Marine Renewable Energy:
Enabling Green Marine and Maritime Ecosystems Towards a Sustainable Blue Economy

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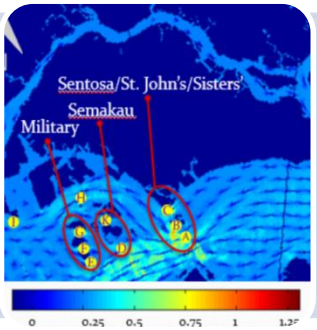
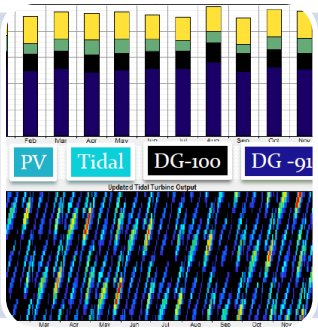
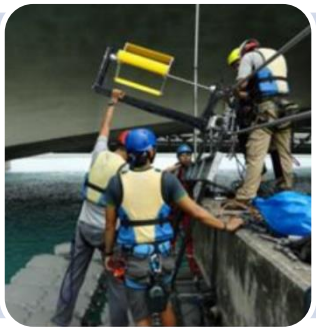
fluid . energy . intelligence

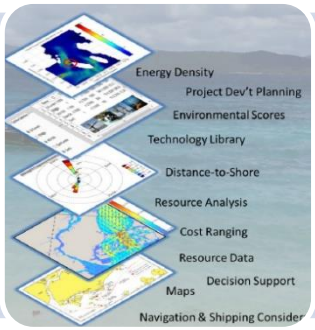
Making Marine Renewable Energy a Reality!

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









Resource assessment

Collects preliminary data via independent surveys, or oversee Licensed Surveyors to collect data for marine energy resource assessment.

Project Intelligence

In-house team of hydrodynamists to carry out quality checks, simulation, processing and analysis of data.

Project management

Provides project management services for project developers, from pre-feasibility studies to resource assessments, techno-economic studies, planning and execution of deployment or installation operations.

Research and Development

Manages performance assessment campaigns or plan and execute tests for technology developers. These tests may be long-term tests at a specific site, or in other forms like tow tests.

Report Product

Produces report products, which informs project developers regarding feasibility of project development in numerous sites of interest.

Oceans - Their Significance

Around 70.8% of Earth's surface -> 361, 254,000km^2.

Produces more than 70% of the oxygen on Earth.

40% of the world's population live within 100km of an oceanic coast.

10% of the world's population depend on fishing for livelihood.

Makings of Sustainable Marine Ecosystems

- Minimal greenhouse gas footprint of various activities in the marine space
- Efficient and sustainable use of marine space and resources through improved planning, engineering and operations
- Strive for minimal impact on marine environment by human activities
- Continued monitoring and regulating of interactions between human activities and the environment

Through What Means?

DECREASE RELIANCE ON FOSSIL FUEL

GREEN ENERGY PRODUCTION

RESOURCE AND WASTE MANAGEMENT

FORWARD THINKING INFRASTRUCTURES AND TECHNOLOGIES

REGULATIONS OF MARINE ACTIVITIES

CONSERVATION AND WILDLIFE PROTECTION AREAS

PROTECTION AGAINST INVASIVE SPECIES

EDUCATION AND INCREASE AWARENESS

Electrification: More than just electricity supply

- Electrification of Transportation
- Electrification of Vessels
- Electrification of Ports
- Automation of Processes
- Energy Storage Systems
- Aquaculture Applications
- Water Production (e.g. Desalination)
- Ice Making
- Others?

