream Energy



Total Resource[1]	~3 TWh/year
Technically[2] Extractable Energy Resource	~900 – 1,200 GWh/yr
Practically[3] Extractable Energy Resource	**~300-600 GWh/yr**

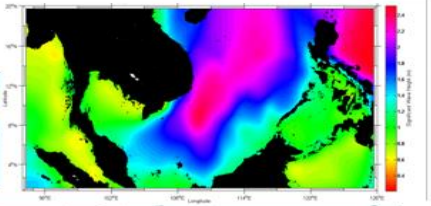
SITE	Peak Power (MW)	Annual Energy Yield (GWh / yr)
A	105	115.96
B	65	71.78
C	15	101.52
D	20	22.09
E	3	3.31
F	12	3.22
G	5	15.48
H	15	5.06
I	5	15.34
J	2	7.95
K	3	1.66
TOTAL	250 MW	363.36 GWh/yr

Notes:
- [1]Energy Density of ~1MWh/m^2/month *5km length (channel width) *50m ave. depth *12 months
- [2]Water-to-Wire Efficiency: 0.3 to 0.4
- [3]Without detrimental environmental effects , Significant Impact Factor (SIF): 0.1 to 0.2
- Velocity Data from PORL, TMSI, NUS

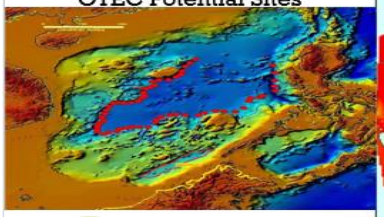
ERI@N

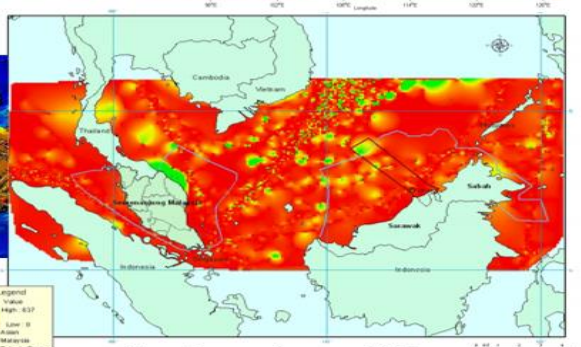
* Others in SEA: Malaysia, Vietnam, Brunei

- Brunei: 660 GW Wave
- Malaysia
  - Straits of Malacca (Tidal Current)
  - Sabah (OTEC)



OTEC Potential Sites

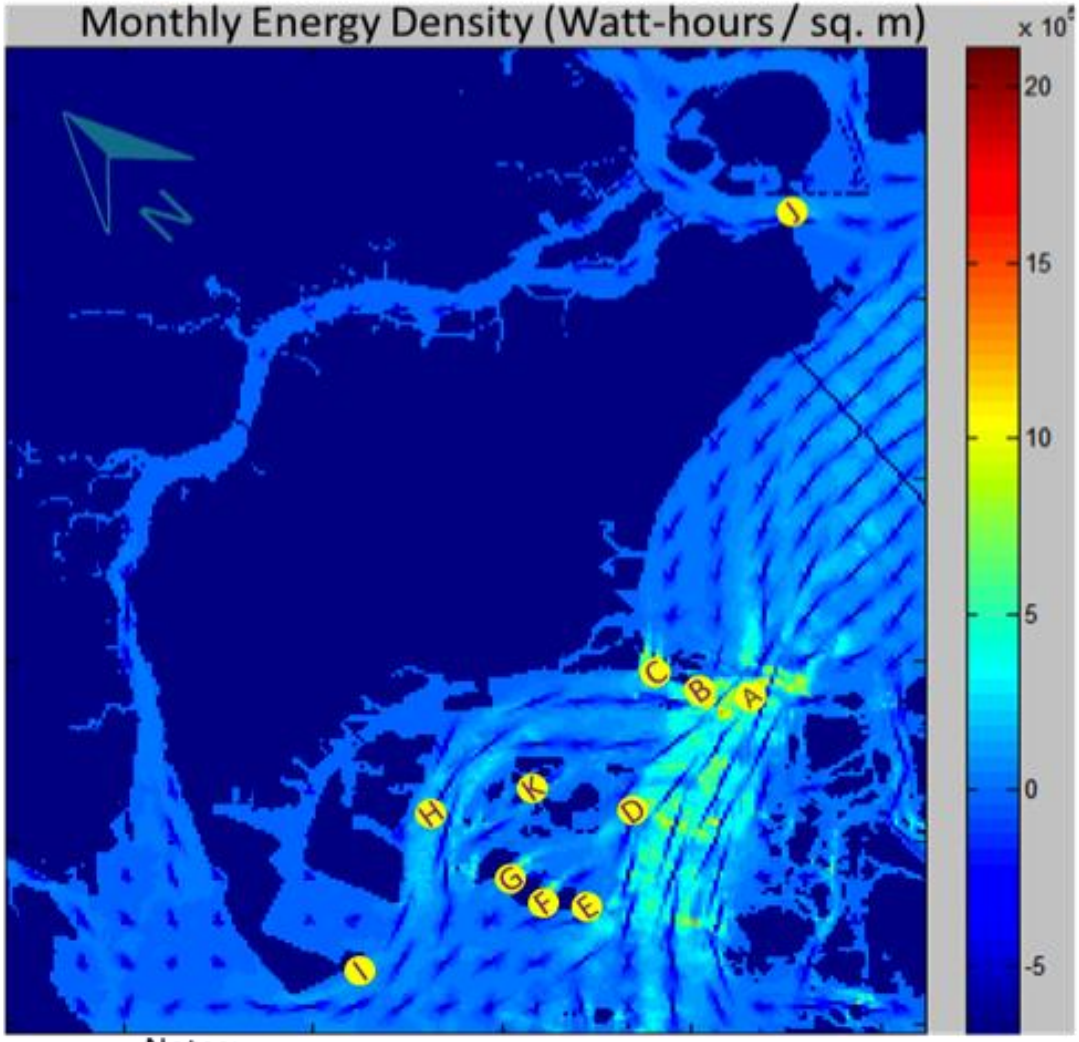




seacore
southeast asian collaboration for ocean renewable energy

Wave Energy for year 2007

Singapore Tidal In-Stream Energy



Total Resource[1]	~3 TWh/year
Technically[2] Extractable Energy Resource	~900 – 1,200 GWh/yr
Practically[3] Extractable Energy Resource	**~300-600 GWh/yr**

SITE	Peak Power (MW)	Annual Energy Yield (GWh / yr)
A	105	115.96
B	65	71.78
C	15	101.52
D	20	22.09
E	3	3.31
F	12	3.22
G	5	15.48
H	15	5.06
I	5	15.34
J	2	7.95
K	3	1.66
TOTAL	**250 MW**	**363.36 GWh/yr**

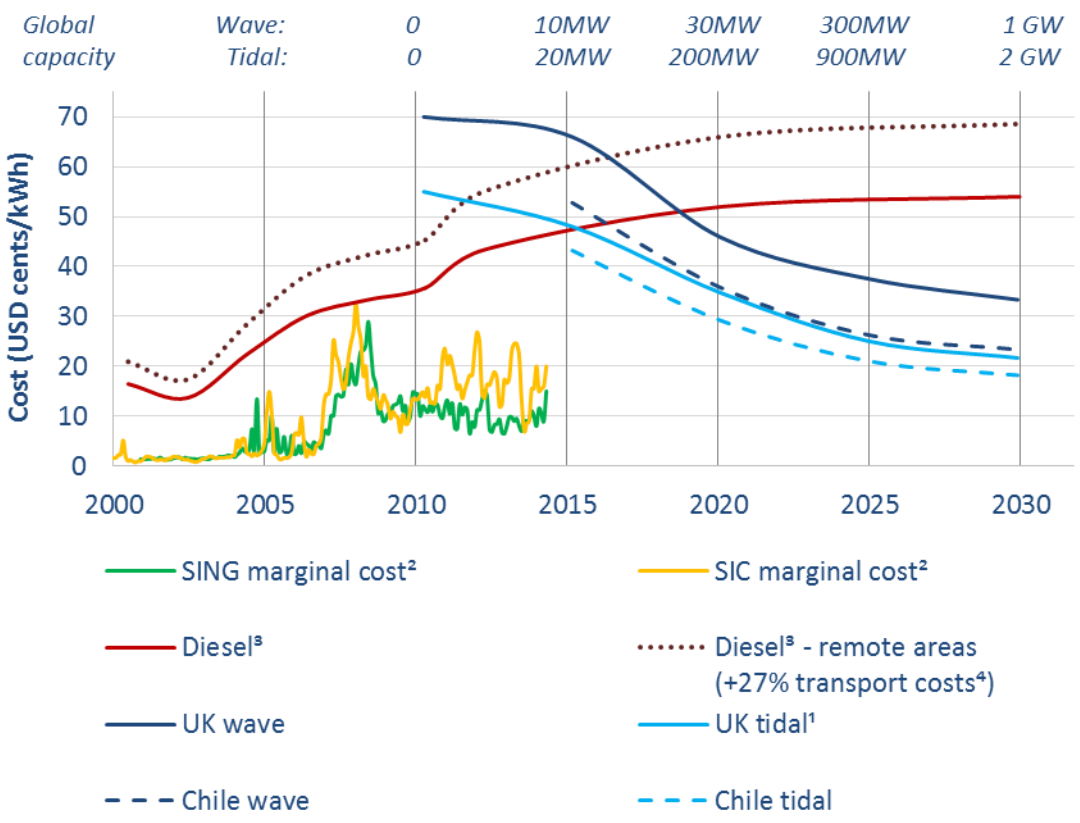
Notes:

- [1]Energy Density of ~1MWh/m^2/month *5km length (channel width) *50m ave. depth *12 months
- [2]Water-to-Wire Efficiency: 0.3 to 0.4
- [3]Without detrimental environmental effects , Significant Impact Factor (SIF): 0.1 to 0.2
- Velocity Data from PORL, TMSI, NUS

ERI@N

http://blogs.ntu.edu.sg/seacore/files/2014/10/singapore4.png

Wave and tidal



Sources: [1]Carbon Trust; [2]CNE; [3]World Bank/Bloomberg; [4]Chilean Ministry of Energy

Marine energy markets:

LONG TERM
Grid electricity

MEDIUM TERM
Diesel replacement; water pumping and desalination (mines)

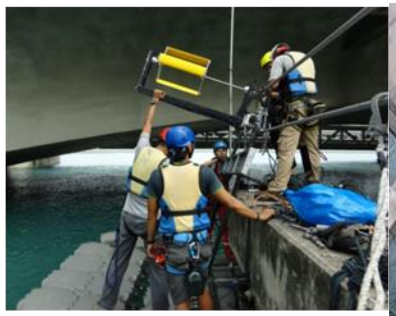
SHORT TERM
Remote diesel replacement

Marine Renewable Energy towards the Tropics

OceanPixel
Fluid. Intelligence.

OES OCEAN ENERGY SYSTEMS

IEC IEC-TC114



Sentosa

Acoustic Doppler Current Profiler

SEA + Global

ASEAN Center for Energy

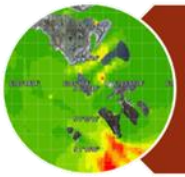
Singapore

seacore
southeast asian collaboration for ocean renewable energy

TMFT

ERI@N

RD&D



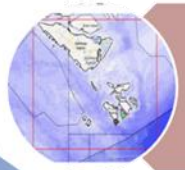
Resource

Low Flow(<3m/s), Low Wave, Low Tidal Range

Device Assessment

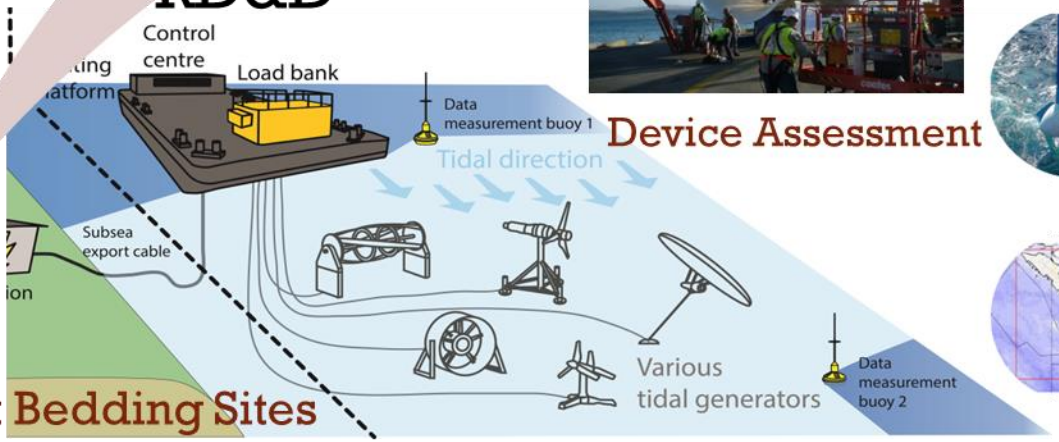
Environment

Shallow Waters, Tropical Biofouling, High Turbidity, Ecology



Marine Spatial Planning

Dredging, Reclamation, Shipping Channel/Anchorage, Defence, Protected Areas



Test Bedding Sites

Some Costs in South East Asia

- Sinkers: $500 to $1k / ton → $100/ton
- Surveys (ADCP Transect + Seabed-mounted): $100k → $30k-$50k
- Barge-Based Floating Support System: $250k → $50k to $100k
- Tug boats / Survey Vessels: ~$10k/day → $1k - $5k/day
- Feasibility Studies: $500k-600k/site → $150k - $300k/site
  - Environment Compliance Certificate (5MW to <100MW): $50k-$100k
- Deployed 2m Diameter Tidal Turbine
  - Support Structure(Floating)+Mooring+Installation = $60k
- Piling, Crane Barges, Cabling…

Technology Zones

Hs> 1m

Medium Energy
Medium Risk
Array Approach

Hs> 0.5m

Huge Waves
High Energy
High Risk
Offshore Challenges

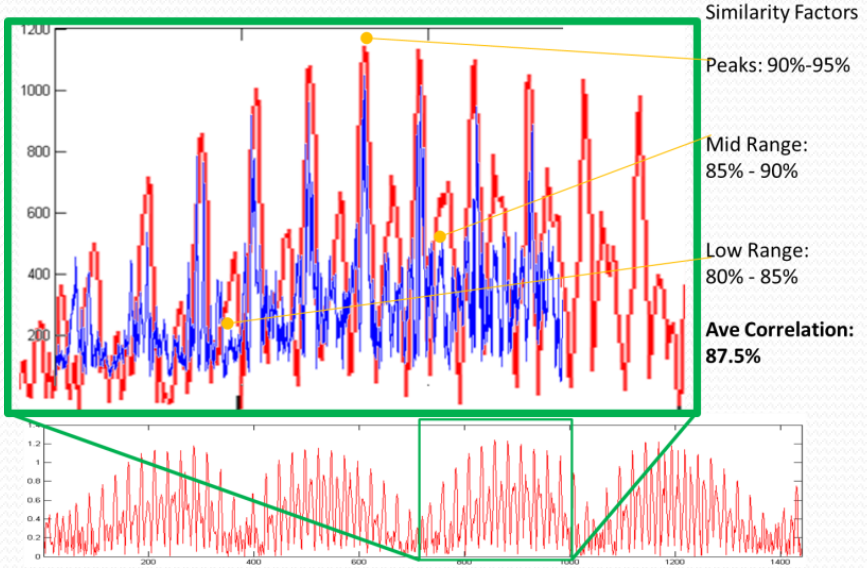
Hs < 0.5m

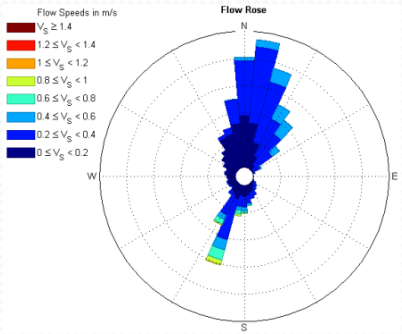
Multi-function Device
'Low Wave' Resource Capture

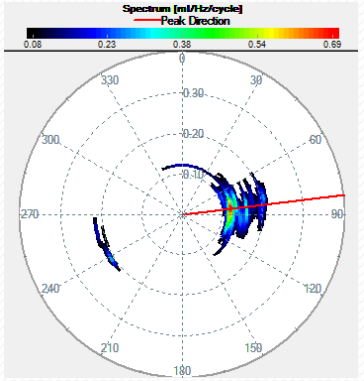
'Dry Setup', Low Risk, Easier Maintenance

