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Marine Investment in the Blue Economy

Horizon 2020 Coordination and Support Action Project

The Maribe combinations

Mike Blanch, BVG Associates, Associate Director / Operations Director / lead on Financial Modelling and offshore wind

and …

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…other Maribe partners

- Gordon Dalton and Eoin Moynihan, University College Cork
- Ian Masters and Dimitris Pletsas, Swansea University
- Sander Van den Burg, Wageningen Research (formerly Stichting Dienst Landbouwkundig Onderzoek (DLO))
- Kate Johnson, Heriot Watt University (ICIT)
- Pedro Diaz, Universidad de Cantabria
- Roland Wijnen, Business Models Inc.

… and especially the companies described

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Socio-economic impact of combinations

- Combinations ONLY not actual projects so **pre-company involvement**
- Trade-off between IRR, and jobs and gross value added (GVA)
- Best IRR project likely to have least jobs (depending on proportion of spend that goes on labour)
- Forecast jobs and GVA might be great for a specific project but if project is too expensive it will not happen so has zero socioeconomic benefit
- Too early stage to predict jobs and GVA – we would do this as part of Environmental Impact Assessments as part of consenting

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Parameter categories

- Socio-economic
- Other barriers
- Revenue opportunity
- Growth drivers
- Supply competition

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Parameters marked

- Up to 33 marked
- High level
- No weightings
- Parameters marked as whether the combination:

1	Disadvantageous
2	Neutral
3	Advantagous

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Results

- All advantageous overall as average score > 2.00
- Order by average score:

Sector that determines sizing	Other Sector	Number of parameters marked	Number of parameters with disadvantageous marks	Fraction of parameters with disadvantageous marks	Average score	Rank on average score
Floating Offshore Wind	Desalination	33	2	6%	2.39	1
Fixed Offshore Wind	Aquaculture	31	3	10%	2.39	2
Floating Offshore Wind	Wave	33	3	9%	2.36	3
Floating Shipping Terminal	Aquaculture	31	1	3%	2.29	4
Floating Offshore Wind	Aquaculture	31	2	6%	2.26	6
Aquaculture	Wave	33	1	3%	2.27	5
Floating Shipping Terminal	Wave	33	3	9%	2.15	7

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- Disadvantageous factors may be highly significant going forward
- There is a handout for the indicators with disadvantageous marks for discussion later.

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9 specific projects

- Now considering specific projects with companies
- All 9 include energy generation
- 2 include fixed foundation wind
- 3 include floating foundation wind
- 5 include wave
- 1 includes future provision for Ocean Thermal Energy Conversion (OTEC) once it is proven

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MUP/MUS	Sector 1	Sector 2	Company 1	Company 2	Basin
MUS	Fixed Offshore Wind	Aquaculture	Maribe Combo (from MERMAID)		Baltic and North Sea
MUP	Floating Offshore Wind	Wave	JJ Campbells		Atlantic
MUP	Floating Offshore Wind	Wave	Floating Power Plant		Atlantic
MUS	Floating Offshore Wind	Aquaculture	ACS	Besmar	Atlantic
MUP	Floating Offshore Wind	Desalination	EcoWindWater		Mediteranean
MUP/MUS	Floating Shipping Terminal	Aquaculture	Grand Port Maritime de Guyane		Caribbean
MUP	Floating Shipping Terminal	Wave	Float Inc.		Atlantic
MUS	Wave	Aquaculture	Wave Dragon	Seaweed Energy Solutions & BELLONA	Atlantic
MUS	Aquaculture	Wave	AquaBioTech	Albatern	Mediteranean

- Listed and described below in no particular order

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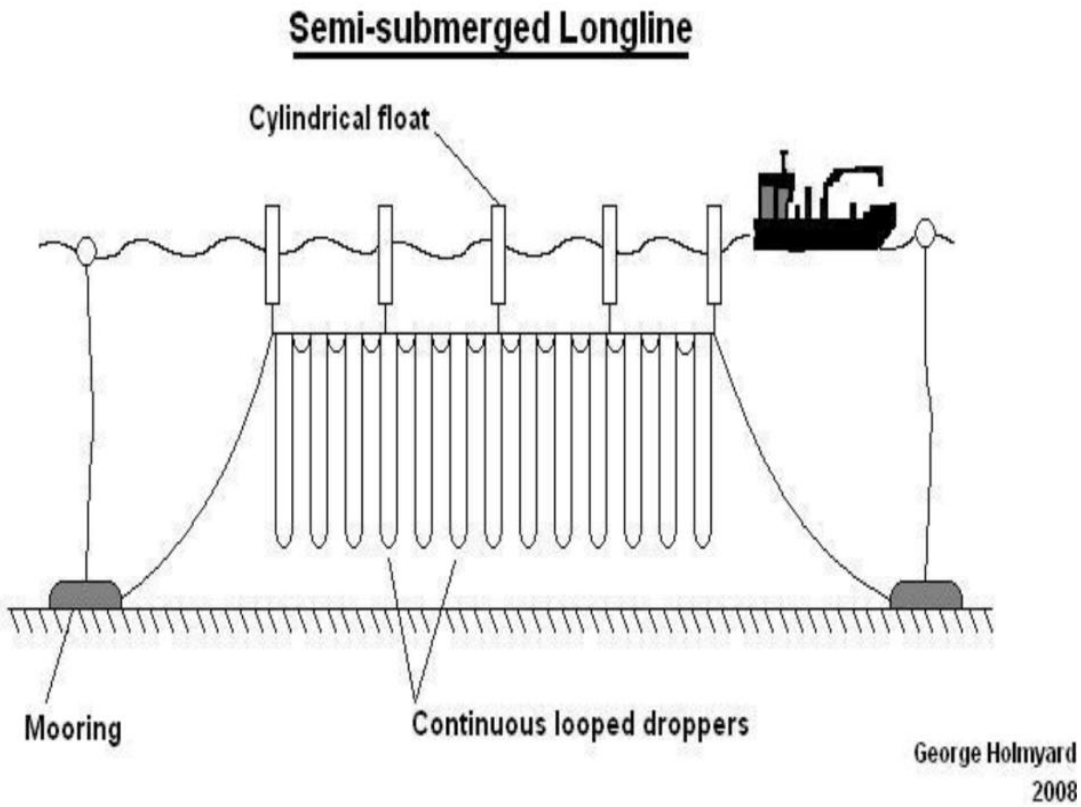
AQUACULTURE + FIXED OFFSHORE WIND

