Pelastar TLP Floating Wind Turbine Foundation

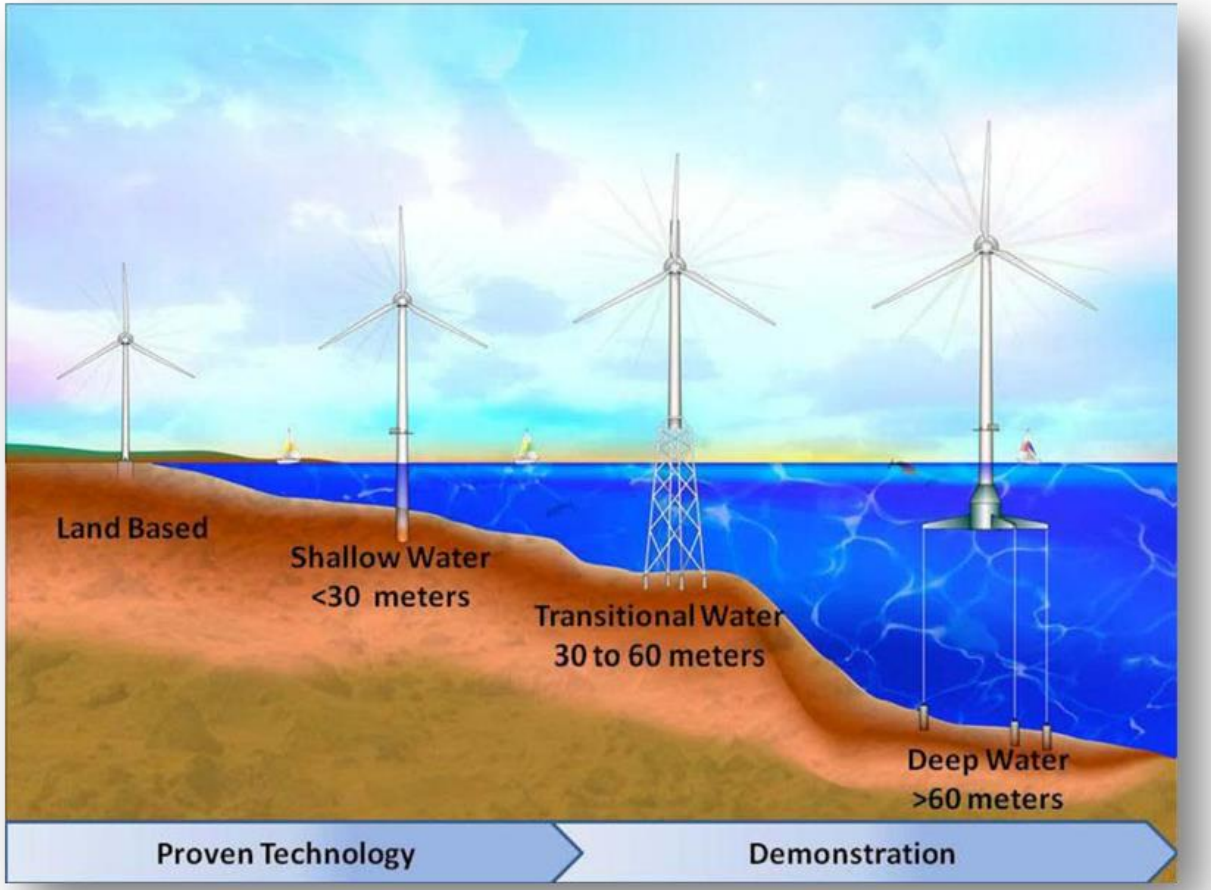
William Hurley
Glosten Associates

PRESENTED AT ***TEN YEARS OF INNOVATION***

THE ETI AND THE *PELASTAR* TLP FLOATING WIND TURBINE FOUNDATION

WORKING WITH THE ENERGY TECHNOLOGIES INSTITUTE

- **ETI Focus Area: Deep Water Wind**
- **The Tension Leg Platform**
  - Less mature technology
  - Potential for Lowest Cost of Energy
  - Technical Challenges that need solutions
- **ETI Push for Ambitious Goal**
  - *Take Concept through Front-End Engineering Design (FEED) for a FULL SCALE Demonstration (6MW) Project Offshore*
- **Engineers working with Engineers**



DEEP WATER FOUNDATION OPTIONS

Spar:

- Hywind (Statoil)

Semi-submersible:

- WindFloat (PPI)

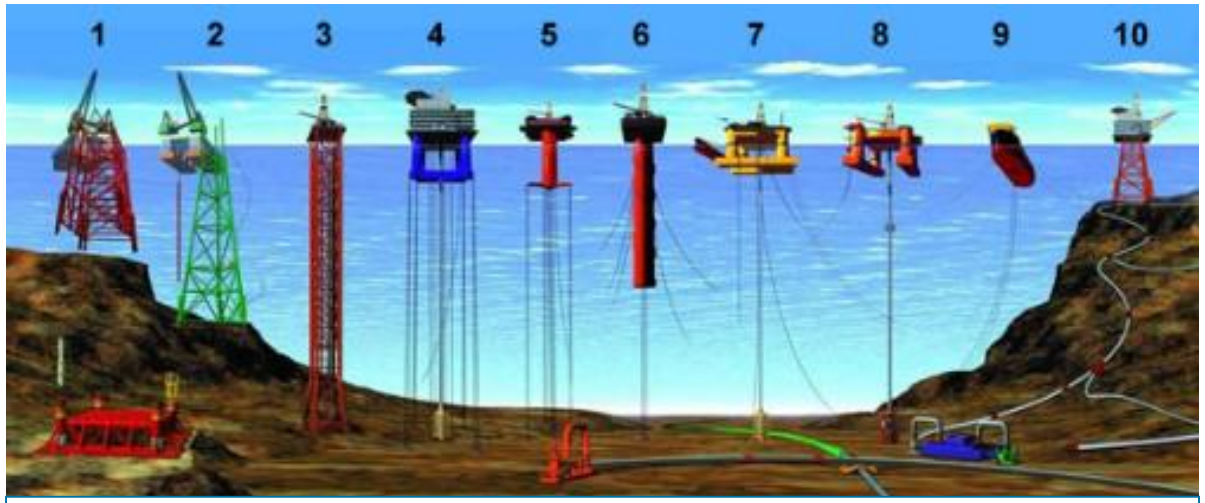
TLP:

- *Not demonstrated*

Cost Drivers	Jacket	HyWind	WindFloat	*TLP*
Onshore Assembly	✘	✘	✓	✓
Lightweight Structure	-	✘	✘	✓
Turbine Performance	✓	✓	✘	✓
Siting Flexibility	✘- 45m max	✘	✓	✓
Serial Production	✘	✓	✓	✓

TENSION LEG PLATFORM TECHNOLOGY

Oil and Gas Platform Precedent

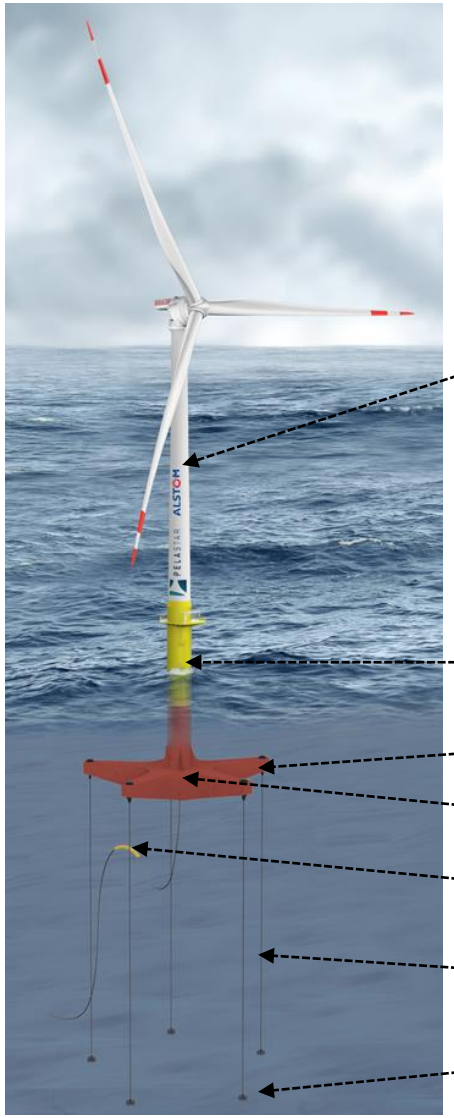


#4 above is the Magnolia TLP, considered the worlds tallest structure at 1,432 meters from seabed to top of platform.