Sustainable Integrated Development for Islands & Coasts

Aquaculture & Fisheries

Green Transport – Sea and Land

Green Maritime Ecosystem – Ports, Vessels, Aquaculture, Desalination, Water, Ice/Cooling ++

Renewable Energy + Green Transport
+ Aquaculture + Water Production
+ Freezing/Cooling + Local Content
+ Other Sustainable Initiatives

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Marine Renewable Energy

*"Renewable energy production which makes use of marine resources or marine space."**

*European Science Foundation

- Offshore Wind
- Floating Solar
- Marine biomass (micro- and macro-algae)

Ocean Renewable Energy

- Currents (Ocean Current, Tidal Currents/In-Stream)
- Tides (Tidal Range)
- Waves
- Salinity / Osmotic Gradient
- Thermal Gradient

Ocean Renewable Energy

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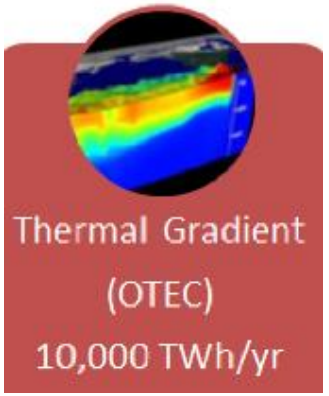
5 Ocean Renewable Energy Resources*

- **Ocean Current / Tidal In-Stream** energy is harvested by Current/Hydrokinetic turbines placed underwater where fast-flowing currents turn the generator blades similar to what wind does with wind turbines.
- **Tides (Tidal Range)** Tidal Barrages utilize the potential energy from the difference in height between high and low tides.
- **Wave** energy is produced from the surface motion of ocean waves or from pressure fluctuations below the surface.
- **Ocean Thermal** energy conversion (OTEC) uses the temperature difference between the surface seawaters (warm) and the deep seawaters (cool) to drive a heat engine to produce electricity.
- **Salinity Gradient** power is the available energy (or chemical potential) from the differences in salt concentration between the fresh water and seawater.



*IEA-OES

Marine Renewable Energy:
Technology Readiness

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Marine Floating Solar | Offshore Wind

Salinity Gradient
A handful of university-based research projects have been conducted, as well as small-scale system operation

Deep Ocean Current
Very few active concepts being developed; laboratory-scale tank testing has occurred

OTEC
A few test facilities (mostly pilot-scale) trialed, but no long-term operation

Wave Energy Converters
Full-scale prototypes being tested. Many leading WEC designs have remained at this stage for some time

Tidal Stream
Leading developers testing individual prototypes in locations representative of potential commercial sites, generating grid-connected electricity. Demonstration in arrays still lacking

Tidal Range
Most mature of the ocean energy technologies, with a proven track record stretching back to the 1960s but limited deployment to date

Technology Readiness Level (TRL)	1	2	3	4	5	6	7	8	9
	Basic principles observed and reported	Technology concept and/or application formulated	Analytical and experimental critical function and/or proof of concept	Technology (system or components) validated in a laboratory experiment	Laboratory scale, with similar system validation in a realistic working environment	Engineering/ pilot-scale, with prototype system or model demonstrated in an actual working environment	Full scale or prototype technology demonstration in an actual working environment	Actual system completed and qualified ready for deployment through test and demonstration	Technology operational, over full range of expected lifetime conditions

Source: IRENA

Increasing Maturity

Global Initiatives

OCEAN ENERGY SYSTEMS

EMEC ORKNEY
The European Marine Energy Centre Ltd

FORCE
Fundy Ocean Research Center for Energy

NETHERLANDS		
RESOURCE	INSTALLED CAPACITY (kW)	CONSENTED PROJECTS (kW)
Wave Power		
Tidal Currents	130	3000
Salinity Gradient	50	

UK		
RESOURCE	INSTALLED CAPACITY (kW)	CONSENTED PROJECTS (kW)
Wave Power	3730	40000
Tidal Currents	5600	96000

CANADA		
RESOURCE	INSTALLED CAPACITY (kW)	CONSENTED PROJECTS (kW)
Tidal Currents		20450
Tidal Power	20000	

SWEDEN		
RESOURCE	INSTALLED CAPACITY (kW)	CONSENTED PROJECTS (kW)
Wave Power	180	10400-10600
Tidal and Ocean Currents	7.5	