1. Mussel farming and offshore wind

- Multi-use of space – structures are separate allowing access to turbines
- Considered feasibility for Dutch Borssele wind farm
  - Development of wind farm is a given, with fixed structures
  - Water depth between 15m and 35m
- Double long lines (continuous) attached to anchors
- Annual production target for mussels: 5.5 million kg of mussel seed



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AQUACULTURE + FIXED OFFSHORE WIND

- Recently closed tender for Borssele wind farm had option for multi-use of space. Likely to be more common requirement in the future.
- Adding mussel aquaculture is likely to increased returns despite the small CAPEX compared with the wind farm
- Conventional mussel farming has declined in yields – potential reinvigorated by this action to farm mussels. Proven technology for mussel seed collection. Mussels are responsible for much biofouling in area.
- Mussel longlines will act to damp sea – may give improved access to (some) turbines
- Additional risks are expected to be limited making it more likely that wind farm developers will be willing to accommodate such multi-use

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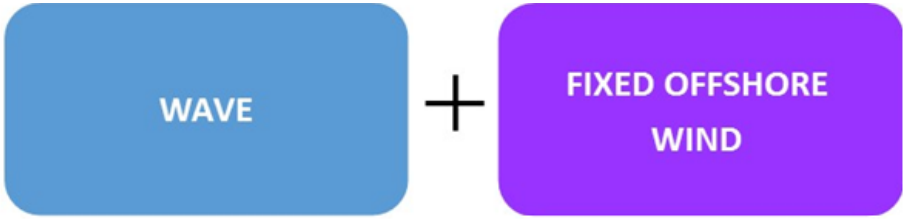

2. JJ Campbell & Associates CúNaMara wind and wave platform

- The CúNaMara platform combines wind and wave energy generation technologies, comprising 8 MW of wind and 16 MW of wave
- Further potential uses include photovoltaic power, aquaculture and others
- Preferred location off West coast of Europe in depths of up to 100 metres
- At a typical site, the platform will produce 77.5 GWh per annum, equivalent to the electrical consumption of 21,000 typical homes

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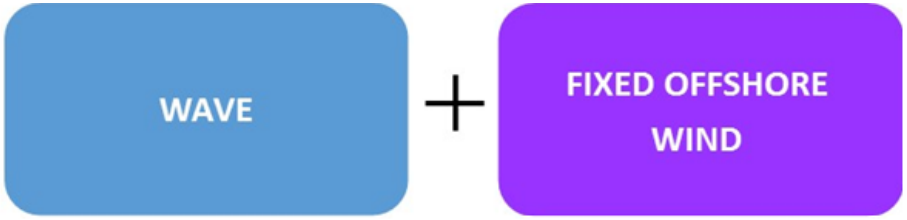

CúNaMara wind and wave platform

- Oscillating Wave Colum (OWC) technology is a proven method of converting wave energy to electricity
- Floating platform allows electricity generation in greater water depths
- The modular nature of the platform allows the platform hull to be constructed onshore
- Concrete hull construction used as more cost effective compared to steel construction
- Having two renewable energy technologies on one platform allows for aggregation of wind and wave resources to provide smoother power delivery to grid

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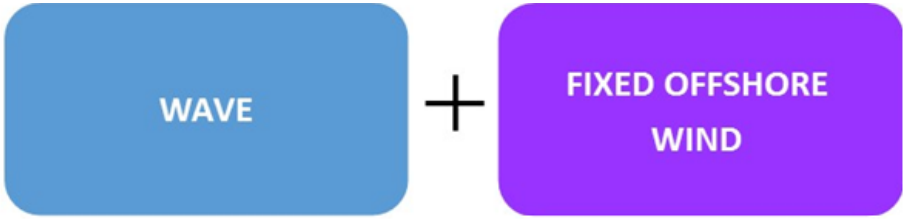

CúNaMara wind and wave platform

- Next stage: further tank testing leading to 1:4 sea trials
- Third Phase Commercial farm rated at 480 MW farm and comprising 20 MUPs
- Levelised cost of energy for third phase commercial farm currently predicted to be 178 €/MWh assuming WACC 8.9%. Recognise LCOE needs to be much lower.

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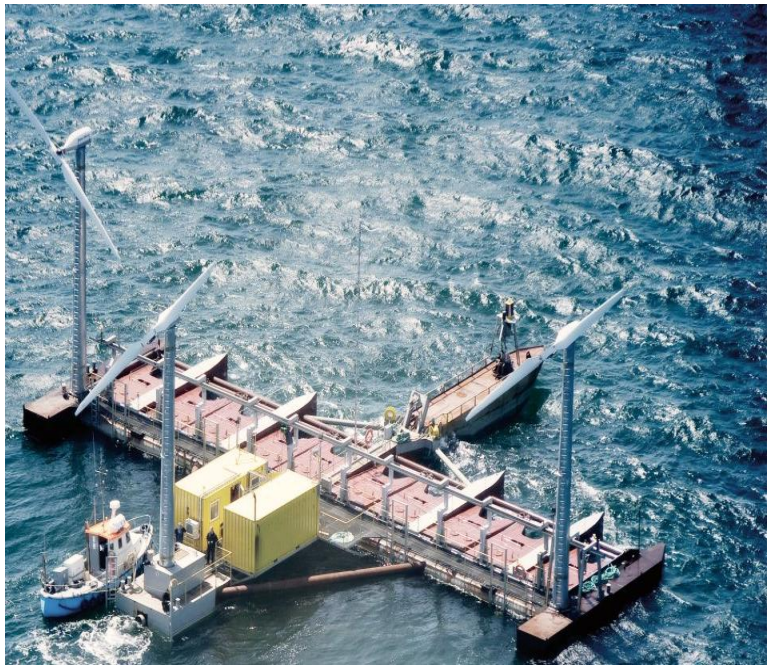
FLOATING OFFSHORE WIND + WAVE