Tidal Resource Validation

Tidal Current Simulation VS ADCP Data





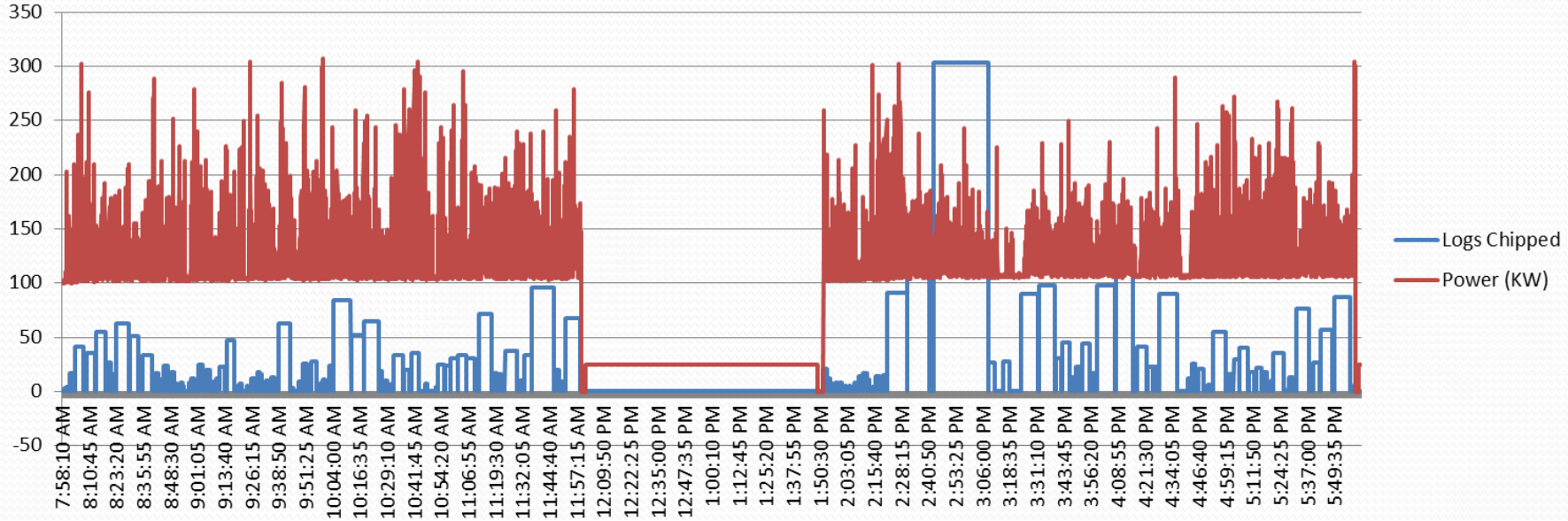


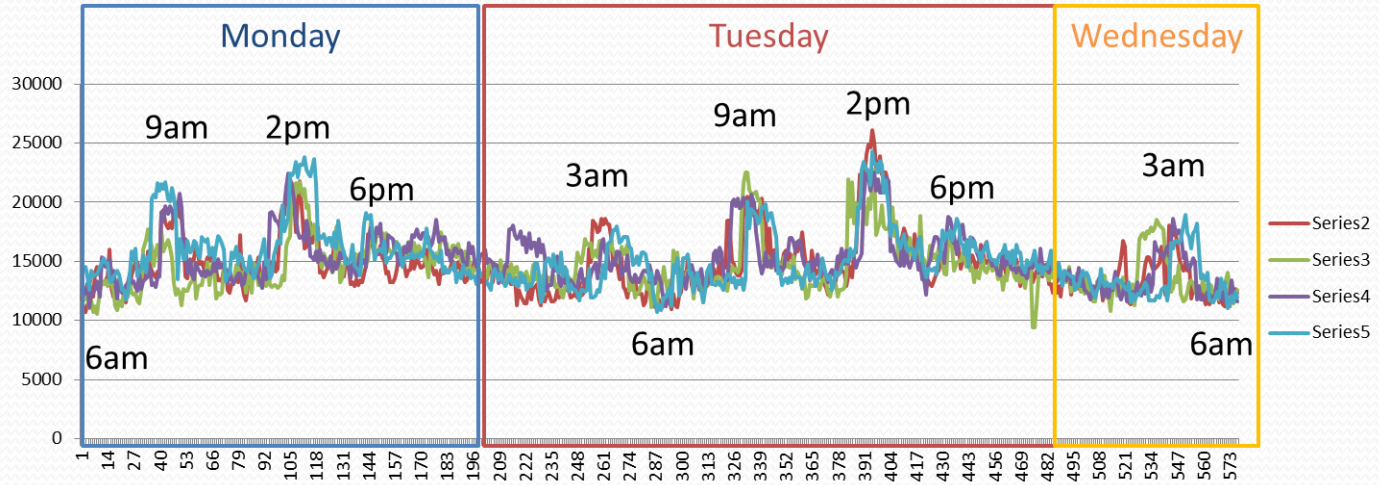
SEA Case Study: Island with Industry

The BUMWI Micro-Grid

SHIP LOADING
BC-15
BC-14
BC-12A
TOWER HOIST CRANE
INDUSTRY
CHIP YARD
GENSET
NEW WORKSHOP
GENERAL OFFICE
WATER PUMP
WAREHOUSE
SPORTS FIELD
DORM
BADMINTON
BATHROOM
MOSQUE
YOU ARE HERE
FUEL WAREHOUSE
1
2
3
4
5
6
7
8
BUMWI
Main & Sub-Main Plan