- **Worlds tallest skyscraper is 828m tall.**
- **A PelaStar is 285m tall from seabed to blade tip. (with 6MW – 150m blade diameter turbine in 100 meters of water)**

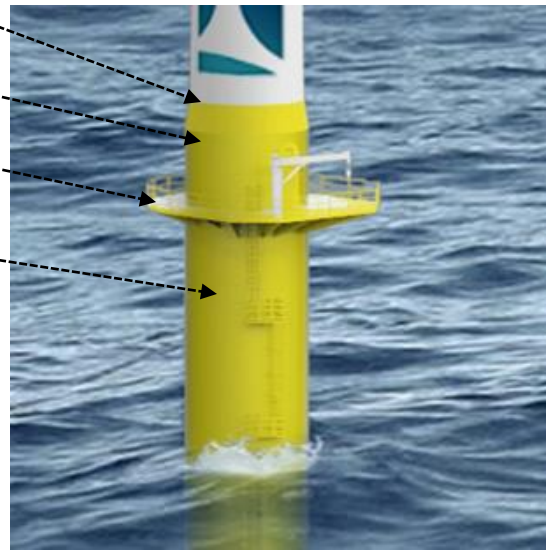
#5 - The SeaStar TLP, the oil and gas precedent for PelaStar

PELASTAR TECHNOLOGY SUMMARY



Developed by engineers seeking the best deep-water turbine foundation solution at the lowest cost

- Tower
- Interface Flange
- Transition Piece
- Access Platform
- Upper Column
- Arm
- Lower Hull
- Export Cable
- Tendon
- Anchor



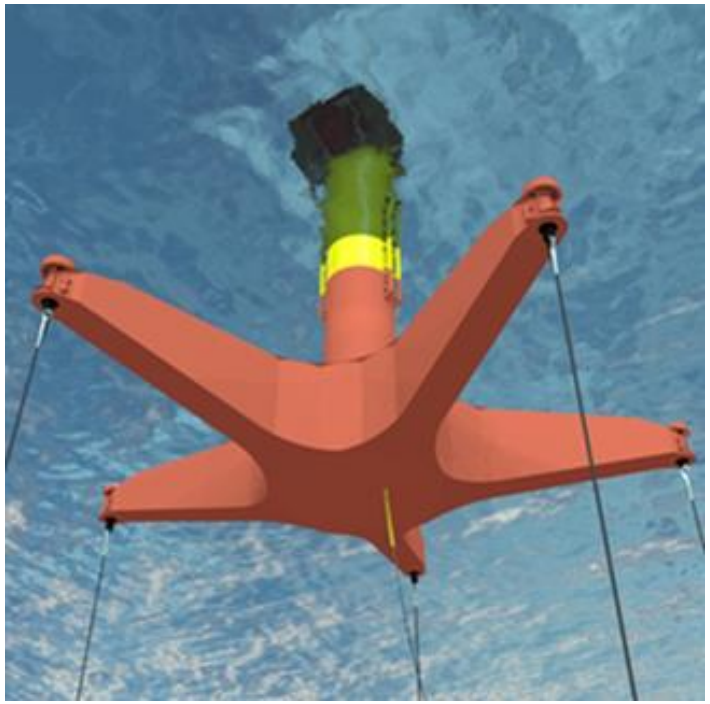
OUR ETI PARTNERSHIP ADVANCED TLP TECHNOLOGY

An Engineered Technology Development Driven by a Focus on Lowering CoE

- **Advanced TLP Technology to Technical Readiness Level (TRL) 5**
- **Established a design, analysis and regulatory framework**
  - Participation in DNV JIP contributed to floating foundation regulatory rules development
  - DNV GL approved Basis of Design and reviewed the FEED-level design
- **1:50 scale model tests performed**
  - with software validation reviewed and studied by DNV GL with results co-published