3. Floating Power Plant A/S

- FPP is the only company in the world that has supplied power to the grid from a combined floating wind and wave device. 4 offshore tests have collected two years of offshore data for a ½ scale prototype



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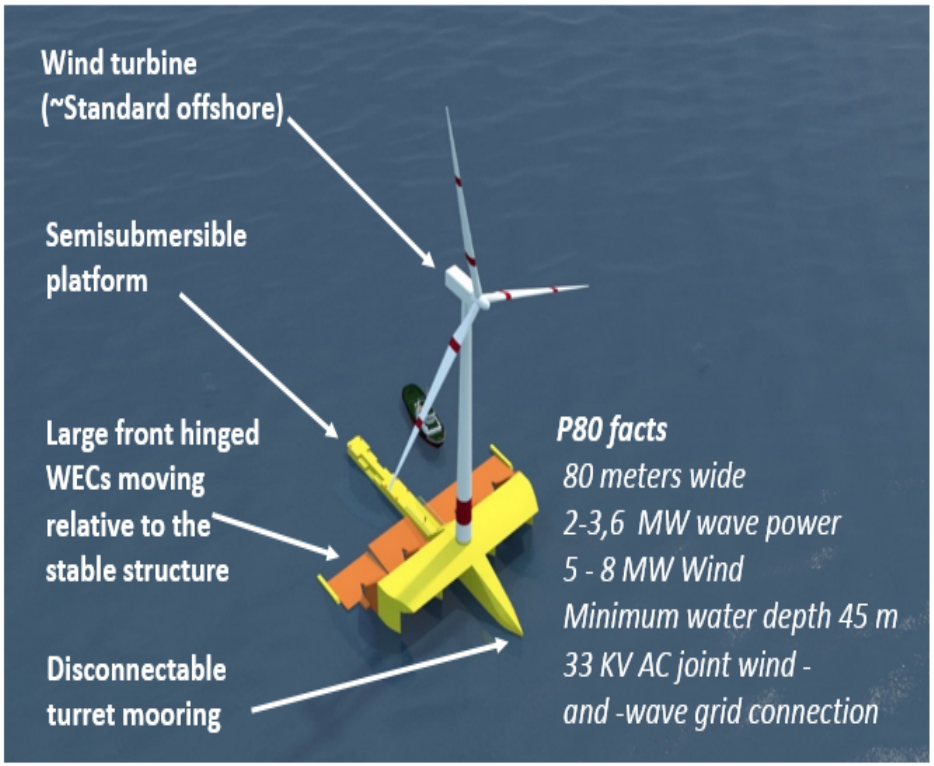
FLOATING OFFSHORE WIND + WAVE



An unique design combination that passively turns into primary wave direction
=> More wave power
=> Safe access zone

Design based on:

- Stable semi submersible platform **- oil & gas component**
- Build via panel line modules – **standard ship principle**
- Mooring / flexible sub-sea cables - **oil & gas components**
- Disconnetable and vaning turret **- oil & gas components**
- Wind turbine – **offshore wind turbine**
- Power export standards – **offshore wind standards**

- Unique wave device and PTO systems placed on a known stable structure
- Integrated on one platform where all components are placed indoors

- For the +45 meter water depth market segment

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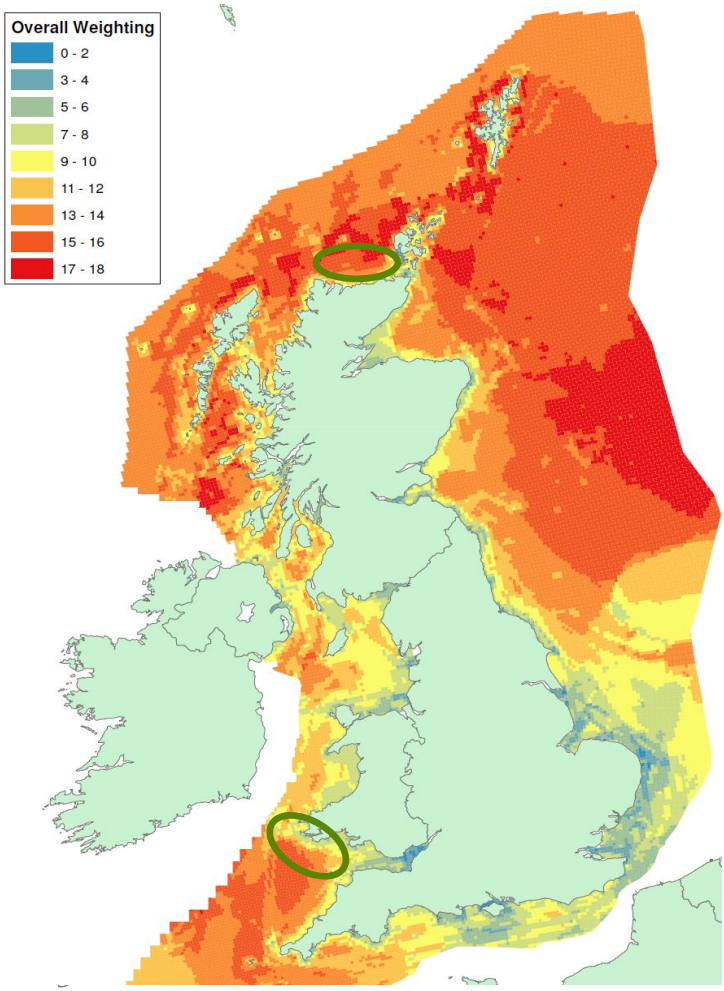
FLOATING OFFSHORE WIND + WAVE

Commercial projects in pipeline

- Step up approach in process
  - Phase 1: Pilot 7 MW (5MW wind + 2 MW wave)
  - Phase 2: build out to 35 MW (+4 devices)
  - Phase3: build out to 196 MW (+23 device)
- Katanes Floating Energy Park
  - 10km off the coast of N.Scotland, 70m water
  - 10m/s avg wind, 19kW/m wave energy
- Dyfed Floating Energy Park
  - 24 km off the coast of Wales, 60m water
  - 10.3m/s avg wind, 20kW/m wave energy



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AQUACULTURE + FLOATING OFFSHORE WIND

4. FLOCAN5

- Cobra, Besmar Aquaculture S.L. and PLOCAN are working on collocating a pilot floating 5 MW turbine with an existing organic sea bass farm (FLOCAN5) and then expanding both by factor of 5
- The Canaries site chosen for the prototype is ideal for its wind and environmental sea conditions,
  - the organic farm pilot was already located in one of the most “high energy sites” in Europe before its use for wind was considered.
- The goal is to test (at TRL8) if it is possible to have the two industries together and how much benefit is really created by multi-use of space.