DENMARK		
RESOURCE	INSTALLED CAPACITY (kW)	CONSENTED PROJECTS (kW)
Wave Power		115

BELGIUM		
RESOURCE	INSTALLED CAPACITY (kW)	CONSENTED PROJECTS (kW)
Wave Power		Up to 20000

NORWAY		
RESOURCE	INSTALLED CAPACITY (kW)	CONSENTED PROJECTS (kW)
Wave Power	200	

CHINA		
RESOURCE	INSTALLED CAPACITY (kW)	CONSENTED PROJECTS (kW)
Wave Power	350	2860
Tidal Currents	170	4500
Tidal Power	3900	200

USA		
RESOURCE	INSTALLED CAPACITY (kW)	CONSENTED PROJECTS (kW)
Wave Power		1365
Tidal Currents		1350

REPUBLIC OF KOREA		
RESOURCE	INSTALLED CAPACITY (kW)	CONSENTED PROJECTS (kW)
Wave Power	500	300
Tidal Currents	1000	1300
Tidal Power	1000	1300
OTEC	220	1000

PORTUGAL		
RESOURCE	INSTALLED CAPACITY (kW)	CONSENTED PROJECTS (kW)
Wave Power	700	

SPAIN		
RESOURCE	INSTALLED CAPACITY (kW)	CONSENTED PROJECTS (kW)
Wave Power	296	300

ASEAN CENTRE FOR ENERGY · ACE ·

SINGAPORE		
RESOURCE	INSTALLED CAPACITY (kW)	CONSENTED PROJECTS (kW)
Wave Power	16	
Tidal and Ocean Currents		2.5

>1,000 Sites
200MW each

openhydro
a DCNS company

MEYGEN

ATLANTIS RESOURCES

LOCKHEED MARTIN

seacore
southeast asian collaboration for ocean renewable energy

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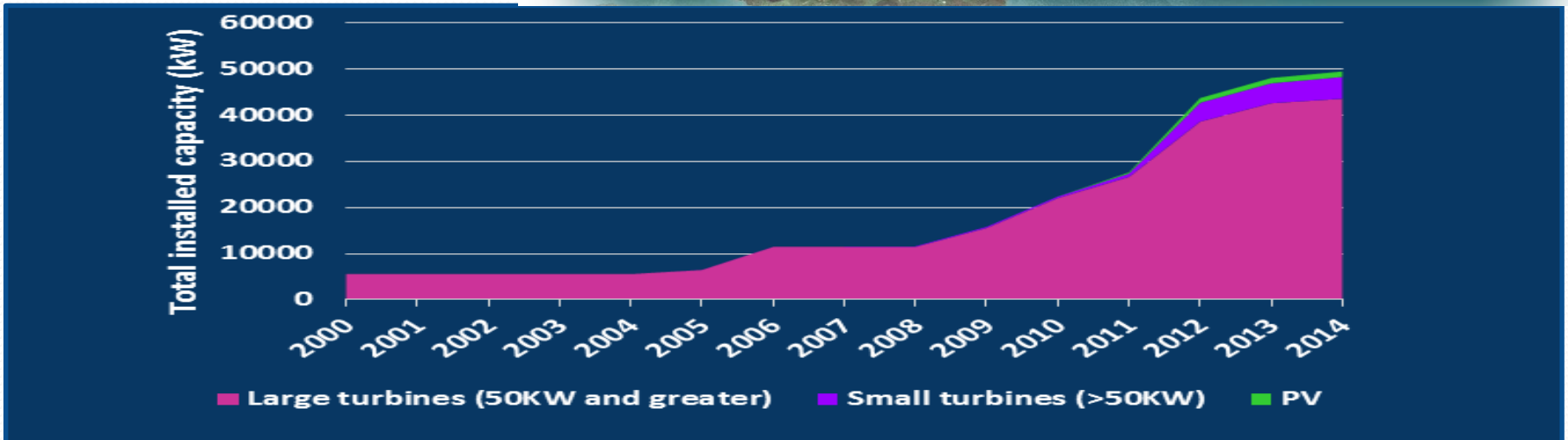
Sustainable Energy – Islands Example

