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SOLAQUA

Offshore Floating Solar Energy:
the next frontier in renewable energy

Luciano Mule'Stagno

www.offshoresolar.org

Aim of the presentation : Offshore Solar

- Why?
- Where?
- Who?
- When?
- How?

Solar Farms - Space

Are great – last for over 20 years, no moving parts, no noise, relatively cheap.

BUT they do require lots of area

A 100MWp solar farm needs about 1km^2.
Difficult to find, expensive

This is an easy solution for countries and regions with lots of free land but not for others.

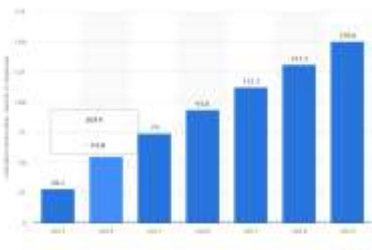
And transmission losses will still be significant if the farm is far from the city.

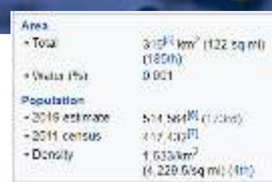
Solar Farms - Space

Name	Country	Location	Capacity MW_{DC} or MW_{AC}	Annual Output (GWh)	Land Size (km^2)	Year
Bhadla Solar Park	India	[illegible]	2,245		57	2020
Huanghe Hydropower Hainan Solar Park	China	[illegible]	2,200			2020
Pavagada Solar Park	India	[illegible]	2,050		53	2019
Benban Solar Park	Egypt	[illegible]	1,650		37	2019
Tengger Desert Solar Park	China	[illegible]	1,547		43	2016
Noor Abu Dhabi	United Arab Emirates	[illegible]	1,177		8	2019
Mohammed bin Rashid Al Maktoum Solar Park	United Arab Emirates	[illegible]	1,013			2020
Kurnool Ultra Mega Solar Park	India	[illegible]	1,000		24	2017
Datong Solar Power Top Runner Base	China	[illegible]	1,000			2016
NP Kunta	India	[illegible]	978			2021
Longyangxia Dam Solar Park	China	[illegible]	850		23	2015
Villanueva Solar Park	Mexico	[illegible]	828		27.5	2018
Copper Mountain Solar Facility	United States	[illegible]	802*		16.2	2016
Mount Signal Solar	United States	[illegible]	794	1,187	15.9	2020

Solar Farms – Cost of Land

In a small country like Malta, finding space for a 100MWp
Or even a 20kWp farm is next to impossible.
And land is expensive.





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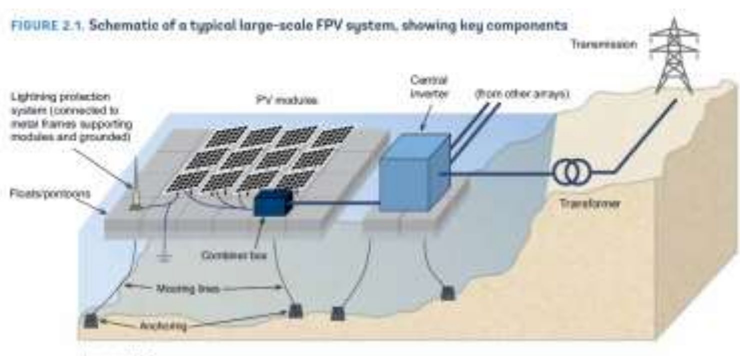
Floating PV Systems

- Not that different other than floats and anchors.



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Floating Systems - Disadvantages

- Higher moisture, more corrosive environment
- Access and installations might require more planning
- Catering for changes in water level, freezing, etc…
- Potential environmental impact
- Ability to sustain wind and waves

A 500 kW floating array located in Bayan County, where temperature can be less than minus 20 degrees Celsius.

Image: Sungrow

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7

Floating Systems - Advantages

- Does not use valuable land
- System can be closer to where consumption is happening
- Reduced water evaporation and algae growth
- Can have similar LCOE to land based systems
- May perform better due to cooler, cleaner environment, and ability to actively cool.
- No shading, ability to rotate
- Can be integrated with other uses/sources

Source: © Ocean Sun

Source: © ISIGENERE

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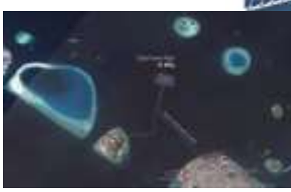
8

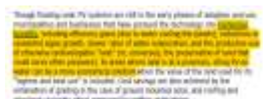
The Market

- Floating solar is happening around the world on lakes reservoirs and ponds.

We are one of the pioneers of solar at sea, but others are following.

Floating Solar Panels Market Size to Reach USD 2.70 Billion by 2025: Grand View Research, Inc.