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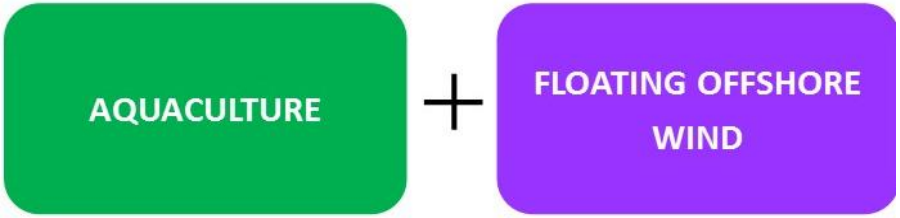

- Fish farm expected to benefit from:
  - CCTV camera security (less robbery)
  - Sheltered spot to grow small fish (better survival and production security).
  - An increased economic performance of about 10 % from O&M synergies with wind farm.
- Wind farm expected to benefit from:
  - Enabling more local benefits (more local job creation).
  - Image of a more “green” project.
- If the pilot demonstrates that the combination is beneficial, further integration of the combinations will be considered in the proceeding project.

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AQUACULTURE + FLOATING OFFSHORE WIND

- Both will share vessels for O&M
- MUS in this project at “simple” share of space and no physical connexion that could potentially jeopardise each sector
- If beneficial, combination could be further integrated in proceeding project.

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FLOATING OFFSHORE WIND + DESALINATION

5. EcoWind Waters' Floating Wind-Desalination MUP

- 35 kW prototype
- Potable water and energy

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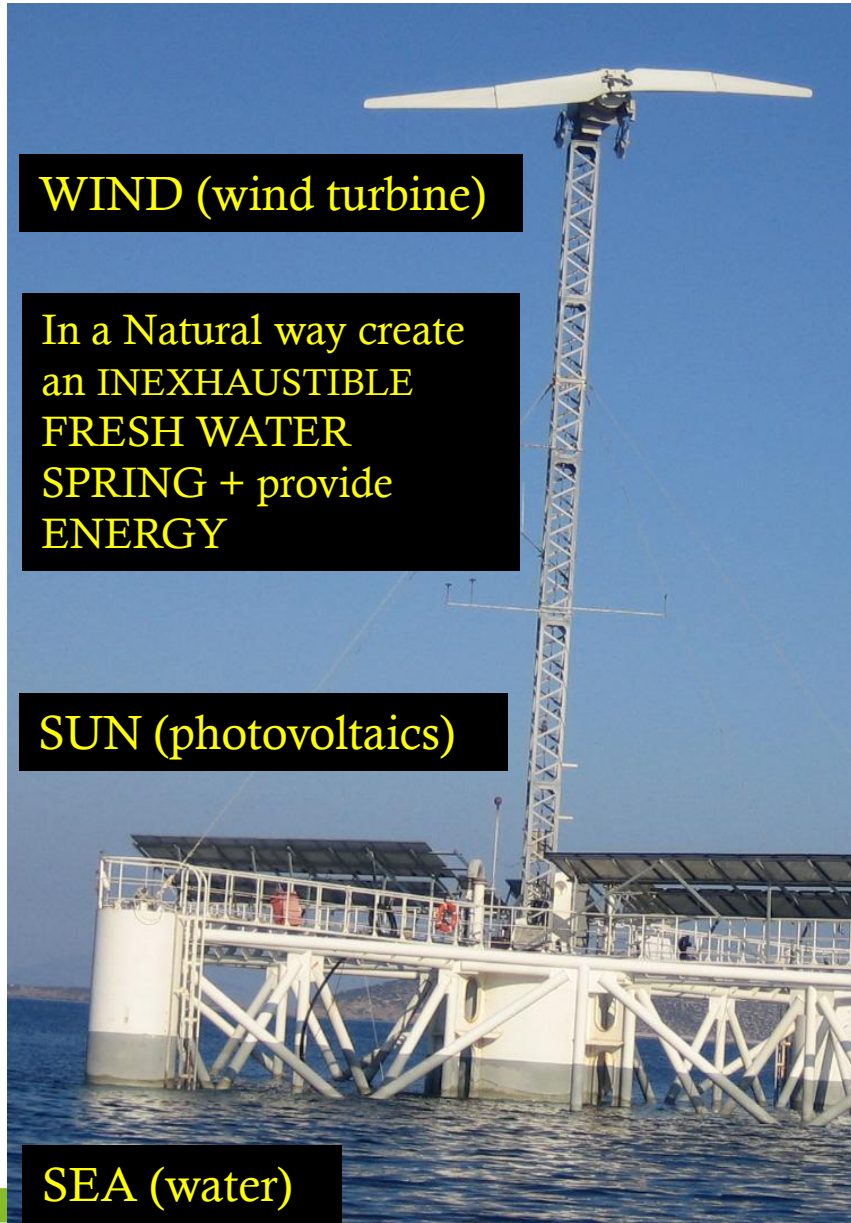
FLOATING OFFSHORE WIND + DESALINATION

- Ecological
  - No fossil fuels, 100% RES
  - No chemical pre-treatment of sea water
  - Far away from the coast, without any impact on the island
- Scalable
- Autonomous , Unmanned
- Low installation and maintenance costs
- Transportable
- Integrated with any RES device (Wave, tidal energy devices etc..)