Total = > 5,000 MW deliverable capacity

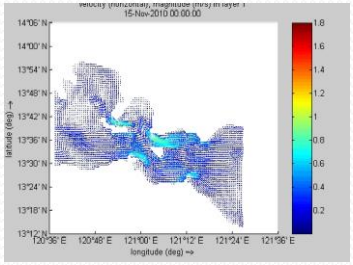
Key		
Onshore wind	40 MW existing/planned	
New onshore wind	100-200 MW	
Wave	500-1000 MW	
Tidal	500-2,500 MW	
Offshore wind	1000 MW	
Wave leases	550 MW	
Tidal leases	500 MW	
Mirco & other	2.5 MW	
Gas & other	20 MW	Dispersed
EMEC sites	5 + 7 MW	Dispersed and

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



Developing Countries' Initiatives

Simulation Studies

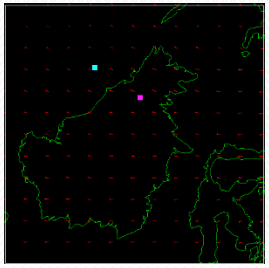


Myanmar
Tidal Barrage

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)

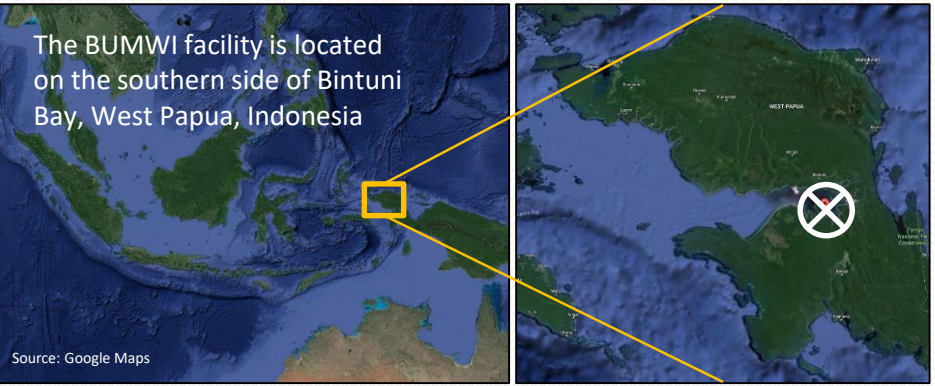
Philippines
Tidal Barrage

Singapore
Tidal Turbine Testing

Source: SEAcORE 2013

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