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Floating Systems – State of Play

- As of 2019 there were over 2GWp of floating solar systems.
- All of them on lakes, reservoirs and ponds.
- Mainly in China, Japan, Europe and S. Korea.
- Using an under-utilized resource – fresh water bodies – reduces evaporation, cost-competitive.

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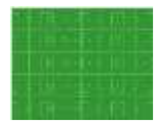
Solar Farms

- For some countries this is also not an option – no lakes/large reservoirs
- Once we consider offshore, the possibilities become almost endless.
- Systems could be placed strategically close to where the maximum consumption is occurring.

20MWp



10,000 m^2

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11

Solar Farms

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The Mediterranean

Will soon have over 500M people living on its shores.

Many areas of high population density – especially in the 5+5 region.

From: GRID-Arendal

Cost of Land

- Land close to large cities is also very expensive and difficult to find

New York

Shanghai

- Whereas plenty of space is available at sea.

(Yellow squares represent 100MWp area)

Technology

- Permanent moored structures already exist.
- So why not PV farms?

SolAqua

- SolAqua – aimed to prove the economical and technological viability of offshore installations in open sea and determine the best design ✓
- SolAqua 2 – aimed to develop the design and validate it through modeling ✓
- SolAqua 2.1 – aims to build and test that design and validate it through wave-tank tests and maximize power output. ✓

State of Play – Floating Solar

- As of 2019 there were over 2GWp of floating solar systems.
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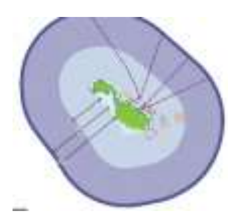
From: https://www.mibetsolar.com/

SolAqua Motivation

- Scarcity of large spaces on land for solar farms
- Need for more renewable energy
- A very large marine territorial area
- Highest solar insolation in Europe
- High land prices

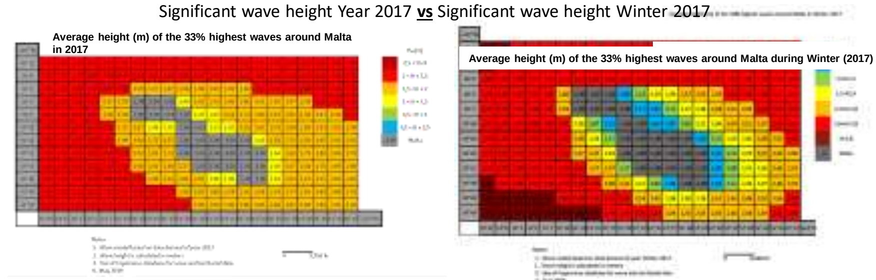


Target – LCOE equal to or close to land based systems

Wave Studies

- Significant wave heights, periods and occurrence in Malta was gathered from the Copernicus Marine Services* and other data gathered by UM

Significant wave height Year 2017 **vs** Significant wave height Winter 2017



* https://resources.marine.copernicus.eu/?option=com_csw&task=results

Figure: Wave assessment (Report: Waves Study in Malta v.4)

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19

Design

- In SolAqua we determined that for the project to be viable, and to reduce the forces/area and anchoring cost – a bigger platform is better.
- In SolAqua 2 we spent a year modeling, designing and deciding on practicality of construction of our design.

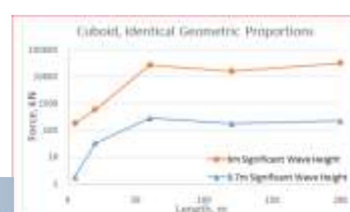

Figure 8: Maximum forces observed on cuboid platform

M. Aquilina, Prof. L. Mule` Stagno, Ing. M. Grech and Prof. Ing. T.Sant, "Determining the Optimum Shape and Size for an Offshore Floating Photovoltaic System" OSES 2016, Malta 2016

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20

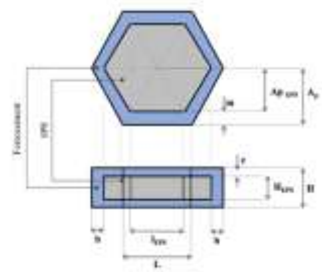
Design

- The design we settled on is a modular hexagonal shape.
- Each platform is small enough

To construct on land – but large enough to hold a significant amount of panels.

- Platforms would be tied/

chained together.



Anchoring, Mooring and Configuration

- Catenary lines, using chain and rope
- Length ~5 times depth
- Platforms tied together forming large area for panels.