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FLOATING OFFSHORE WIND + DESALINATION

EcoWind Water's MUP next steps

- Initially aimed at islands that have potable water delivered, are in danger from salinisation, and limited space especially access to erect medium sized wind turbines
- Next step 0.8 MW pilot
- Then 2MW commercial unit

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AQUACULTURE + FLOATING SHIPPING TERMINAL + OFFSHORE LOGISTICS & SERVICES

6. Multi-use Offshore Platform (MOP)

- Grand Port Maritime de Guyane (GPMG) is one of the 11 large sea ports operated by the French State, handling more than 95% of the goods traffic of French Guiana

- GPMG is developing a floating multi-use terminal for shipping (container transfer hub), oil and gas logistics hub, and fisheries & aquaculture support. This facility is designed to be located on the maritime cross route between from East to West, Central America and Western Africa, and from South to North, Brazil and Caribbean Islands.

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AQUACULTURE + FLOATING SHIPPING TERMINAL + OFFSHORE LOGISTICS & SERVICES

Step 1 in 2026, a 14 ha platform to deal with:

15000 TEU per year

logistic support for 2 O&G platforms

5000t/yr of aquaculture; fish

Power source:

- Diesel or, if ready, OTEC
- Consumption : 25000MWh/yr

Step 2 in 2030, a 20 ha platform to deal with:

30000 TEU per year

logistic support for 3 O&G platforms

5000t/yr of aquaculture; fish

Power source:

- OTEC 5 / 10 MW
- Consumption : 35000MWh/yr

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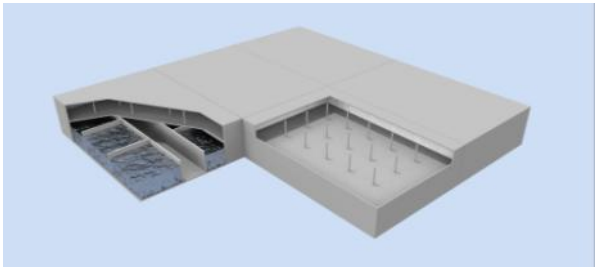
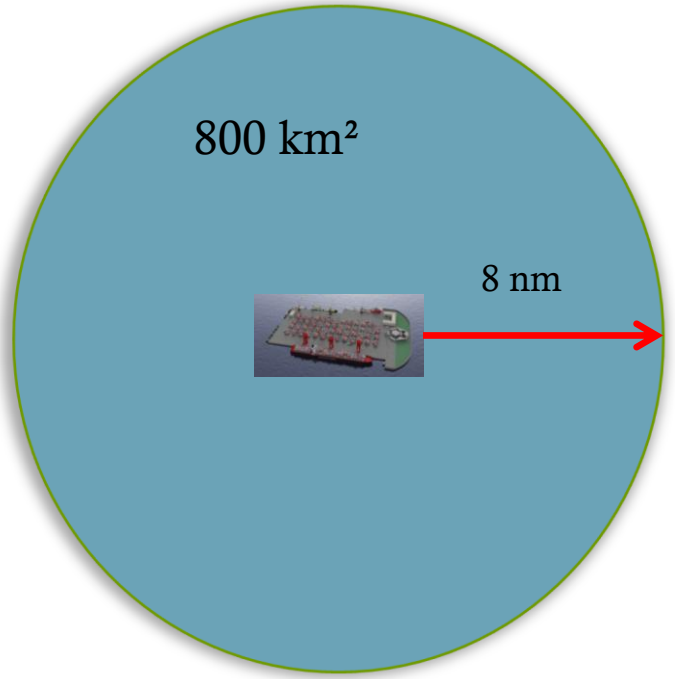
AQUACULTURE + FLOATING SHIPPING TERMINAL + OFFSHORE LOGISTICS & SERVICES

- A new approach of sustainable offshore multi-trophic aquaculture in a circular economy scheme
- From juvenile to market product in the same location



Juveniles raised in tanks in platform



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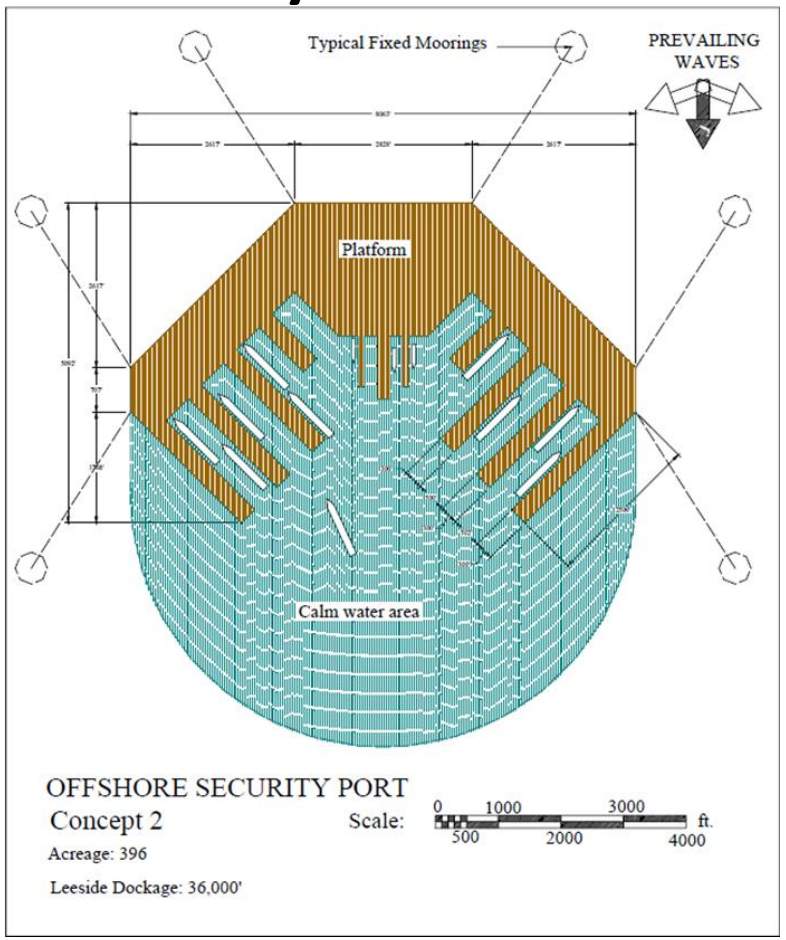
FLOATING SHIPPING TERMINAL + WAVE