ADVANCED TLP CONFIGURATION TO 5 ARMS

- **Provided Redundancy and Reliability not found in 3 or 4-Arm Designs**



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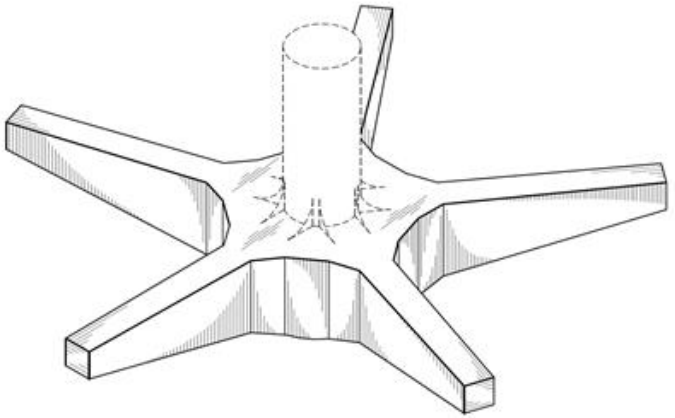
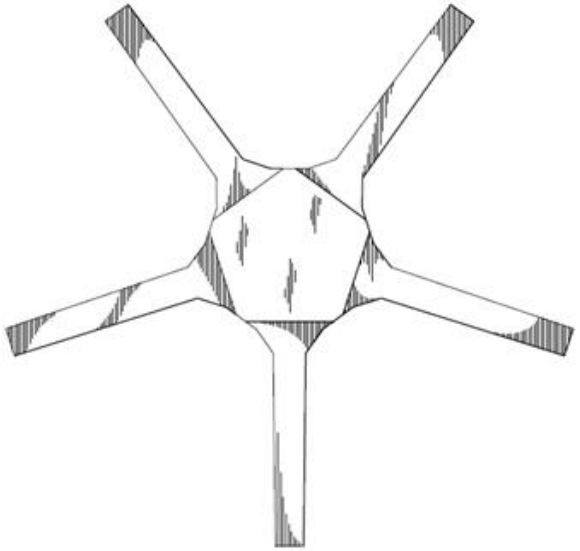


