Agenda

1. ESTEYCO: WHO WE ARE

2. OUR VISION

3. OUR SOLUTION: ELISA PROJECT-GBS TECHNOLOGY

4. IMPLEMENTATION STRATEGY

5. PROTOTYPE SELFBUOYANT CONCRETE TELESCOPIC TOWER AND FOUNDATION
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5. PROTOTYPE SELFBUOYANT CONCRETE TELESCOPIC TOWER AND FOUNDATION
ESTEYCO: 47 years consulting engineering experience
Civil, Environmental and Architectural Engineering
Evolution to Energy Sector
Leaders in civil works in wind energy sector
Pioneers in precast concrete towers

10 years experience at wind turbine concrete towers

+500 WTG towers designed and built, in 6 countries

Designs from 80m up to 160m both for conventional and the disruptive self-lifting tower. Some of our designs WF:

AGUA DOCE WF—IMPSA. Brasil
52 WTG 1,5MW HH100m

LES FORQUES WF—GAMESA. Spain
2 WTG 2MW HH100m

TRAIRÍ WF—SIEMENS. Brasil
50 WTG 2,3MW HH80m

COL DE PANISOT WF—ALSTOM. Spain
3 WTG 3MW HH100m

GOSTYN WF—ACCIONA. Poland
11 WTG 3MW HH120m

PEDRA GRANDE WF—WEG. Brasil
180 WTG 2,1MW HH120m
International presence in renewable Energy Sector

Permanent offices in 5 countries.
Participation in 400+ Wind Farms.
10GW+ installed power.
Renewable projects in 33 countries.
Developers, Consulting Firms, Turbine manufacturers, EPC
Disruptive offshore technology
Telescopic tower
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THE OPPORTUNITY: MARKET’S UPCOMING NEEDS

MAIN CHALLENGES

 Increasing water depths
 Increasing turbine size
 Need for cost reduction (both CAPEX and OPEX)
 Call for large scale industrialized deployment of foundations - Capacity of the supply chain
 Dependence on costly and scarce installation vessels
 Asset integrity

>90% of present offshore wind
>70% of future offshore wind
A new market to be exploited

>90% of present offshore wind
>70% of future offshore wind
A new market to be exploited
THE OPPORTUNITY: CURRENT FOUNDATION TECHNOLOGY

- 78.8% - 2,301. Monopiles / Monopiles
- 10.4% - 303. De gravedad / Gravity
- 4.7% - 137. Jacket / Jacket
- 4.1% - 120. Tripodes / Tripods
- 1.9% - 55. Tripiles / Tripiles
- 0.1% - 2. Experimental / Experimental
- 0.1% - 2. Flotante / Floating
Why should offshore substructure concepts get to be principal in Customer’s decision process?

**CAPEX significant reduction**

Foundation and installation are the main CAPEX factors in offshore, while they are secondary in onshore.

Our alternative foundation reduces these two costs items very significantly (30% to 40%).

**Overall Project Risks reduction**

No expensive and complex industrial development.

Significantly lower Project risks due to single installation campaign and no need of scarce, special purpose vessels.

**Shorter Time to Energy**

Single installation process.

No scarce vessels ➔ acceleration plans simple and economical.
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ELISA PROJECT

SELF-INSTALLING OFFSHORE SUBSTRUCTURE

Telescopic tower configuration allowing for both self-transportation and self-installation of the complete wind turbine, to be fully assembled onshore.

Make the most out of the required gravity based foundation, using it also as a temporary self-buoyant platform with virtually no extra-cost.
SELFBUOYANT CONCRETE TELESCOPIC TOWER AND FOUNDATION

MAIN ADVANTAGES

- Significant **cost reduction** (30-40%) as compared to Jackets or XXL Monopiles for 35m+ water depth and 5MW+ turbines
- Direct **scalability** in terms of turbine size, water depth, construction infrastructure and installation means.
- **Full in-shore assembly** of the overall WTG on harbor: **lower risk**
- Complete **independence of heavy-lift vessels**: **lower risk**
- Well suited for **industrialized construction** and very **intensive in local content** of workforce, raw materials and installation means.
- Robust and durable concrete substructure for greatly **improved Asset Integrity**.
- Simplified logistics based on economic and readily available means, resulting in **flexibility in scheduling** and installation speed: **lower risk**
- **Suitable for most soil conditions**, including soft or rocky seabed.
- More **environmentally friendly** than steel alternatives regarding both impact on sea life and carbon footprint.
INSTALLATION PROCESS

The unit can be towed with the aid of an auxiliary floating system (AFS), as described in next sections.