7. Float Incorporated‘s Security Port

- Float Incorporated ‘s Security Port, is a floating multi-use platform designed to serve as a shipping and container terminal off the south of Ireland



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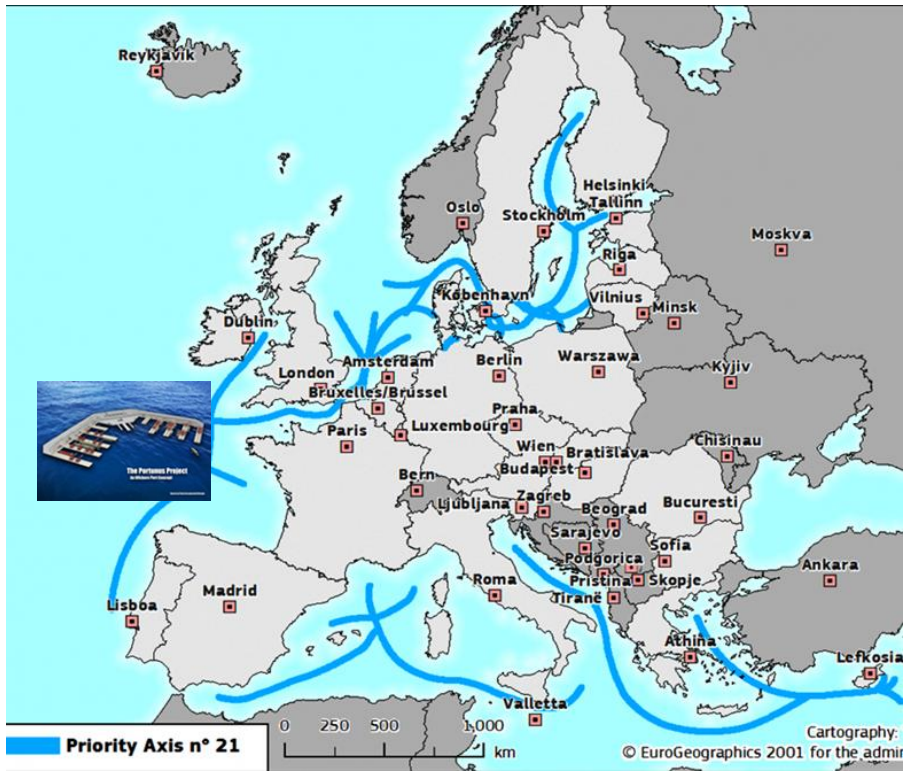
Marine Investment for the Blue Economy

FLOATING SHIPPING TERMINAL + WAVE

7. Float Incorporated's Security Port

- Pneumatically Stabilized Platform (PSP) which permits the construction of stable, floating, reinforced concrete foundations of unlimited size for any use on any body of water deep enough to float them.
- Rho-Cee Wave Energy Converter (ρC) (shipping + waves) a broadband, impedance-matched wave energy conversion structure that transforms the hydrodynamic power of waves at sea into usable electric energy.
- Potential Energy Storage (PES) system permits the storage of captured energy in the form of compressed air within the confines of the PSP's cylinder interstitial volumes.
- LNG terminal provides MUP baseload electricity, potable water, regasification for MUP use.

- **EU Motorways of the Seas -** Anchored offshore from Mizen Head, Ireland



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FLOATING SHIPPING TERMINAL + WAVE

7. Float Incorporated's Security Port

- The Float Inc. Security Port - shipping terminal configuration – total surface approximately 135 hectares
  - 8 berths for Ultra-Large Container Ship (ULCS) vessels
  - 8 berths for Short Sea Shipping (SSS) vessels
  - 4 service berths
  - Automated TEU handling equipment for 100% screening and container weighing + automated guided vehicles for TEU moves
  - Overall annual TEU (twenty-foot equivalent units) throughput
    - Minimum capacity of 17.5+Million TEU with maximum capacity of 70+Million TEUs per year without need to expand the Float Inc. Security Port structure.
  - Strategically positioned Float Inc. Security Port offshore from Mizen Head, Ireland:
    - Elimination of ULCS vessels voyage time via the English Channel between 8 to 12 days – costly voyage reductions for shipping companies.
    - Necessitates re-activation of an estimated 1,100 SSS vessels – currently idle in the EU.
      - NB: SSS vessels could be modified/rebuilt to utilize LNG fuel – reducing CO_2 output by 30%.
    - Revives seafarer employment for the EU & member states concerned –
      - NB: One SSS vessel requires 10-seafarers as crew, an estimated total of 10,000+ seafarers.
    - Direct Short Sea Shipping vessels deliver containers to destined EU member state – thus reducing costly, time consuming, and CO_2 pollution from across EU road transhipments.

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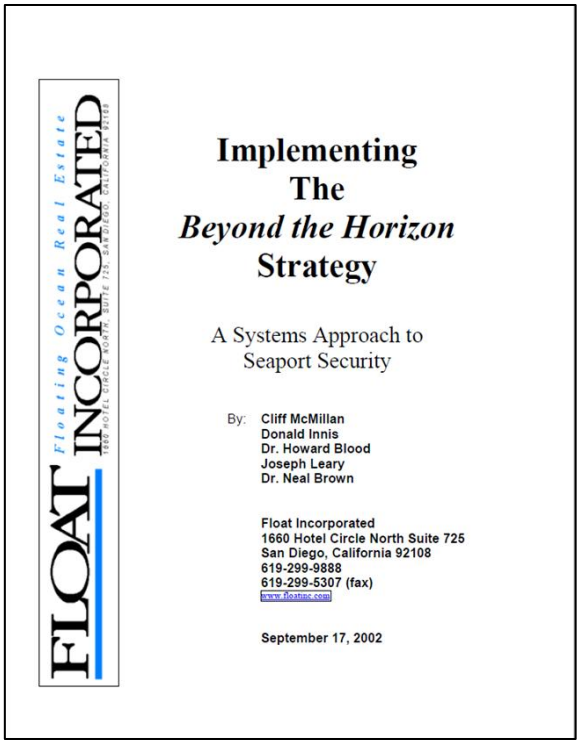
FLOATING SHIPPING TERMINAL + WAVE

7. Float Incorporated ‘s Security Port

- The Rho-Cee Wave Energy Converters
  - Renewable energy generated by the Rho-Cee WEC systems to be utilized on-board the Float Inc. Security Port thus reducing the consumption of LNG on-board.
  - Estimated 240,665MWh/year – overall 54.95MW rating.
  - If not required for immediate use, electricity can be converted to compressed air and stored within the interstitial spaces of the PSP - estimated 1,349MWh capacity within interstitial spaces of the PSP.