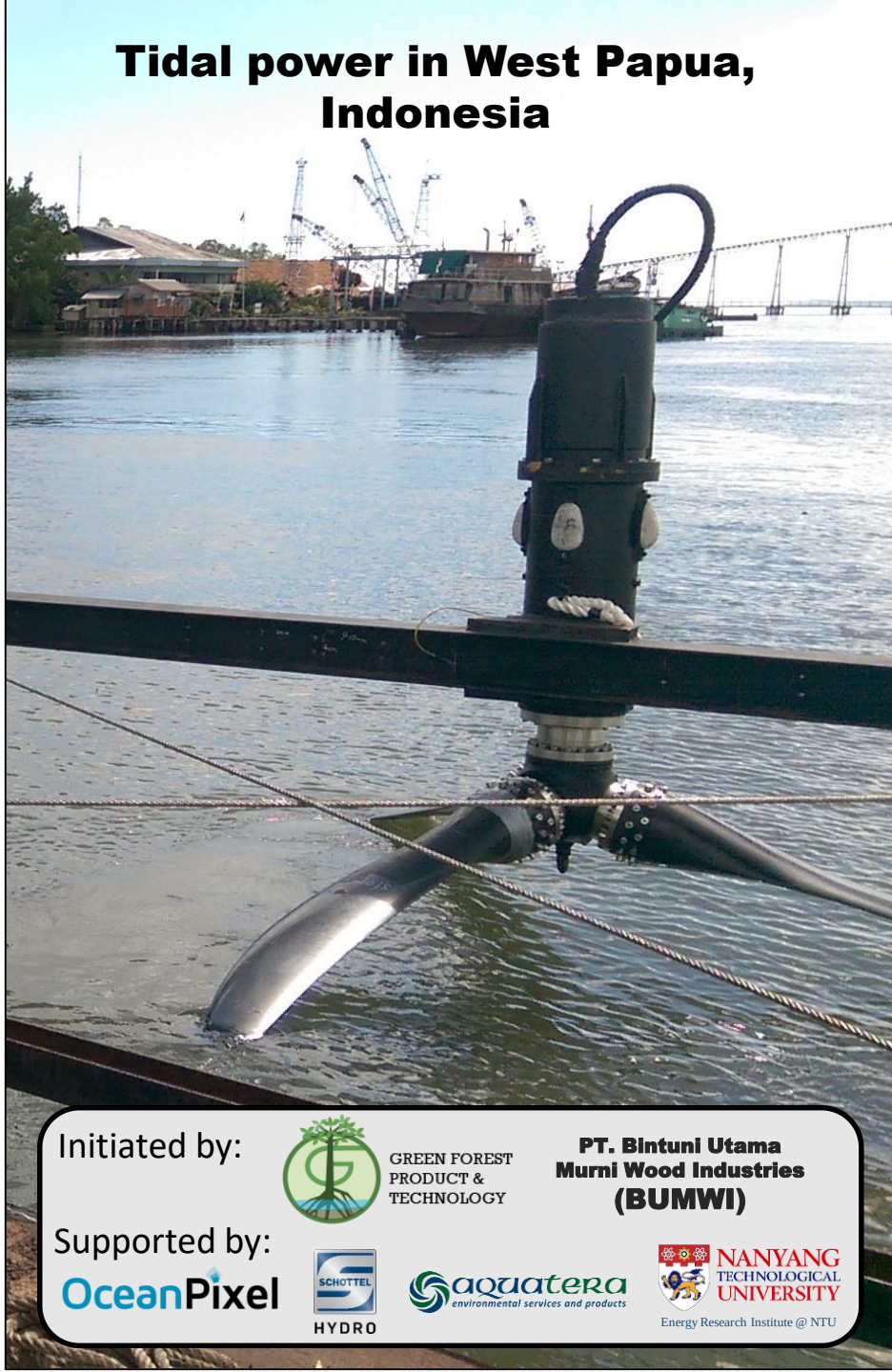
The carbon footprint of the plant is now set to be reduced by harnessing power from nearby tidal currents.



The BUMWI facility is located on the southern side of Bintuni Bay, West Papua, Indonesia

Source: Google Maps

Tidal power in West Papua, Indonesia



Initiated by:

GREEN FOREST PRODUCT & TECHNOLOGY

PT. Bintuni Utama Murni Wood Industries (BUMWI)

Supported by:

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SCHOTTEL HYDRO

aquatera environmental services and products

NANYANG TECHNOLOGICAL UNIVERSITY

Energy Research Institute @ NTU

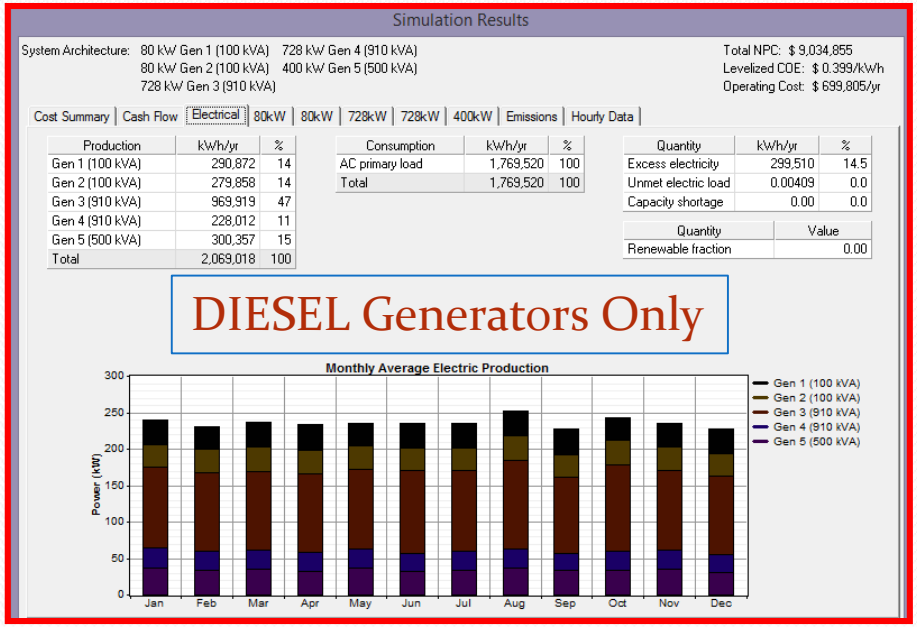
The project approach combines appropriate technology with local content and know-how.