Usually, This AFS is only required for the ballasting process.
Once the unit has reached the seabed, the AFS is removed by merely opening its hydraulic pin, and starts its trip back to port, folded, towed by a single tug boat. Then the upper tower sections are lifted by operating the strand jacks, which only requires one installation management vessel. At a later stage, a different vessel/barge deploys the scour protection and carries out the solid ballast infill (pumped sand)

The tower remains unmanned at all stages, though access is possible if required.
Each transport team consists of two tugboats of 65 t

Towing of Prototype sub-structure with 50t tug
Auxiliary Floating System (AFS) is required for the ballasting process. The AFS ensures high levels of stability during the complete ballasting process. It avoids the need to dedicate large material quantities in the structure to provide stability during this short temporary situation, which is wasted material for the rest of the structure’s lifetime (like, for example, cone-shaped GBS solutions). It is low cost as compared to heavy duty vessels, unmanned and fully reusable for multiple units.
BALLASTING

Connection of third tug boat for positioning

Repositioning of transport tugboats (2) to work on traction mode (pulling from the proa)

Umbilical connection between Support Control Ship and structure

Unmanned structure at all times. Accessibility to all means possible in case of contingency

AFS construction in ASTICAN for 5MW prototype
Remote water flow control

GPS monitoring of position, and instrumented monitoring of inclination, water infill per compartment, etc

Underwater surveillance with ROV

Duration considered only until touchdown
Tower self-lift by means of Heavy Lift Strand Jacks

All works carried out at the access platform, including tower lift and joint execution

Proven technology in multiple sectors, including offshore

Existing “out of the shelf” and fully reusable hydraulic heavy lift jacks, which provide high capacity and accuracy at low cost

Lifting operation 1 day/tram (8-12m/Hour)
INDEPENDENCE OF HEAVY LIFT VESSELS

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ECONOMIC VALUATION. KEY NUMBERS

<table>
<thead>
<tr>
<th>Case study EA1: 72WTG 7MW (depth 40-45m)</th>
<th>%</th>
<th>k€/unit</th>
<th>k€/MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Civil works</td>
<td>1.8%</td>
<td>89</td>
<td>13</td>
</tr>
<tr>
<td>Manufacturing facilities</td>
<td>6.0%</td>
<td>301</td>
<td>43</td>
</tr>
<tr>
<td>Others</td>
<td>2.0%</td>
<td>102</td>
<td>15</td>
</tr>
<tr>
<td><strong>Total yard</strong></td>
<td><strong>9.8%</strong></td>
<td><strong>492</strong></td>
<td><strong>70</strong></td>
</tr>
<tr>
<td>Materials</td>
<td>45.7%</td>
<td>2.295</td>
<td>328</td>
</tr>
<tr>
<td>Substructure assembly</td>
<td>7.0%</td>
<td>353</td>
<td>50</td>
</tr>
<tr>
<td>Port towing</td>
<td>2.8%</td>
<td>140</td>
<td>20</td>
</tr>
<tr>
<td>Wet storage</td>
<td>0.7%</td>
<td>33</td>
<td>5</td>
</tr>
<tr>
<td><strong>Total ex-works manufacturing</strong></td>
<td><strong>56.2%</strong></td>
<td><strong>2.821</strong></td>
<td><strong>403</strong></td>
</tr>
<tr>
<td>Turbine assembly and precommissioning</td>
<td>2.7%</td>
<td>136</td>
<td>19</td>
</tr>
<tr>
<td>Seabed, solid ballast and scour protection</td>
<td>17.0%</td>
<td>855</td>
<td>122</td>
</tr>
<tr>
<td>Tower transport and ballats</td>
<td>9.4%</td>
<td>474</td>
<td>68</td>
</tr>
<tr>
<td>Erection tower-lift</td>
<td>4.0%</td>
<td>200</td>
<td>29</td>
</tr>
<tr>
<td>Instrumentation and monitoring</td>
<td>0.8%</td>
<td>40</td>
<td>6</td>
</tr>
<tr>
<td><strong>Total installation</strong></td>
<td><strong>34.0%</strong></td>
<td><strong>1.704</strong></td>
<td><strong>243</strong></td>
</tr>
<tr>
<td><strong>Total DIRECT COST</strong></td>
<td><strong>100%</strong></td>
<td><strong>5.018</strong></td>
<td><strong>717</strong></td>
</tr>
<tr>
<td><strong>Total EPC</strong></td>
<td><strong>100%</strong></td>
<td><strong>6.523</strong></td>
<td><strong>932</strong></td>
</tr>
</tbody>
</table>