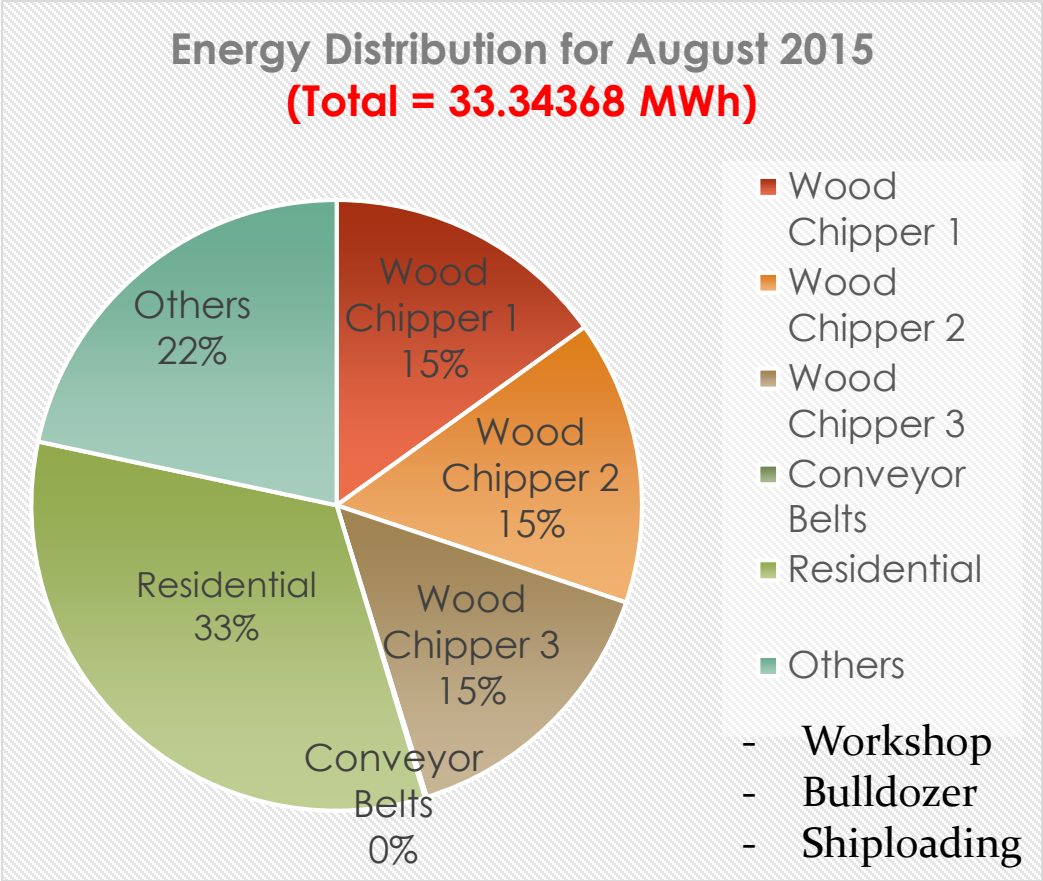
Industrial Island Energy Use



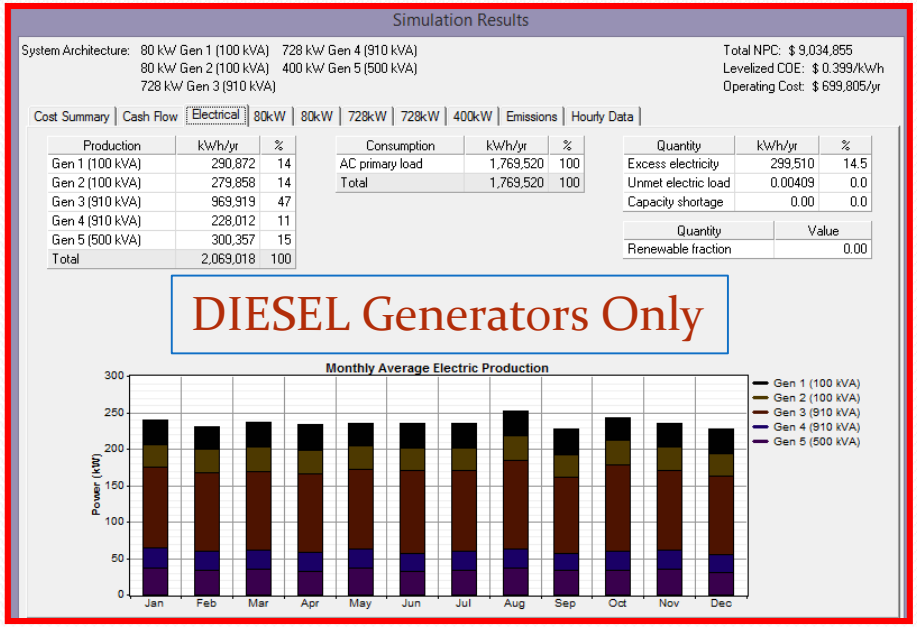


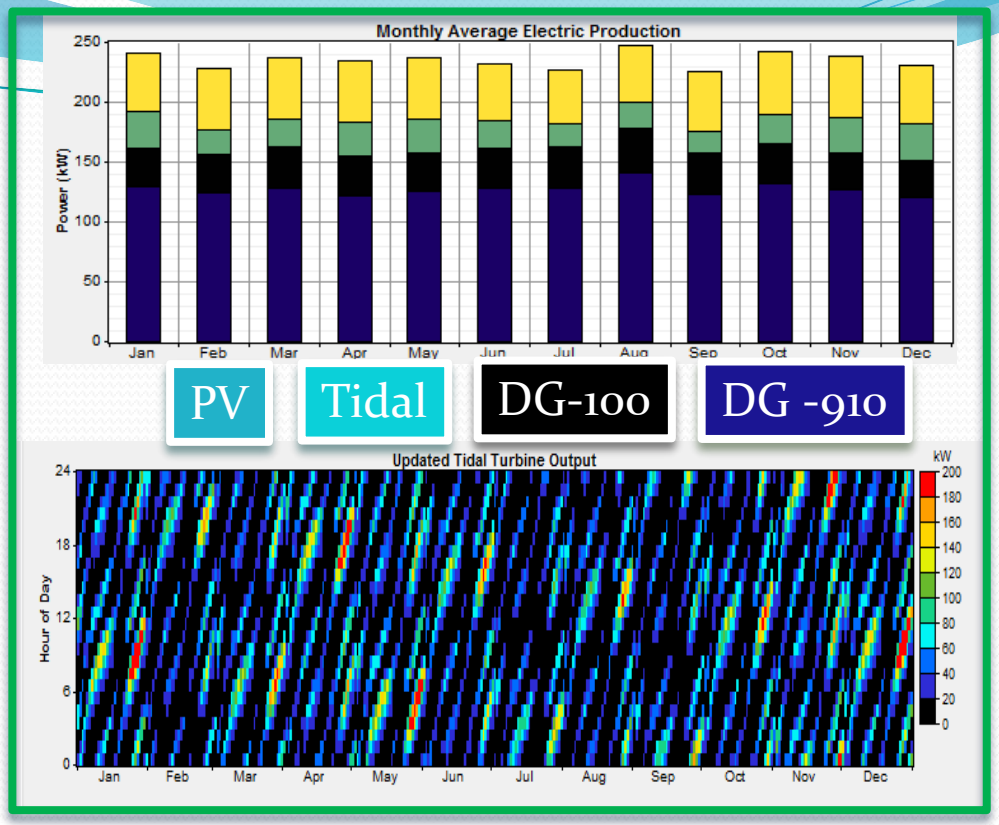
Summary of Energy Statistics

- **Diesel Cost (Aug)**
  - 18,800li x $0.89/li
  - $16,732
- **Eff. Electricity Rate:**
  - $0.5/kWh
- **Electricity Costs**
  - ~$7,563 Industry
  - ~$5,502 Residential
  - ~$3,667 Others
- **Electricity Cost/Log:** $0.045
  - Logs/Month:~165k
  - 21 x 7,870 logs/day

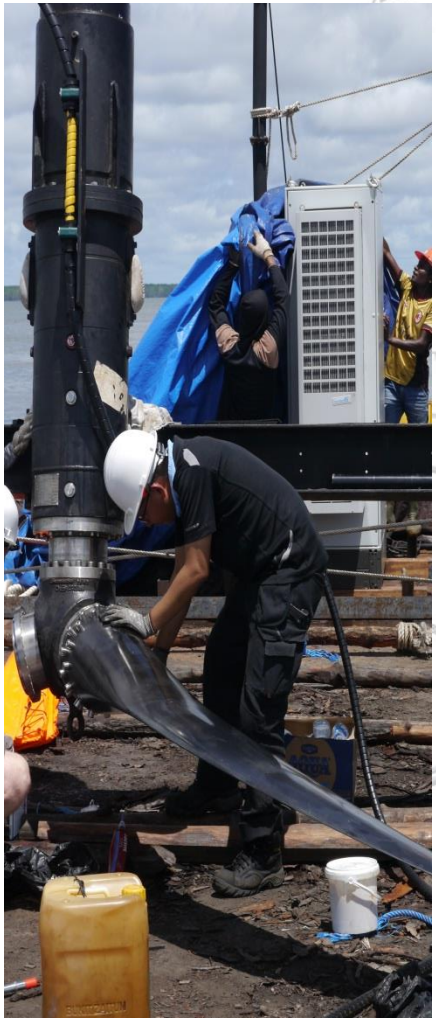


Case Study: Hybrid System for an Island Micro-Grids





Power System Config.	RE Fraction	Excess Electricity	LCOE (USD/kWh)
Diesel GenSets (910, 100 kVA) + Batt (576kWh) + Solar (300kWp) + Tidal (200kWp)	**31.6%**	**12.6%**	**0.3 – 0.37**
Diesel GenSets (910kVA, 100 kVA) + Batt (720kWh) + Solar (600kWp)	38.6%	20.1%	0.386
Diesel GenSets (910kVA, 100 kVA)+Batt.(1440kWh)	0.0 %	2.47%	0.456
Diesel GenSets (2x 910, 500, 100 kVA)	0.0 %	14.5%	**0.50**



OceanPixel
Fluid. Intelligence.

Tidal Turbine Utility Pole

OceanPixel
Fluid. Intelligence.

Tidal power in West Papua, Indonesia

Initiated by:

GREEN FOREST PRODUCT & TECHNOLOGY

PT. Bintuni Utama Murni Wood Industries (BUMWI)

Supported by:

OceanPixel

SCHOTTEL HYDRO

aquatera environmental services and products

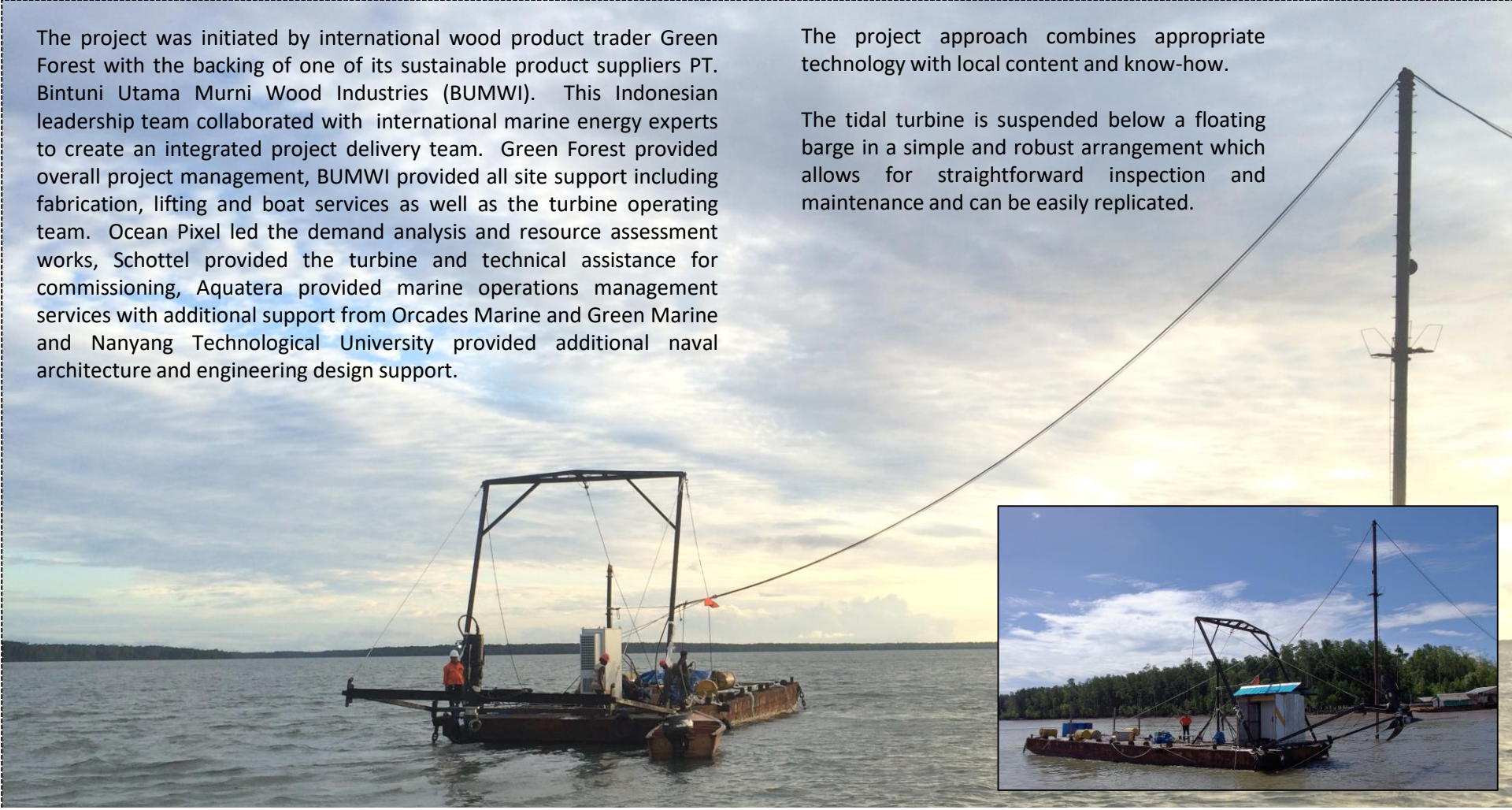
NANYANG TECHNOLOGICAL UNIVERSITY

Energy Research Institute @ NTU

The project was initiated by international wood product trader Green Forest with the backing of one of its sustainable product suppliers PT. Bintuni Utama Murni Wood Industries (BUMWI). This Indonesian leadership team collaborated with international marine energy experts to create an integrated project delivery team. Green Forest provided overall project management, BUMWI provided all site support including fabrication, lifting and boat services as well as the turbine operating team. Ocean Pixel led the demand analysis and resource assessment works, Schottel provided the turbine and technical assistance for commissioning, Aquatera provided marine operations management services with additional support from Orcades Marine and Green Marine and Nanyang Technological University provided additional naval architecture and engineering design support.