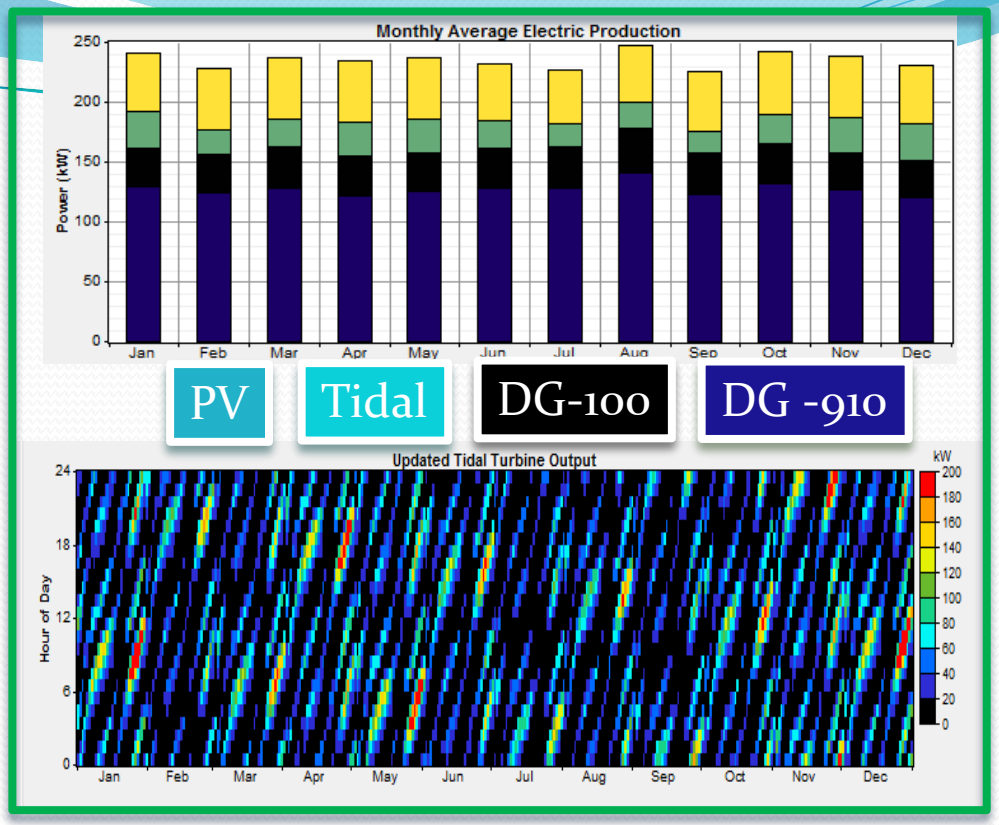
The tidal turbine is suspended below a floating barge in a simple and robust arrangement which allows for straightforward inspection and maintenance and can be easily replicated.

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.