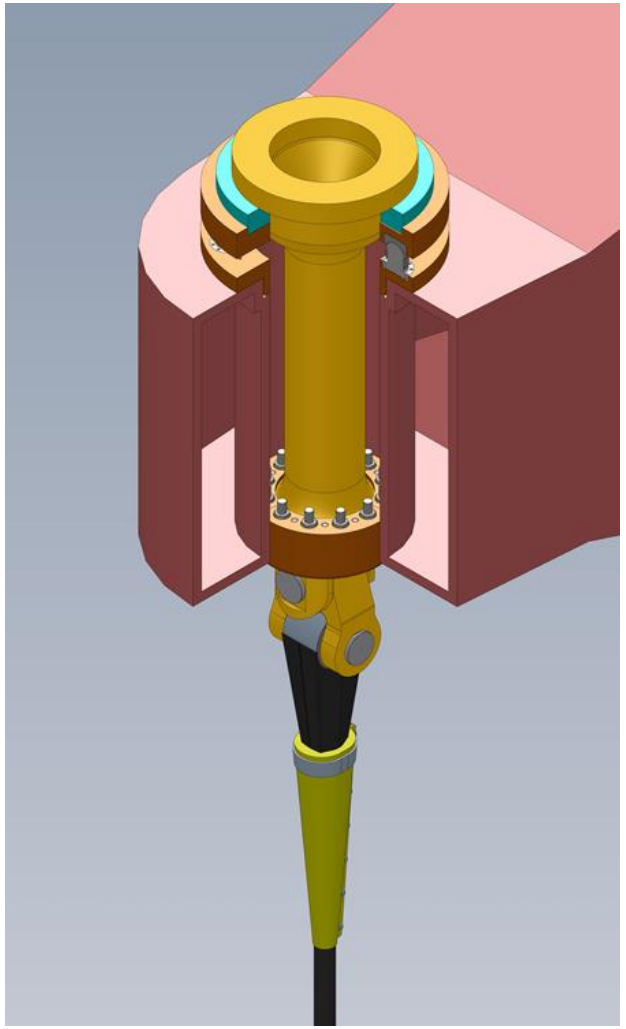


Design Patents awarded in EU, US and Japan

ADVANCED TENDON TECHNOLOGY

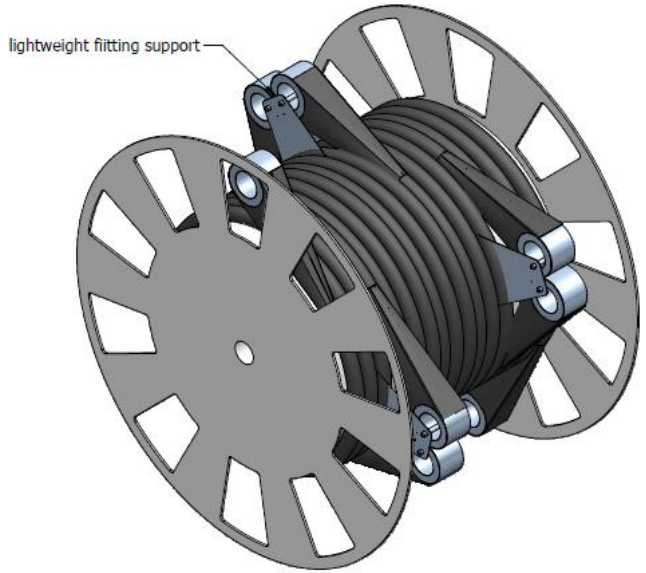
Synthetic Cable Tendons solve many of the traditional TLP mooring and installation challenges

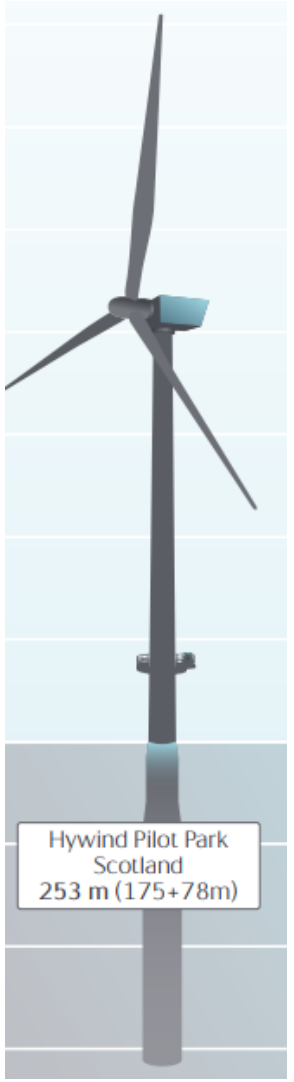
- Enable simultaneous tendon and platform installation
- Minimize need to adjust tendon tensions to balance uneven loads at installation *Patent Pending*
- Tolerate slack-line events in extreme conditions



TENDONS VS. CHAIN - 6MW FLOATING FOUNDATIONS

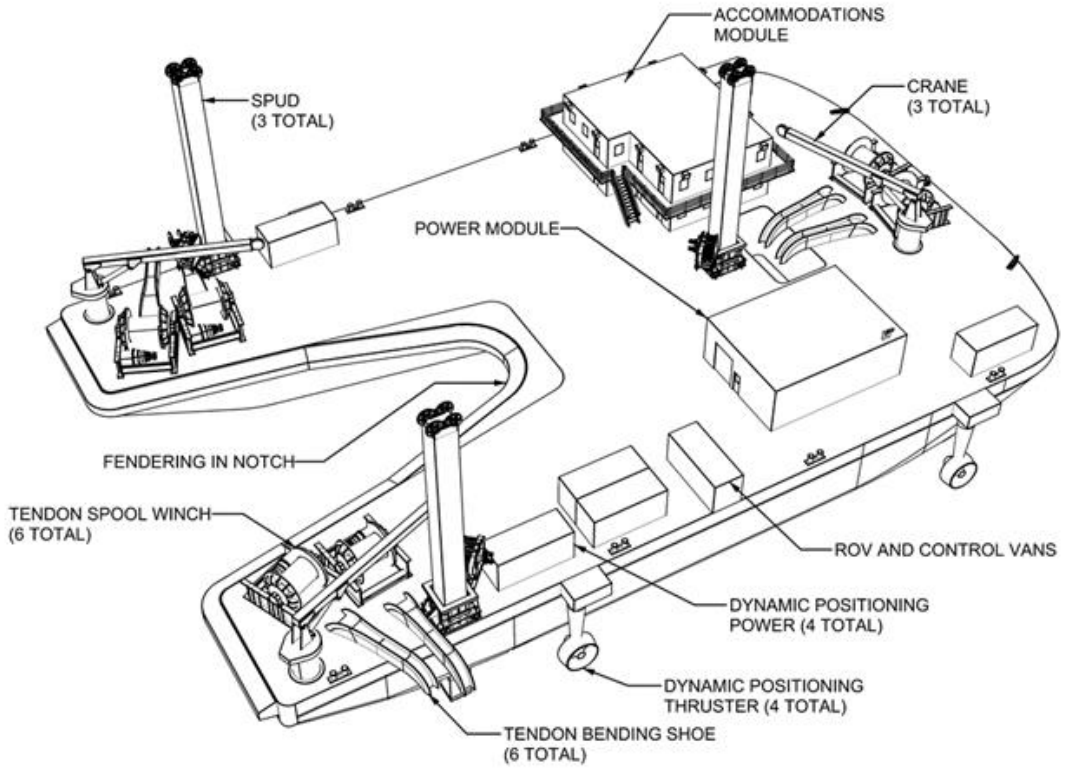
	PelaStar	*Hywind*
Mooring System (in 100m water depth)	5 Vertical Synthetic Tendons, 7.5” dia, totaling 420 meters and 10 tons	3 Catenary Chains, 6” dia, totaling 2,400 meters and 1,200 tons.