Upfront investment around 35M€ for +500MW, including molds and Auxiliary Floating system.

Ex-works part representing over 56% of the cost with little or no risk. Very controlled costs.

Contingency of 10% is considered over on-shore activities

Seabed regularisation is likely to be required, plus anti-scour protection.

if detailed assessment leads to the conclusion that dredging is required to a certain extent, to both reduce scour issues and face sand mobility ones, it would be assessed as an extra cost of 240 to 300k€/position (40k€/MW)

Other items (towing, lifting) present few uncertainties, representing very controlled costs too.

Contingency of 10% is considered over offshore installation cost

This is a conservative exercise. Savings of 10% of CAPEX are reasonable to be expected based on negotiation, planning and product evolution.

Actual costs for a similar scenario: 1.6 to 1.8 mio€/MW
Medium term improvements by market 25% (expected): 1.3mio€
The concrete structure is in principle maintenance-free. No exposed steel elements. No systematic maintenance actions. No consumables.

This will depend in good practice design and construction, for which plenty of experience and detailed reference codes exist. High strength concrete and industrialised construction and precasting practice enhance quality control and manufacturing precision.

Maintenance instructions shall provide guidelines for preventive periodic inspection.

Systematic maintenance shall only be needed in the upper steel section (located in a higher less demanding area) and in the secondary steel components (ladder, railings, safety points, davit crane).
ATOMS Technology
(Under Development)
“Attachable Towable O&M System”

The project aims to develop a pioneer system which expedites and allows for reductions in overall O&M costs for offshore wind farms in excess of 20%.

The system is able to join the wind tower in solidarity to ensure that all loads to be transmitted can be compensated by the telescopic tower structure.
Large corrective actions currently involve multimillion € operations involving heavy-lift vessels specifically mobilised with “urgent” day charter rates. The operations drive a significant part of OPEX average cost previsions.

The tower descent for such large corrective maintenance could make it possible to use instead means with much better availability and much lower cost.

For example, bargemaster conventional crane systems could become a valid option if working height is sufficiently lowered.

Could lower the cost of the guarantee period to be provided by turbine manufacturer during the first years.
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FROM THE IDEA TO A HIGH TECHNOLOGY READINESS LEVEL

Intensive R&D development supported by reference institutions. Investment until 2016 reached nearly 15M€, with resources allocated for experimental demonstration which shall sum up to 25M€ in development by 2017.

(2009-2010)
Ministry of Industry
Initial research and first patents
(306 k€)

(2010-2012)
CDTI
Research and theoretical development
(669 k€)

(2012-2014)
CDTI
Scale Tank Testing + Design optimization
(794 k€)

(2012-2014)
ACCIO
Structural Lab testing + Advanced numerical modelling
(63 k€)

(2013-2014)
EUROSTARS
Telescopic Tower full scale prototype
(1687 k€)

(2014-2015)
EEA GRANTS
Experimental testing + Design Certification
(379 k€)

HORIZON 2020
Open Water Full Scale Foundation Demonstrator
(20,000 k€)