Case Study: Hybrid System for an Island Micro-Grids

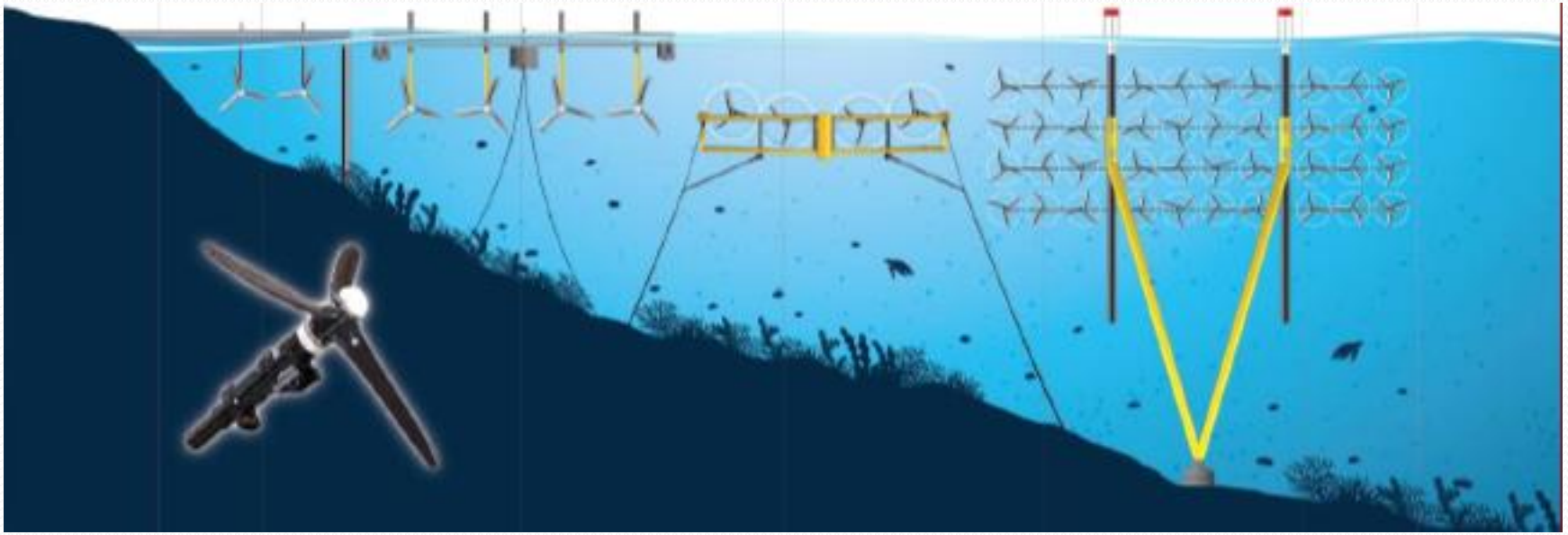




Power System Config.	RE Fraction	Excess Electricity	LCOE (USD/kWh)
Diesel GenSets (910, 100 kVA) + Batt (576kWh) + Solar (300kWp) + Tidal (200kWp)	**31.6%**	**12.6%**	**0.368**
Diesel GenSets (910kVA, 100 kVA) + Batt (720kWh) + Solar (600kWp)	38.6%	20.1%	0.386
Diesel GenSets (910kVA, 100 kVA)+Batt.(1440kWh)	0.0 %	2.47%	0.456
Diesel GenSets (2x 910, 500, 100 kVA)	0.0 %	14.5%	**0.50**

Ocean Energy - Configuration Options

(Tidal In-Stream Energy Device example)



- Jetty-based / fixed structure (e.g. bridges)
- Floating
- Submerged (neutrally-buoyant)
- Seabed-mounted
- Others? – Vessel-mounted?