The project approach combines appropriate technology with local content and know-how.

The tidal turbine is suspended below a floating barge in a simple and robust arrangement which allows for straightforward inspection and maintenance and can be easily replicated.

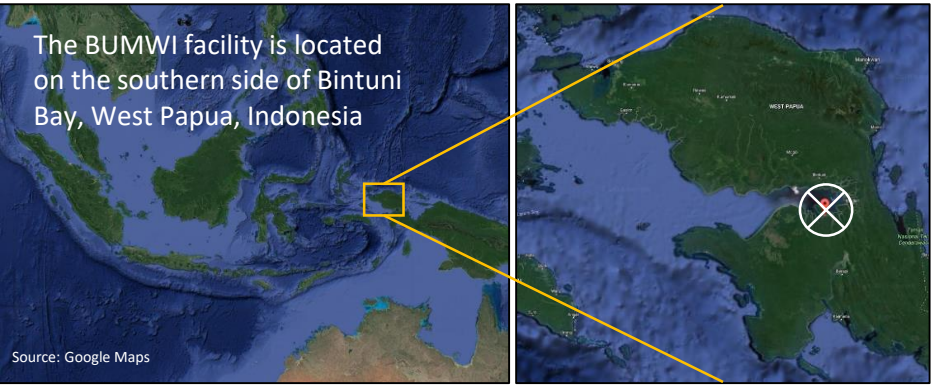


The project has proven the capability of a multi-company team to develop, implement and successfully deploy a tidal turbine in one of the most remote and areas of Indonesia.

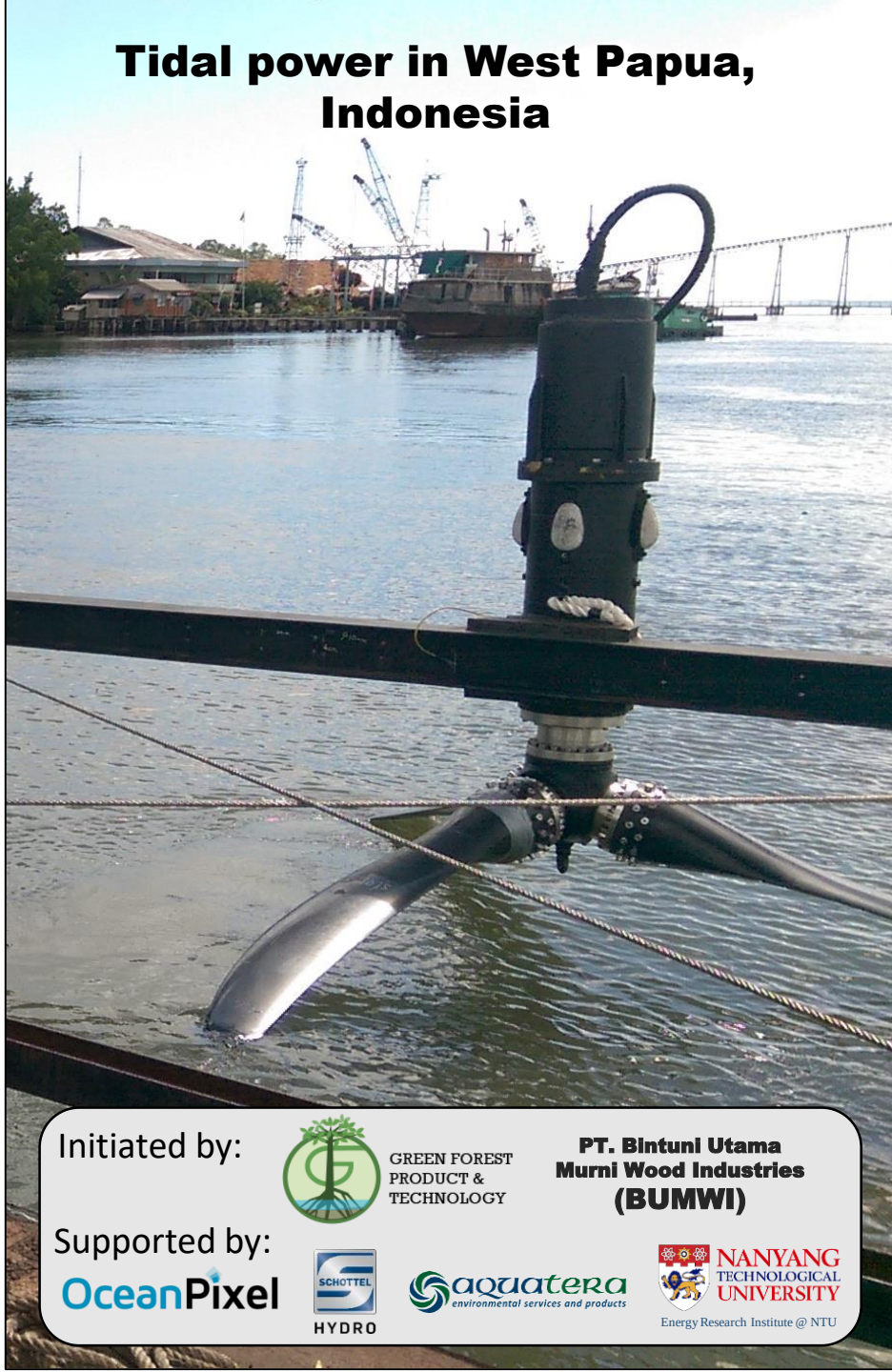
The installation of Schottel Hydro's 50kW turbine in West Papua is a significant step on the journey to use marine renewables to de-carbonise energy supplies across the region.

BUMWI's mangrove chipping operation in West Papua is the first of its kind to receive sustainability certification from the Forestry Stewardship Council (FSC®).

The carbon footprint of the plant is now set to be reduced by harnessing power from nearby tidal currents.



Tidal power in West Papua, Indonesia



Initiated by:

GREEN FOREST PRODUCT & TECHNOLOGY

PT. Bintuni Utama Murni Wood Industries (BUMWI)

Supported by:

OceanPixel

SCHOTTEL HYDRO

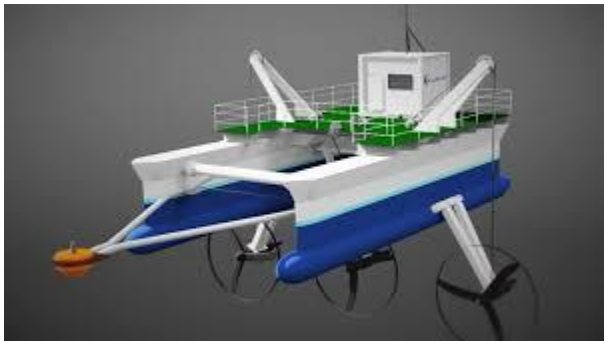
aquatera environmental services and products

NANYANG TECHNOLOGICAL UNIVERSITY

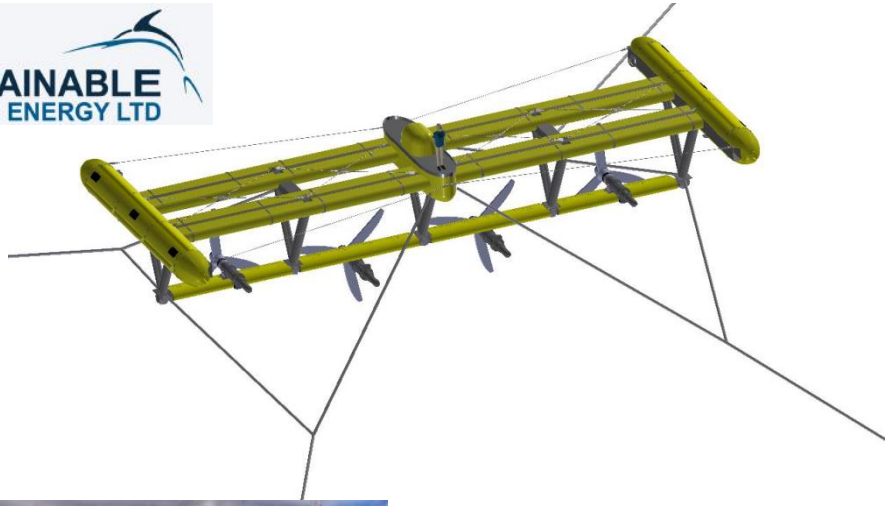
Energy Research Institute @ NTU

Floating Hybrid RE Platforms?