FLOAT INCORPORATED
Floating Ocean Real Estate

Implementing The *Beyond the Horizon* Strategy

A Systems Approach to Seaport Security

By: Cliff McMillan
Donald Innis
Dr. Howard Blood
Joseph Leary
Dr. Neal Brown

Float Incorporated
1660 Hotel Circle North Suite 725
San Diego, California 92108
619-299-9888
619-299-5307 (fax)
www.floatinc.com

September 17, 2002

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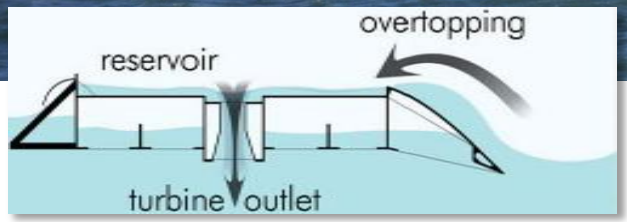
WAVE + AQUACULTURE

8. Wave Energy and Offshore Aquaculture in Wales, UK



- Wave Dragon, Seaweed Energy Solutions and BELLONA are working together on a combined wave and aquaculture project – utilizing the calm water behind the Wave Dragon

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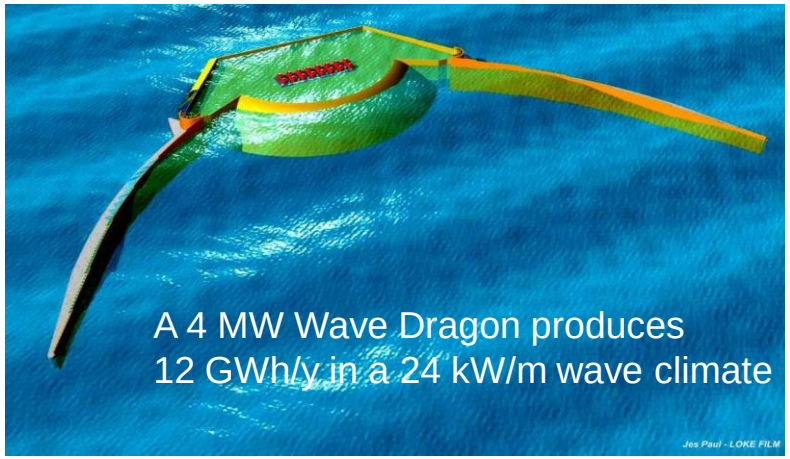
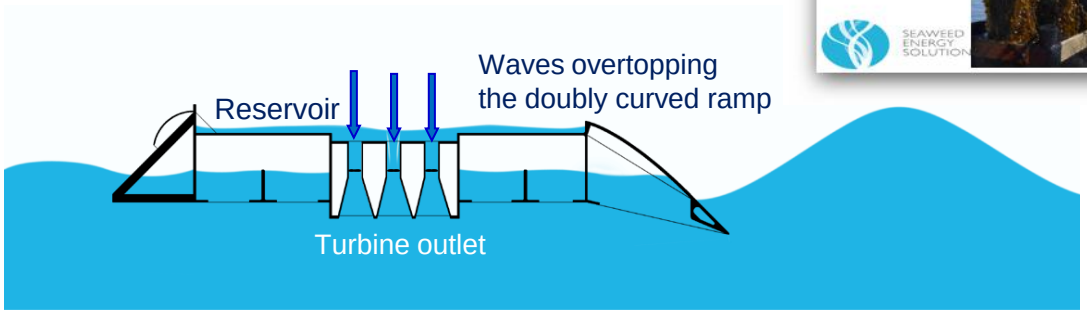
WAVE + AQUACULTURE

8. Wave Energy and Offshore Aquaculture in Wales, UK

- Wave Dragon & Seaweed Energy Solutions





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WAVE + AQUACULTURE

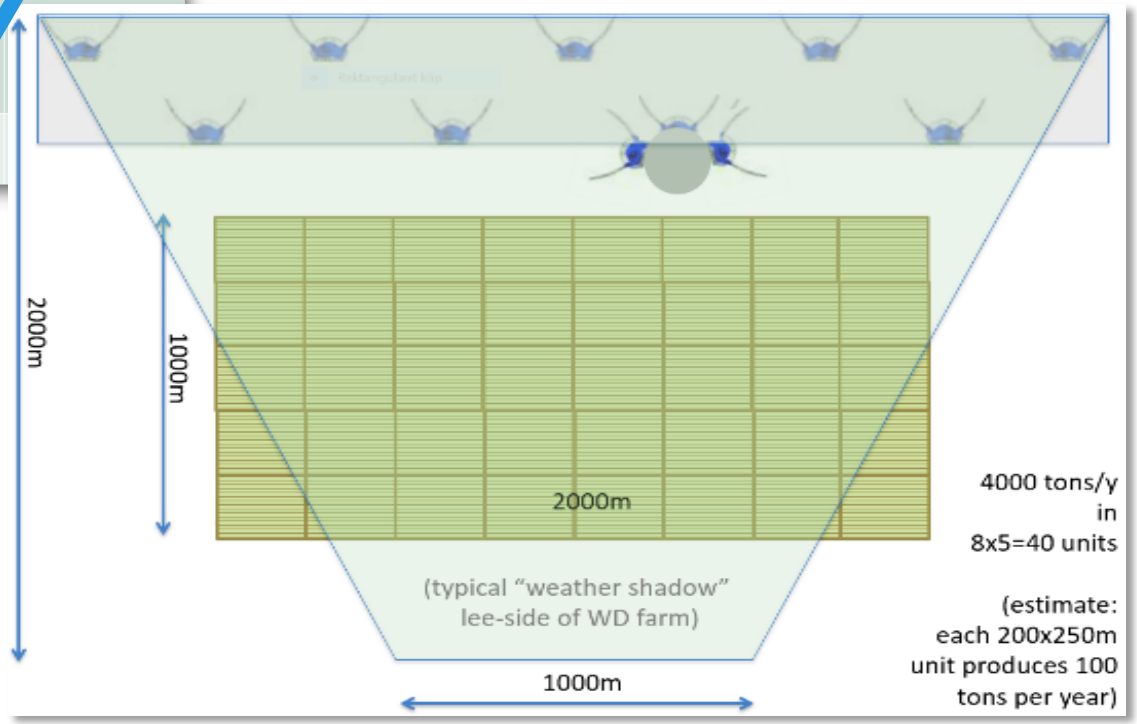
8. Wave Energy and Offshore Aquaculture in Wales, UK