SPECIALIST COLLABORATORS

Intellectual property protection: MULTIPLE INTERNATIONAL PATENTS
RISK ANALYSIS AND MITIGATION

TECHNOLOGICAL RISKS
- Laboratory Validation
- Test Facility Validation
- Certification DNV/GL: TÜV SDU
- Supervision Insurance Company RSA, SWISS RE
- Full scale telescopic tower test

COSTS SAVINGS
- For 40m and deeper > 40% over jackets
- Lower risks, less uncertainty
- Virtually maintenance free

INSTALLATION RISKS
- Full On-shore Assembly
- No heavy-duty special purpose vessel
- Completely craneless
- Wider installation windows

✓ R+D ESTEYCO
✓ Due Diligence Utilities, Turbine Manufacturers, EPC
✓ Prototype 2016
EXTENSIVE TANK TESTING CAMPAIGN OF THE TOWED TRANSPORT
FULLSCALEPROTOTYPEOFTHETELESCOPICTOWER

CONSTRUCTIVEPROCESSFULLSCALEPROTOTYPE. DAGANZO. SPAIN. Mar – Oct 2014
LAB TESTING OF CRITICAL STRUCTURAL COMPONENTS
CERTIFICATION OF THE SELF-ERECTING TOWER SYSTEM

Statement of Compliance

GL Renewables Statement No. DAA-GL-029-2014

This Statement of Compliance for the A-Design Assessment of the Erection Manual for the Wind Turbine Component

Esteyco Telescopic Tower

is issued to

Esteyco Energetica, S.L.
CI Marinas, 27
08005 Barcelona
Spain

This statement attests compliance with the normative references stated below concerning the erection manual. The A-Design Assessment is based on the documentation filed in the Certification Report referenced below and the characteristic data given in the attached Annex.

Certification Report number and title:

75211
75216
2014-12-17
Erection Telescopic Tower, Erection Manual of Pretolape

75216
2014-12-17
Erection Telescopic Tower, Inspection of Telescoping Process

Normative references:
GL Rules and Guidelines – IV Industrial Services – Part II -
Guideline for the Certification of Wind Turbines, Edition 2010,
Sections 1, 2, 3.6 and 9.1

Changes in the erection manual are to be approved by GL Renewables Certification (GL RQ), otherwise this statement loses its validity.

Hamburg, 2014-12-17

KLAHAN

GL Renewables Certification

Statement of Compliance

By DAKKS according EN ISO/IEC 17025:2005

The report is the final document for the certificate with reference number DAA-GL-029-2014.

The certification is valid in the field of certification

Wind turbines

The last edition of the "Guidelines and Criteria of Certification Services GL Renewables Certification GL RQ" is applicable. Current by annex.

Description | Turbine | Power | Turbine Manufacturer / Client | Date | Certification extent | Certification Body
---|---|---|---|---|---|---
HH 80m | AW1500 | 1.5MW | GL | 06/2006 | Design | GL
HH 100m | AW3000 | 3.0MW | GL | 04/2009 | Design | GL
HH 80m | AW1500 | 1.5MW | GL | 05/2010 | Design | GL
HH 100m | AW3000 | 3.0MW | GL | 09/2010 | Design | GL
HH 100m | Generic | 3.0MW | GL | 04/2011 | Design | GL
HH 100m | Generic | 1.5MW | GL | 05/2011 | Design | GL
HH 100m | IV77 | 1.5MW | GL | 05/2011 | Design | GL
HH 100m | TWT2.5 | 2.5MW | GL | 12/2011 | Design | GL
HH 100m | G97 | 2.0MW | GL | 07/2012 | Design | GL
HH 100m | AW3000 | 3.0MW | GL | 09/2012 | Design, IPE | GL
HH 120m | AW3000 | 3.0MW | GL | 09/2012 | Design, IPE | GL
HH 100m | ECO110 | 3.0MW | GL | 11/2012 | Design, IPE | GL
HH 80m | SWT2.3 | 2.3MW | GL | 02/2013 | Design, IPE | GL
HH100m, foundation | ECO110 | 3.0MW | GL | 05/2013 | Design | DEWI-OCC
HH100m, internals | ECO110 | 3.0MW | TÜV Rheinland | 09/2013 | Design, on-site inspection | TÜV Rheinland
HH 100m | IV82 | 1.5MW | GL | 11/2013 | Design | GL
HH 100m | Generic | 3.0MW | GL | 11/2013 | Design | GL
HH 120m | Generic | 3.0MW | GL | 11/2013 | Design | GL
HH 80m | SWT2.3 | 2.3MW | GL | 12/2013 | Design, IPE | GL
TECHNOLOGY READINESS LEVEL