ALLSWATER



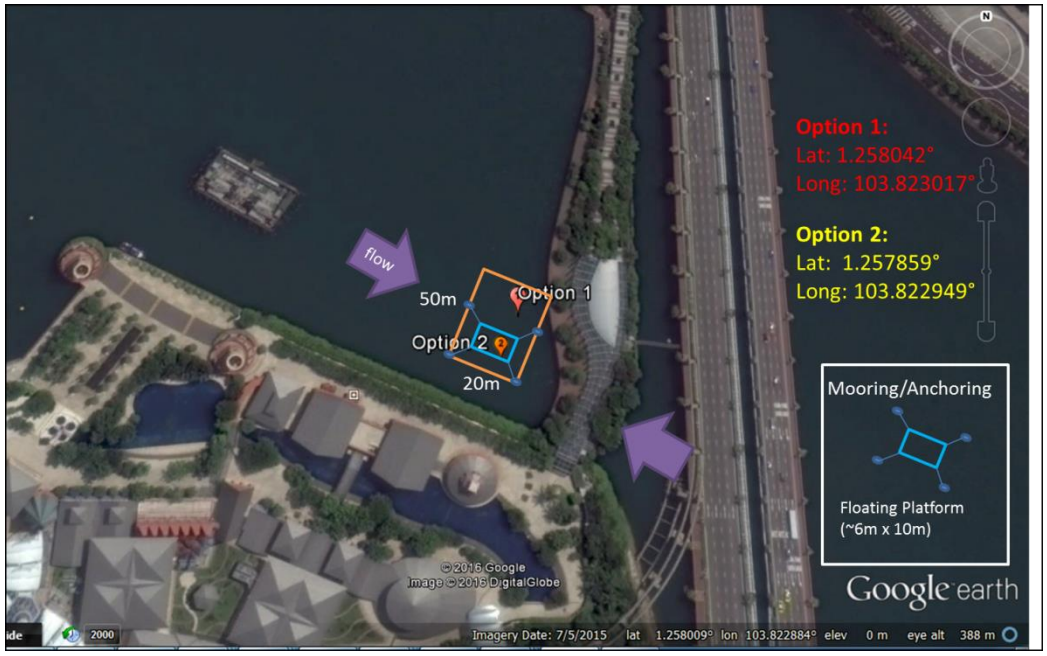
SUSTAINABLE MARINE ENERGY LTD

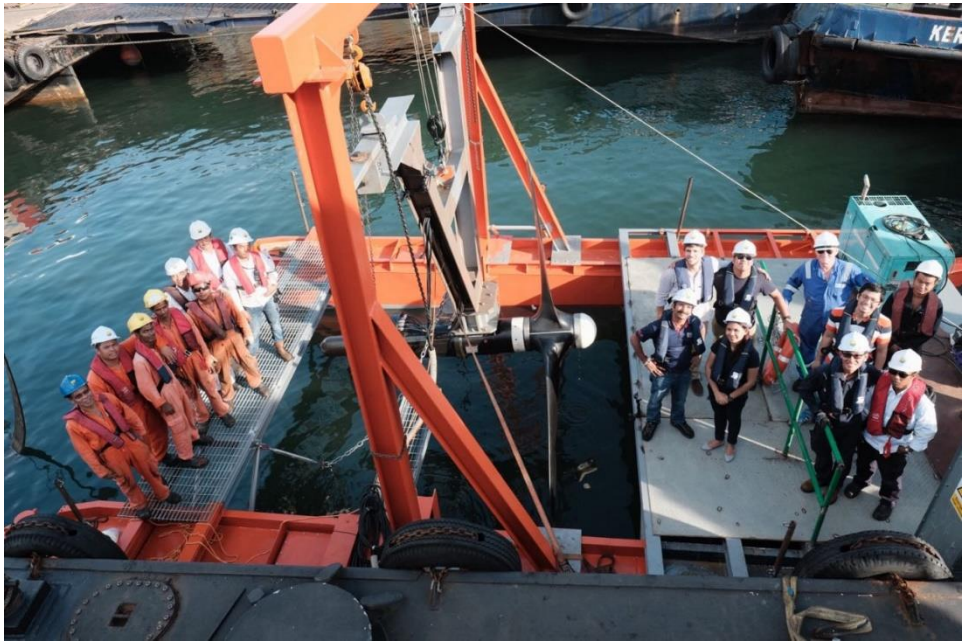


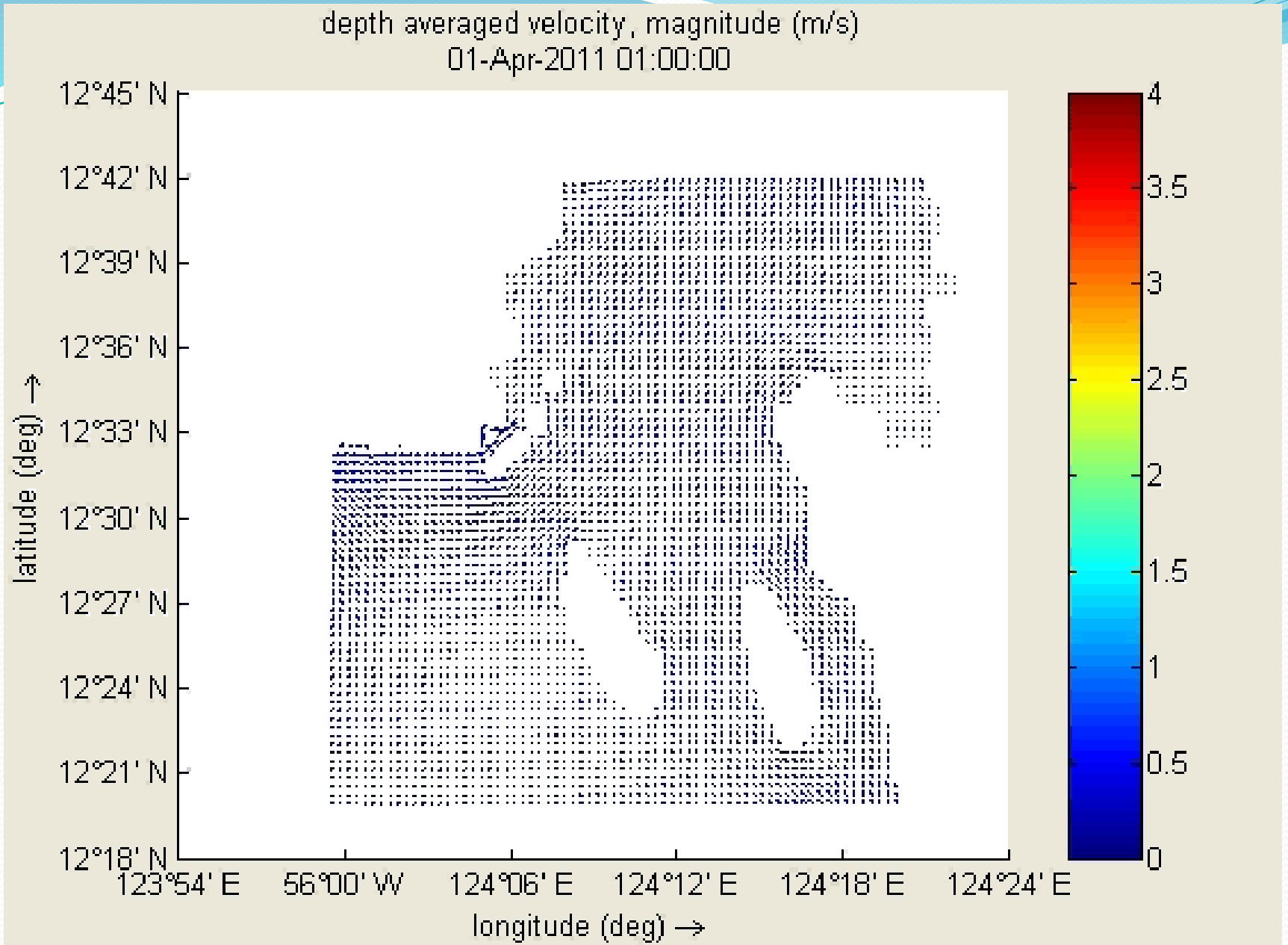
Title: TIDAL IN-STREAM ENERGY DEMONSTRATION IN SG (50kW)

Client: Envirotek Pte Ltd **Collaborators:** Schottel Hydro, OceanPixel, LitaOcean, Sentosa, Aquatera, Orcades Marine, ITP, Braemar Offshore