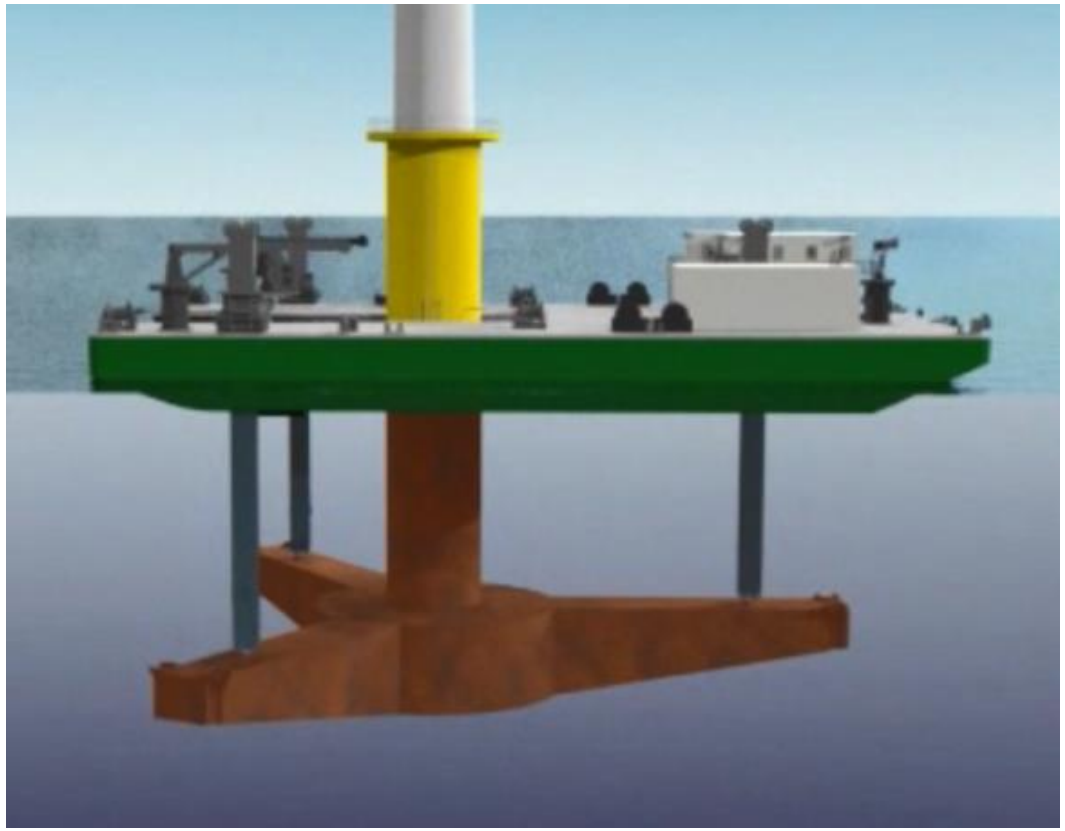


ADVANCED TLP INSTALLATION TECHNOLOGY

- **Design of installation vessel**



Patents awarded in UK and US



Long-term utility-scale installation and deployment method utilizes a dedicated installation barge

DEMO PROJECT FEED STUDY TEAM

Glosten — Engineering, Integration, Cost and Management

ALSTOM — The GE/Alstom 6MW turbine is the first turbine to be integrated with the PelaStar foundation

res — Operations and Maintenance (O&M)