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Hybridized Marine RE Pathway

Off-Grid and Co-App Market → Grid-Connected Project Dev't (Progressive Dev't) → Large Scale Commercial Grid-Tied Projects

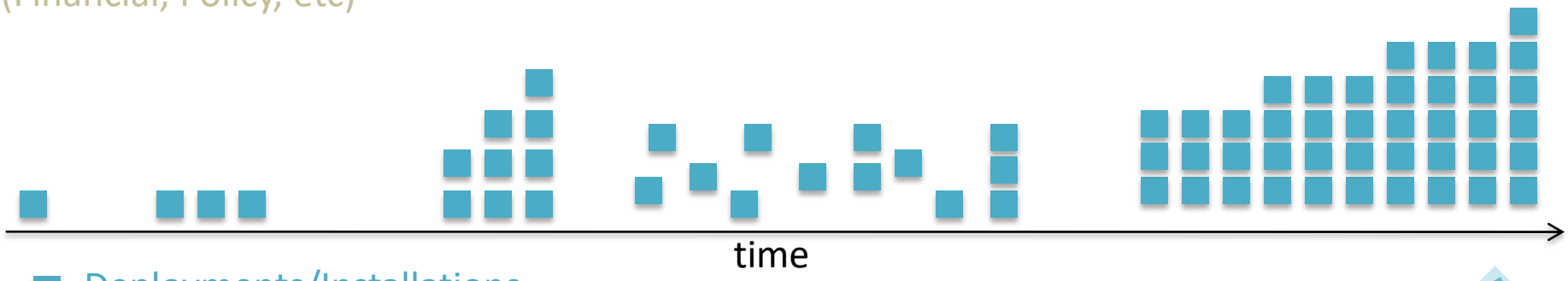
Scoping
Strategic Planning
Scouting

[1-3 years]

Small Scale Pilot (Off-Grid and Micro-grid) → Increase Pilot Capacity (Progressive Dev't) → [3-5 years] → Large Scale Grid-Connected and Other Islands' Micro-Grid Projects

Capability Development
Support Mechanisms
(Financial, Policy, etc)

Outer Islands' Projects



Deployments/Installations

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Building the a Sustainable Future Blue Economy

Long-Term Sustainability
Global Competitiveness
New Products & Services

>$150M in the next 5 years
Inward Investment

Coordination
Alignment
Capability Dev't
Synergy

Offshore
Marine
Maritime
Logistics
Clean Tech
Energy
Intelligence

Enriched
Regional
Ecosystem

Marine &
Maritime
Sustainability
Hub Stage

Seed stage

Various Efforts
Agencies
R&D
Pilots
Network
SMEs
Industries

Potential Pilot Projects





Ocean/Marine Renewable Energy, Floating Solar

Energy Systems Integration

Energy Storage

Testbedding
Other Innovations
Technologies
Business Models
"Learn by Doing"

Transportation

Ports/Marinas/Bays

Ice

Water Production

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Key Take Away Points

- Marine Renewable Energy is coming up.
  - *Tidal/wave energy are potential options, typically hybrid with solar energy, storage and diesel are the way to go*
- Having Market Supports (e.g. Feed-in-Tariff)can accelerate the progress of Marine RE
  - *Pilot, Demos, First movers are needed.*
- Clean Electricity (from the Ocean) is just one aspect, there are also jobs, industries, and other benefits

Summary / Conclusions / Recommendations

- **Marine Renewable Energy Options Exist**
  - Floating Solar, Offshore Wind (can be feasible)
  - Waves and Currents, maybe OTEC and Salinity Gradient
  - Need for a Resource Inventory Review and Suitability Studies for Pilot Projects

- **Green Marine and Maritime Ecosystem**
  - Lower Hanging Fruits – Green Vessels, Green Ports
  - Electrification of a Suite of Applications – Transport, Aquaculture, Food, Water
  - Detailed planning of a Sustainable Integrated Development for Islands and Coasts

- **Progressive Development Approach Towards a Blue Economy**
  - Leverage the Marine/Maritime Ecosystem of the Country/Region(s)
  - Capability Development – Local Supply Chain (especially Services)
  - Demonstration and Pilot Projects can accelerate the uptake
  - Hybrid Systems and Co-Application will be key to success

Realising Marine Renewable Energy Opportunities in the Region

- Strategic Marine Renewable Energy Resource Assessment
- Marine Spatial Planning
- Pilot Projects and Demonstrations
- Industry Development Roadmap
- Survey of Current Human and Resource Capabilities
- Outreach and Awareness Program

Thank You! ☺

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