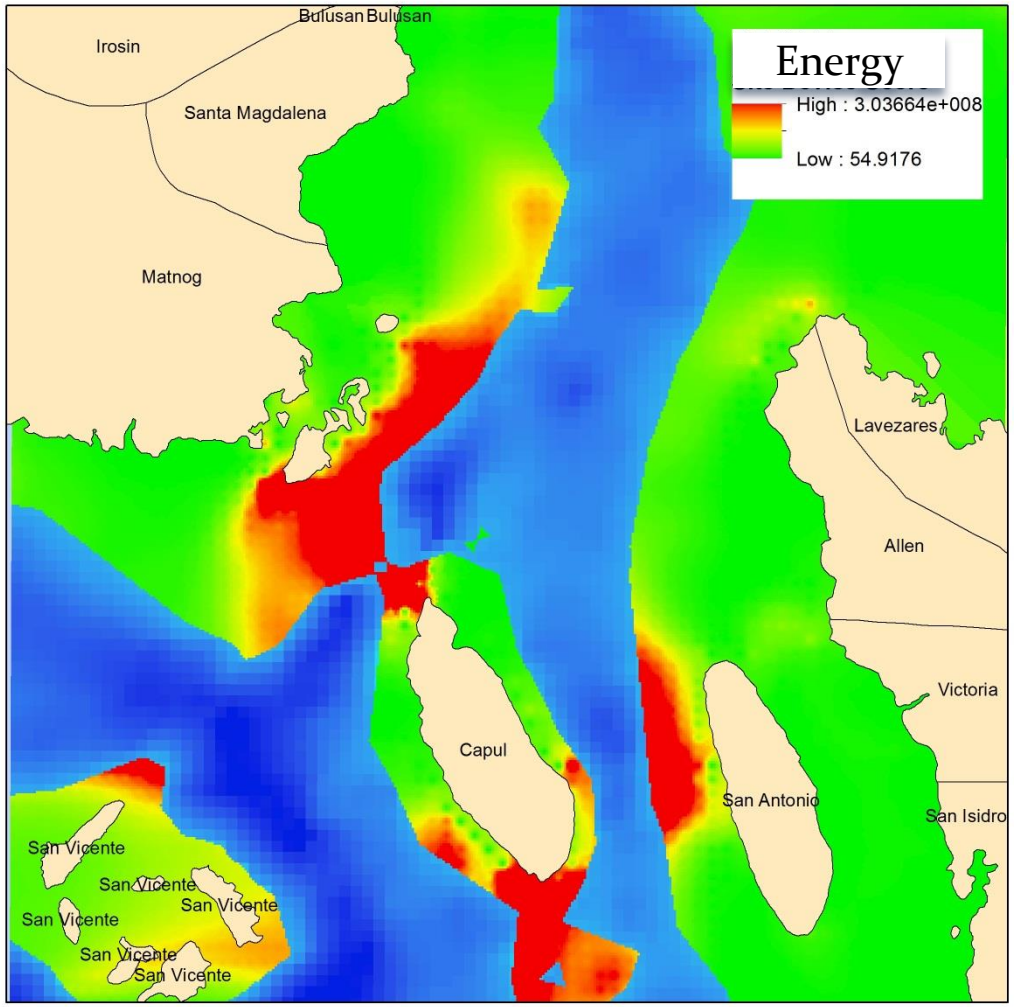
Start: November 2015 *Deployment: February 2017 End: -*

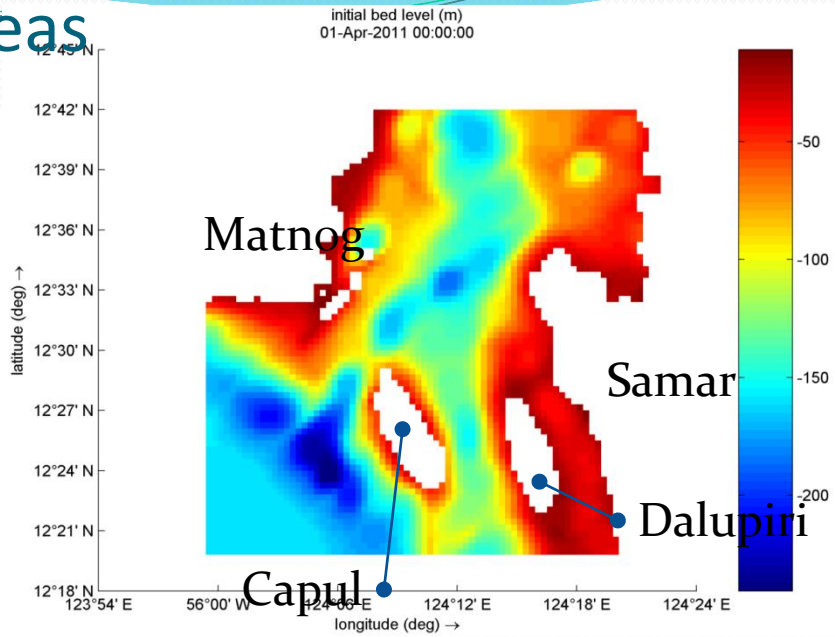


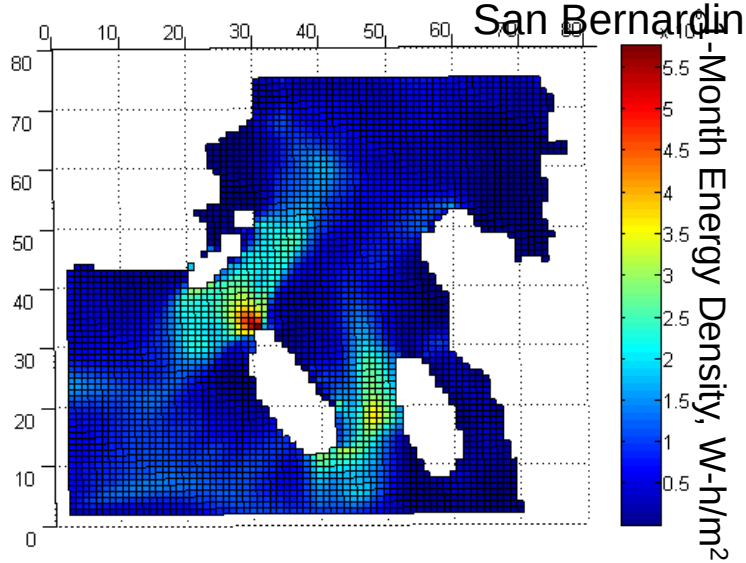



depth averaged velocity, magnitude (m/s)
01-Apr-2011 01:00:00
12°45' N
12°42' N
12°39' N
12°36' N
12°33' N
12°30' N
12°27' N
12°24' N
12°21' N
12°18' N
latitude (deg) →
123°54' E
56°00' W
124°06' E
124°12' E
124°18' E
124°24' E
longitude (deg) →
4
3.5
3
2.5
2
1.5
1
0.5
0

Potential Feasible Installation Areas (Applied Depth-Mask of <100m)





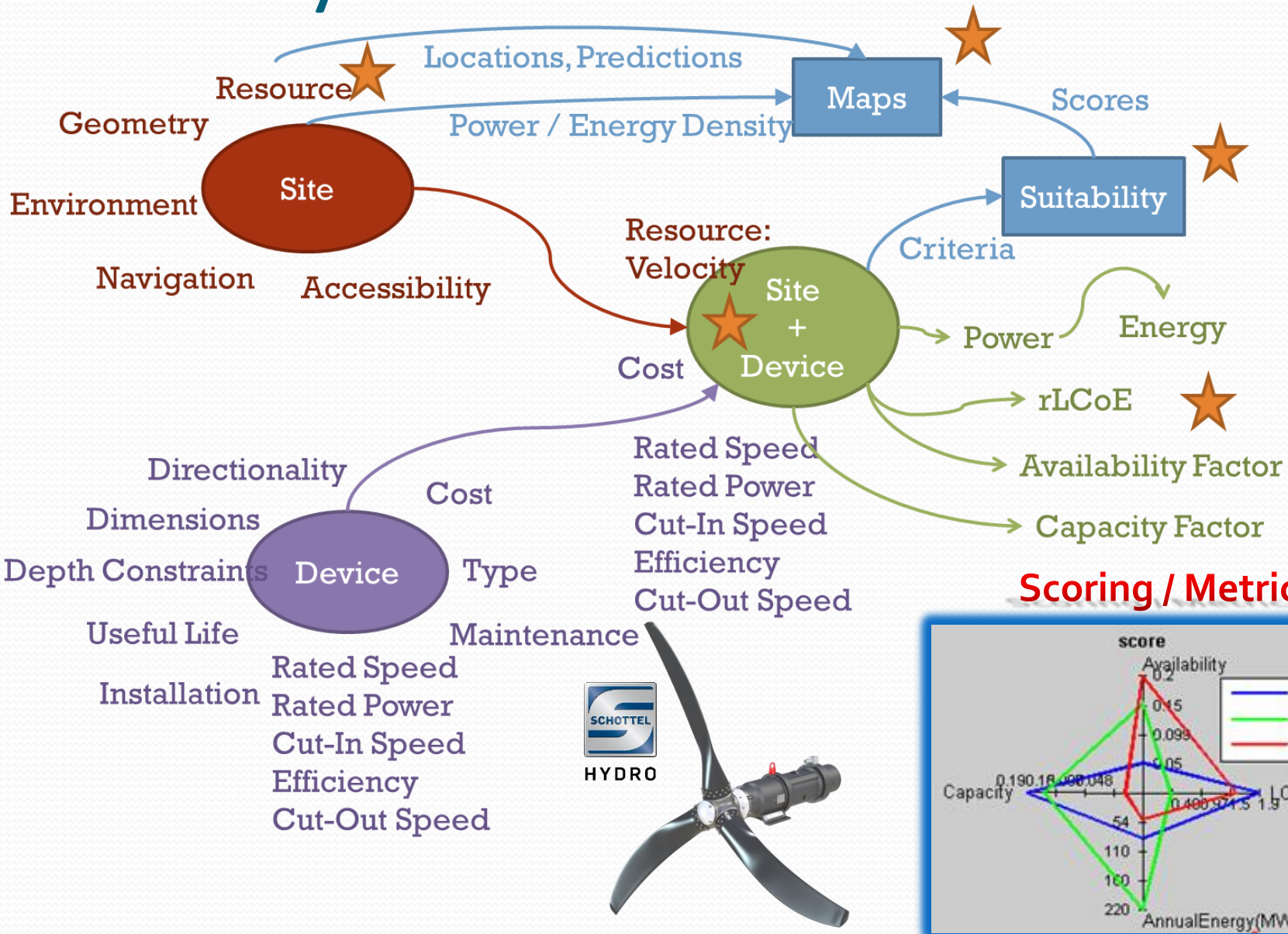


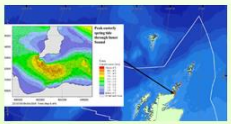
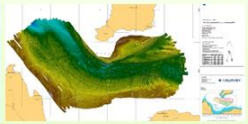
LCOE, IRR, Feed-in-Tariff