- Basic Research
- Applied Development
- Operational Deployment

- Discovery/Concept Definition
- Laboratory Validation
- Open Water Validation
- System Demo & Verification

1Q 2016

2Q 2017
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H2020 SME ELISA / LC3 ELICAN PROGRAMME AND MILESTONES

- Approved grant 13,7M€
- Total investment 15M€ (excluding engineering)
- WTG 5MW 30m depth HH83m: 3M€/MW
- Foundation, tower and installation of foundation, tower and WTG 1,5M€/MW (dry dock, molds & Auxiliary Floating system amortized in one unit)
H2020 SME ELISA / LC3 ELICAN PROGRAMME AND MILESTONES

- Harbour preparation works. JAN 2016
- Foundation construction. JUN 2016
- Tower and auxiliary floating system manufacturing. OCT 2016
- Tower installation on harbor. DEC 2016
- Ballasting Test FEB 2017
- Installation on site. 2Q 2017
- Operation. 2Q 2017
Gravity Base Off-Shore Prototype 5MW

Precast concrete

In-situ concrete
Gravity Base Foundation (-3.5m)

Link: https://vimeo.com/182759028
Password: ESTEYCO
Tower manufacturing
Transport
Tower assembly
Tower assembly
Gravity Base and telescopic tower (wet storage-3.5m)
Auxiliary Floating System
Auxiliary Floating System
Prototype GBS with telescopic tower – February 2017
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<th>INSTALLATION PROCESS AND MEANS</th>
<th>TRANSPARENCY TO WAVE LOADING AND SENSITIVITY TO SEA MOTIONS</th>
<th>USABLE DRAFT RANGE</th>
<th>DEPENDANCE ON SOIL CONDITIONS</th>
<th>INDUSTRIALISABLE AND SCALABLE ONSHORE PREASSEMBLY</th>
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</thead>
<tbody>
<tr>
<td>CONVENTIONAL SPAR</td>
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<td>X</td>
<td>✓</td>
<td>X</td>
<td>✓</td>
<td>X</td>
</tr>
<tr>
<td>TLP</td>
<td>✓</td>
<td>X</td>
<td>✓ ✓</td>
<td>✓</td>
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<tr>
<td>SEMI-SUBMERSIBLE</td>
<td>X</td>
<td>✓ ✓</td>
<td>≈</td>
<td>✓✓</td>
<td>✓</td>
<td>≈</td>
</tr>
</tbody>
</table>
EVOLVING FROM THE EFFECTIVE SPAR STABILITY CONCEPT
Telwind Fundamentals

**FUNDAMENTALS**

<table>
<thead>
<tr>
<th>Equilibrium Position</th>
<th>Inclined Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \alpha = 0 )</td>
<td>( \alpha &gt; 0 )</td>
</tr>
</tbody>
</table>

**MAIN COMPONENTS**

- **Telescopic Tower**
- **Upper Tank**
- **Suspension Tendons**
- **Lower Tank**
- **Mooring Lines**
- **WTG**
COMPETITIVE ADVANTAGES PURSUED