Figure 7: potential mooring patterns

Mooring - Simulation

The mooring design and behaviour of the system were simulated using Ansys Aqwa

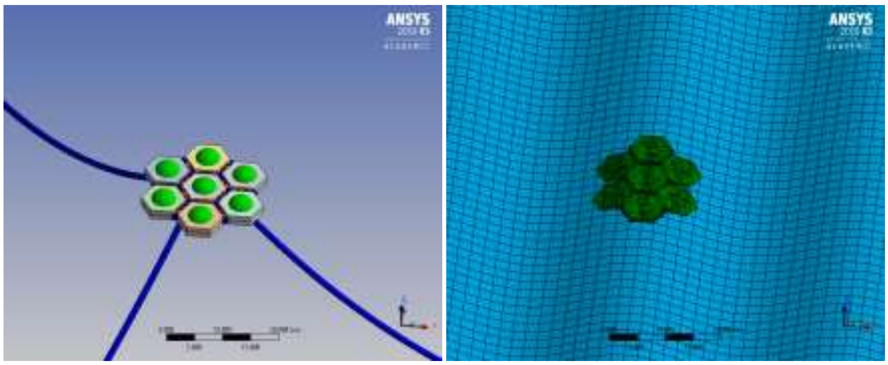


Figure: ANSYS AQWA Results

Experimental Verification

- The next step, undertaken in SolAqua 2.1 was to build scale models and test them in a wave tank.

University of Malta has a small wave-tank (1m depth 1:50 scale)

Centrale Nantes (France, 5m deep, 1:10)

We also considered the tank at Malta Film Studios in Rinella (Malta, 2m deep, 1:25)

Experimental Verification

- Malta Film Studios has wave generating capabilities but has never been used as a wave-tank – so it would require calibration.

Facility	Real model	UoM	Rinella	Centrale Nantes
Water Depth	50 m	1 m	2 m	5 m
Scale Ratio	1:1	1:50	1:25	1:10
Model Length (side)	4 m	8 cm	16 cm	40 cm
Wave period	4.5 < T < 10s	0.64 < T < 1.41 s	0.90 < T < 2.00 s	1.42 < T < 3.16s
Wave length	32 < λw < 156 m	0.63 < λw <3.12 m	1.27 < λw < 6.25 m	3.16 < λw < 15.62 m
Wave height	1 < Hs < 5 m	2 < Hs < 10 cm	4 < Hs < 20 cm	10 < Hs < 50 cm

- In the end we decided to use the two Maltese sites for practical reasons

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Experimental Verification

- Models (7 platforms) were built in 1:50 and 1:25 scales.
- The experiment at UM was performed in 2019-2020 over several sessions. Due to their small size those platforms were made of wood but adjusted to have the same density as the real platforms. Cameras and sensors were fitted in various locations.

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Experimental Verification - phase 1 (UM)

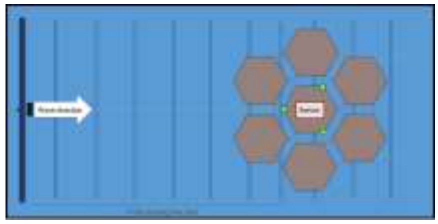

Figure 11: University Wave Tank Results (scale 1:5

Experimental Verification - phase 1 (UM)

video

Experimental Verification - phase 2 (Rinella)

- The Malta Film Studios tank is 2m deep (except a central deeper portion) and very large (91m x 122m)
- They have several wave-generators.
- Since the system is used for movies, the wave properties have never been measures.
- Our first task was therefore to measure the wave properties.

Experimental Verification - phase 2 (Rinella)

Rinella Tank during wave calibration

Rinella Tank

Wave calibration data

Experimental Verification - phase 2 (Rinella)

- The wave calibration at Rinella was successfully performed in late February 2020.
- The model experiment had to be postponed due to Covid measures
- Was finally performed at the end of May 2021

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31

The Testing

- The 1:25 models were constructed in the same manner as the full scale design – with a reinforced concrete shell over a styrofoam core.
- Several instruments were

incorporated to measure motion. Several cameras were also used.

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32

Results

- In the worse conditions the rafts behaved as expected.
- The tilt was never greater than 7 degrees The surface of the rafts were never submerged by water.

- Further analysis of the results is ongoing

The Design

- Near - Offshore solar will make sense in:
- Land constrained islands
- Near large coastal cities
- Our current design focuses on the Mediterranean but simulations shows that it can be readily adapted for more severe conditions.

The Next Step

- A full size set of platforms (40-50m^2 each with minimum 7 units) tested in Maltese waters at approx. 50m depth for 1-2 years.

- This will:

a. prove the financial and technical feasibility and enable the launch of full-size farms
b. Give us further experience and knowledge on the manufacturability and launch of the system

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Other Players

Solar Duck

Ocean Sun

Swimsol

Oceans of Energy

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Thank you for your attention

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37