100 MW	Total Project (20-Years)					
	~USD 378M		~USD 560M		~USD 984M	
	CapEx = $ 233.2M	OpEx = $6.63M/yr	CapEx = $ 406.5M	OpEx = $6.63M/yr	CapEx = $ 810.2M	OpEx = $6.63M/yr
FIT (PhP/kWh)	USD 2M/ MW (LCOE = $ 0.11/kWh)		USD 4M/ MW (LCOE = $ 0.17/kWh)		USD 8M/MW (LCOE = $ 0.3/kWh)	
10	ROI = 95% Profit = ~USD 358M	IRR = 14% Payback = ~6.5 yrs	ROI = 32% Profit = ~USD 177M	IRR = 6% Payback = ~11 yrs		
13.5	ROI = 163% Profit = ~USD 616M	IRR = 21% Payback = ~5 yrs	ROI = 78% Profit = ~USD 434M	IRR = 11% Payback = ~7.6 yrs	ROI = 1% Profit = ~USD 9M	IRR = 3% Payback = ~16.2 yrs
17	ROI = 232% Profit = ~USD 873M	IRR = 28% Payback = ~3.5 yrs	ROI = 124% Profit = ~USD 691M	IRR = 15% Payback = ~6.3 yrs	ROI = 27% Profit = ~USD 267M	IRR = 5% Payback = ~12 yrs

200 MW	Total Project Cost (20-Years)					
	~USD 753.5M		~USD 1,117.3M		~USD 1,966.3M	
	CapEx = $ 465.3M	OpEx = $13.25M/yr	CapEx = $ 811.8M	OpEx = $13.25M/yr	CapEx = $ 1,620.3 M	OpEx = $13.25M/yr
FIT (PhP/kWh)	USD 2M/ MW (LCOE = $ 0.11/kWh)		USD 4M/ MW (LCOE = $ 0.17/kWh)		USD 8M/MW (LCOE = $ 0.3/kWh)	
10	ROI = 95% Profit = ~USD 718M	IRR = 14% Payback = ~6.5 yrs	ROI = 35% Profit = ~USD 354M	IRR = 6% Payback = ~11 yrs		
13.5	ROI = 164% Profit = ~USD 1,233M	IRR = 21% Payback = ~4.5 yrs	ROI = 78% Profit = ~USD 869M	IRR = 11% Payback = ~7.6 yrs	ROI = 1% Profit = ~USD 20M	IRR = 3% Payback = ~16.2 yrs
17	ROI = 232% Profit = ~USD 1,748M	IRR = 28% Payback = ~3.5 yrs	ROI = 124% Profit = ~USD 1,384M	IRR = 15% Payback = ~6.3 yrs	ROI = 27% Profit = ~USD 535M	IRR = 5% Payback = ~12 yrs

Suitability: Sites and Devices



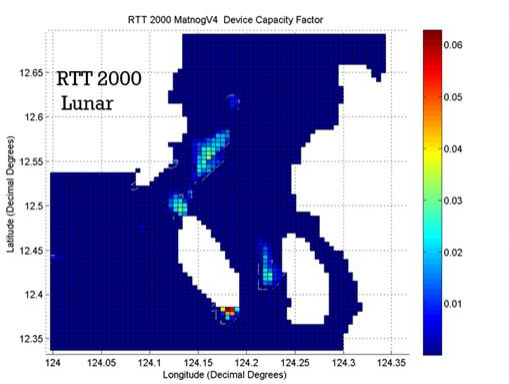




OceanPixel

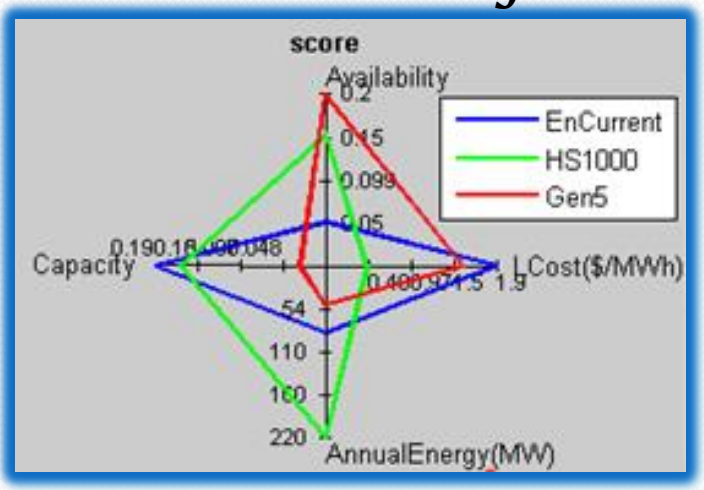
Data Analytics, Intelligence, Suitability, Decision Support

Multi-Site, Multi-Device, Multi-Criteria Geographic Information System

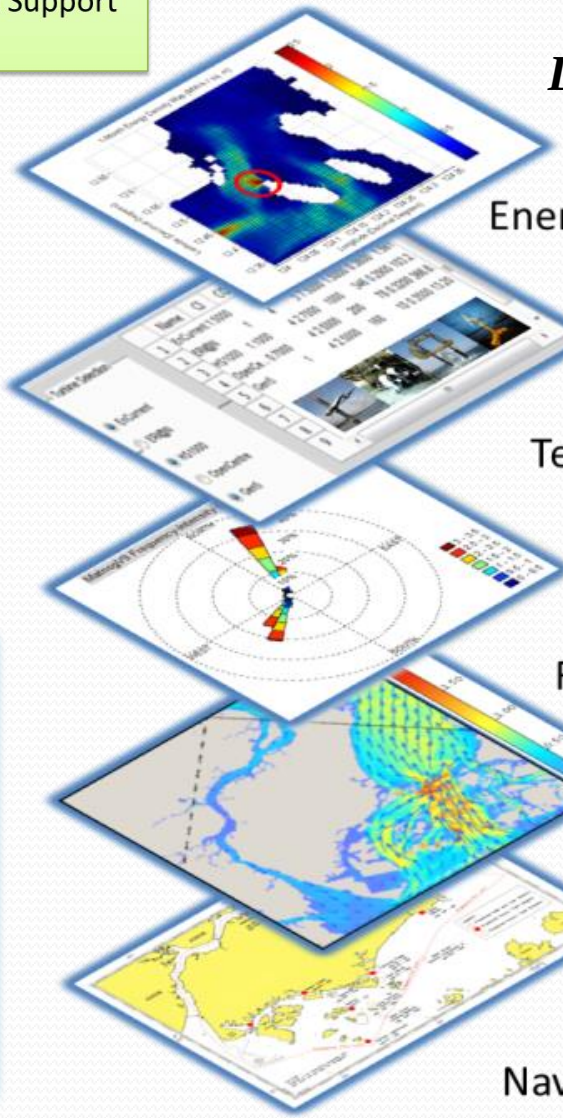
Suitability Maps



Multi-Metric Scoring Tools



Data Analytics



Energy Density

Project Dev't Planning

Environmental Scores

Technology Library

Distance-to-Shore

Resource Analysis

Cost Ranging

Resource Data

Decision Support Maps

Navigation & Shipping Considerations

Summary / Conclusions

- There are Marine Renewable Energy Resources in SEA
- Unique ecosystem in SEA will (hopefully) increase the uptake of marine renewables in the region
- Need for actual projects beyond R&D in SEA…
- Project Pathways may take different forms: from community-scale to commercial grid-connected projects.
- Progressive Development of Sites (Phased Approach) seems to be an attractive strategy for developers

Thank you.

OceanPixel
Fluid. Intelligence.

mike@oceanpixel.org
+65 9066 3584

Unit #02-15 CleanTech One Bldg.
1 CleanTech Loop,
Singapore 637141

aquatera
environmental services and products

DHI

itp

SCHOTTEL HYDRO

ALBATERN
Wave Energy

NANYANG TECHNOLOGICAL UNIVERSITY
Energy Research Institute @ NTU

seacore
southeast asian collaboration for ocean renewable energy