PATENTED CONCEPT AND PROCEDURES

TRANSPORT TO SITE

CONNECTION BETWEEN PLATFORM AND SUSPENDED BALLAST
## COMPETITIVE ADVANTAGES PURSUED

<table>
<thead>
<tr>
<th>Floating Substructure Concept</th>
<th>Material Usage and Elaboration</th>
<th>Installation Process and Means</th>
<th>Transparency to Wave Loading and Sensitivity to Sea Motions</th>
<th>Usable Draft Range</th>
<th>Dependance on Soil Conditions</th>
<th>Industrialisable and Scalable Onshore Preassembly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Spar</td>
<td>⊃</td>
<td>X</td>
<td>✓</td>
<td>X</td>
<td>✓</td>
<td>⊃</td>
</tr>
<tr>
<td>TLP</td>
<td>✓</td>
<td>X</td>
<td>✓ ✓</td>
<td>✓</td>
<td>X</td>
<td>≃</td>
</tr>
<tr>
<td>Semi-submersible</td>
<td>X</td>
<td>✓ ✓</td>
<td>≃</td>
<td>✓ ✓</td>
<td>✓</td>
<td>≃</td>
</tr>
</tbody>
</table>

*Note: The table shows the advantages of different floating substructure concepts. The symbols ⊃, X, and ✓ indicate varying levels of advantage.*
TELWIND CONCEPT: SOLIDARY SUSPENDED BALLAST
PROOF OF CONCEPT TANK TESTING
H2020 TELWIND PROJECT: Integrated telescopic tower and evolved spar floating substructure for low-cost deep offshore wind and next generation of 10MW+ turbines

EU Contribution: \textbf{3,498,530.00 €}


ESTEYCO is also currently collaborating with DNVGL in the project:

\textbf{JOINT INDUSTRY PROJECT (JIP) COUPLED ANALYSIS OF FLOATING WIND TURBINES}
MAIN OBJECTIVES

- Design a 5MW WTG from conceptual to detail-constructive engineering.
- Study the concept scalability for a 12 MW WTG.
- Model Basin Tests in operating, extreme and installation conditions.
- Perform laboratory tests to study the performance of the suspension tendons.
- Obtain the Certification of the design.
- Project dissemination in general and technical forums and conferences.
### Telwind Preliminary Design

#### Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind Turbine</td>
<td>5 MW</td>
</tr>
<tr>
<td>Water depth</td>
<td>80 m</td>
</tr>
<tr>
<td>Hub Height above MSL</td>
<td>86 m</td>
</tr>
<tr>
<td>Nacelle Weight</td>
<td>273 t</td>
</tr>
<tr>
<td>Tower Weight</td>
<td>1026 t</td>
</tr>
<tr>
<td>UT Concrete Weight</td>
<td>4117 t</td>
</tr>
<tr>
<td>LT Concrete Weight</td>
<td>1224 t</td>
</tr>
<tr>
<td>Overall Concrete Weight</td>
<td>6387 t</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Draft</td>
<td>60 m</td>
</tr>
<tr>
<td>Upper Tank draft</td>
<td>20.50 m</td>
</tr>
<tr>
<td>Upper Tank diameter</td>
<td>32.00 m</td>
</tr>
<tr>
<td>Upper Tank height</td>
<td>10-10.5 m</td>
</tr>
<tr>
<td>Lower Tank diameter</td>
<td>15.35 m</td>
</tr>
<tr>
<td>Lower Tank height</td>
<td>16.50 m</td>
</tr>
<tr>
<td>Suspension Cable length</td>
<td>26.06 m</td>
</tr>
<tr>
<td>Overall displacement</td>
<td>12,003 t</td>
</tr>
<tr>
<td>Metacentric height inplace (GM)</td>
<td>&gt;3 m</td>
</tr>
<tr>
<td>Metacentric height transport (GM)</td>
<td>&gt;2 m</td>
</tr>
<tr>
<td>Tilt static angle ($\theta_{STA}$)</td>
<td>&lt;10°</td>
</tr>
<tr>
<td>Overall heave period (T3)</td>
<td>&gt;30s</td>
</tr>
<tr>
<td>Overall pitch period (T5)</td>
<td>&gt;35s</td>
</tr>
</tbody>
</table>
CONCLUSIONS AND NEXT STEPS

A detailed constructive and fully certified design shall be ready in 2017

The technology shall be based on two extensive tank testing campaigns and lessons learned from sister technology Elisa and its 2016 operative 5mw prototype on the Canary Islands.

Objective: Prototype 2018. Looking for funds and partners