Description of projects

	Pilot project in Wales	1st Commercial project in Wales	2nd Commercial project; new location	3rd commercial project
Wave Dragon	1 WD; 4MW	9 WD; 30MW	9 WD; 30MW	
SES	80 tonnes/y	4000 tonnes /y	4000 tonnes/y	

Key figures

	3rd commercial project
Wave Dragon	45WD@4MW = 180MW
SES	20 000 tonnes/y
Pay back	4.3 years
IRR	24.4%



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WAVE + AQUACULTURE

9. Wave Energy and Aquaculture in the Mediterranean Basin

ALBATERN Wave Energy

AQUABIOTECH GROUP

- **Albatern** is working with **AquaBioTech** to integrate of wave energy and offshore aquaculture to provide a sustainable farm system to grow fish for human consumption in offshore locations
- Combination of cage based fish culture and wave energy power
- Main focus is offshore cage culture – main future growth area
- Benefits of combined space use, infrastructure and resource

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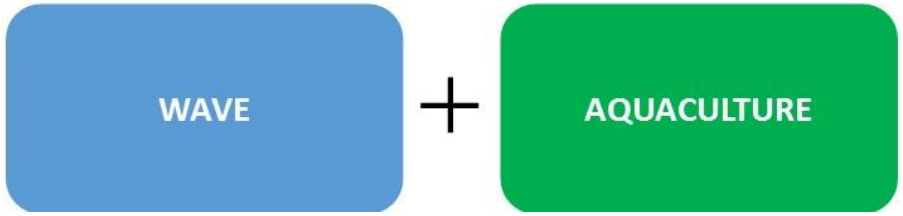

9. Wave Energy and Aquaculture in the Mediterranean Basin

- Suitable for selected nearshore applications
  - Sufficient exposure/energy available
  - Close proximity to onshore facilities
  - Very remote areas with limited power grid access
  - Areas with grid access (grid tied) where power is costly e.g. Malta
- Potential for addition of potable water production to the combination

This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 652629

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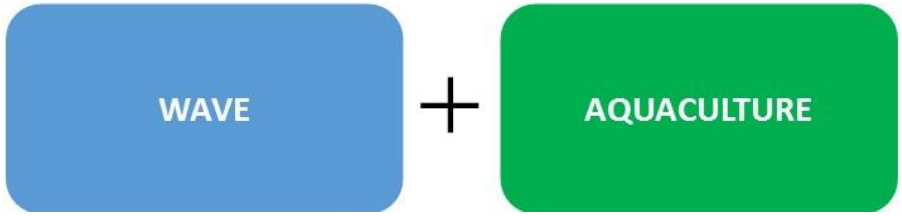

9. Wave Energy and Aquaculture in the Mediterranean Basin

- Mediterranean (Malta) case study has commercial potential and interest
- Pilot project in 2017 south east of Malta aims to prove feasibility of offshore combination at TRL 7. Primarily reduces and potentially replaces diesel generation
- Albatern: 16 x Series 6 (each 7.5kW) with 120kW cable to service barge with Hybrid Plant
- Aquaculture: Target Output of 1150Mt Per Annum - 8 Cages of 7,240m^3 each
- Water depth: 50m to 70m

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WAVE + AQUACULTURE

9. Wave Energy and Aquaculture in the Mediterranean Basin

- Expands to commercial project in 2019 rated at
  - Aquaculture 6000Mt p.a. and
  - Wave 720kW including export connection to shore

3 unit Albatern array at Isle of Muck

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Economic challenges to companies

- What is your comparator?
- For example fixed offshore wind continues to achieve LCOE reductions ahead of predications (DONG Borssele 1 and 2, July 2016)
- In June 2016 eleven major energy companies declared that the potential for offshore wind LCOE reduction stating that with "the right build out and regulatory framework the industry is confident that it can achieve cost levels below €80/MWh for projects reaching final investment decision in 2025, including the costs of connecting to the grid“
- Is there a believable pathway in a meaningful timeframe to compete with the comparator?

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Rating the best projects

- Projects were ranked according to the following metrics:

Metric	Explanation
Levelised cost (LC)	Levelised cost of operation (commercial case) (with current grid electricity price where appropriate) - the lower the LC the better performing the project like levelised cost of energy
Comparator ratio	Comparison of LC against strongest competitor (with same grid electricity price where appropriate) (commercial case)
Business plan	Evaluated by business team based on scores on good were the business plans provided
Risk	Evaluated by risk team based on scores on good were the risk plans provided
Panel score	From Brussels advisory sessions
Consortium score	Consortium partners' score based on overall interaction with companies and learning from scores from panels
IRR/km²	Internal rate of return density (IRR per seabed area) (commercial case)
Jobs/km²	Jobs density (Jobs per seabed area) (commercial case)

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- Pleased to talk further
- LinkedIn group: maribe, Follow on Twitter: @maribeproject
- www.maribe.eu, maribe@ucc.ie

- Thank you for listening; mjb@bvgassociates.co.uk

  +44(0)1793 752 308

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