LDD / KML Keynvor MerLift Ltd — Anchor Fab and Installation

Shipyard/ Fabricator — harland and wolff

Tendon Fibre Technology — DSM

Tendon Fabricator — FIBREMax

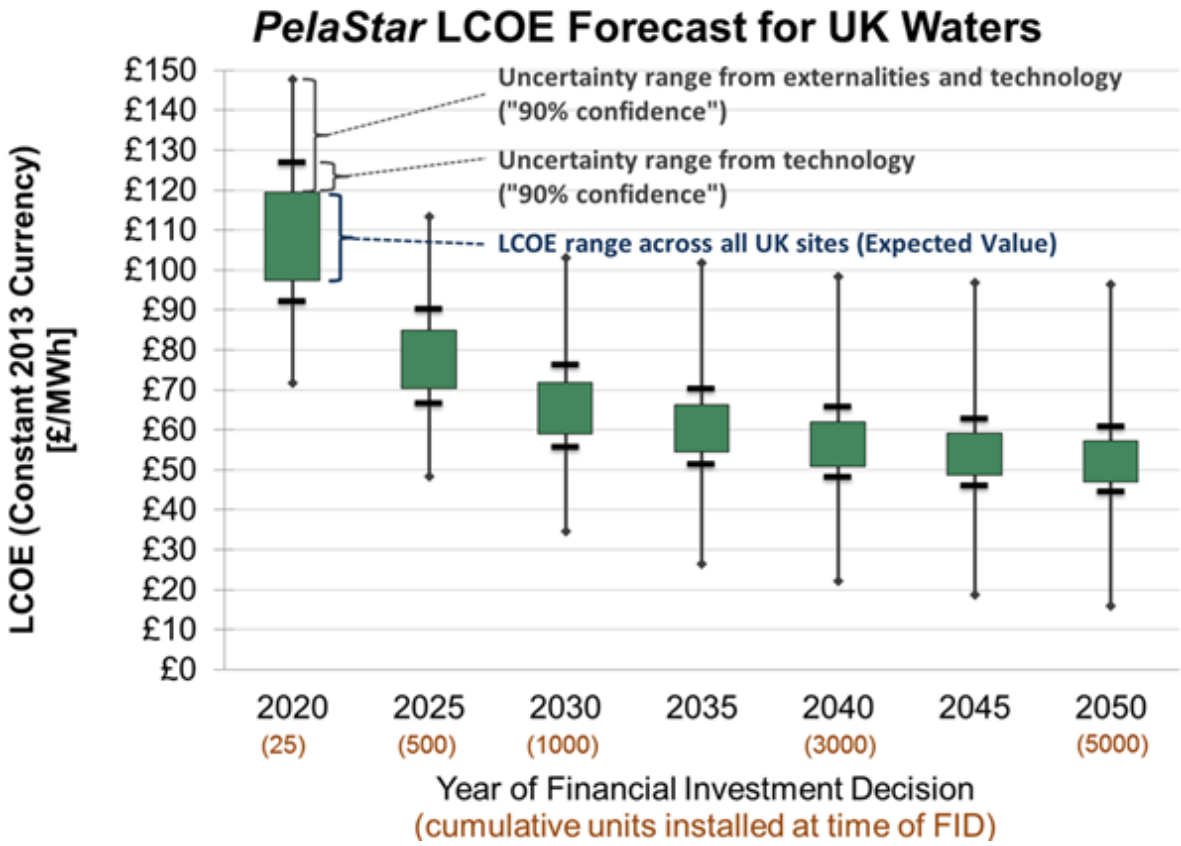
Turbine Assembly and Platform Installation — GeoSea Geotechnical & Offshore Solutions

Project Certification — DNV·GL

ETI Programme Manager: Andrew Scott

DELIVERED FIRST FULLY-VETTED, TRANSPARENT COST DEFINITION TO INDUSTRY

- Demonstrated that the TLP at commercial scale will have the lowest LCOE among all FOWT concepts
  - has the lowest primary steel cost (lowest weight and simple to build),
- Recent steep reductions in bottom-fixed costs, due to competition and learning curves, will lower floating wind baseline cost estimates



This is a 2015 forecast – timeline needs to move out to reflect current industry progress and wind farm development timescales.

TODAY: NEW OPTIONS FOR DEMO INSTALLATION

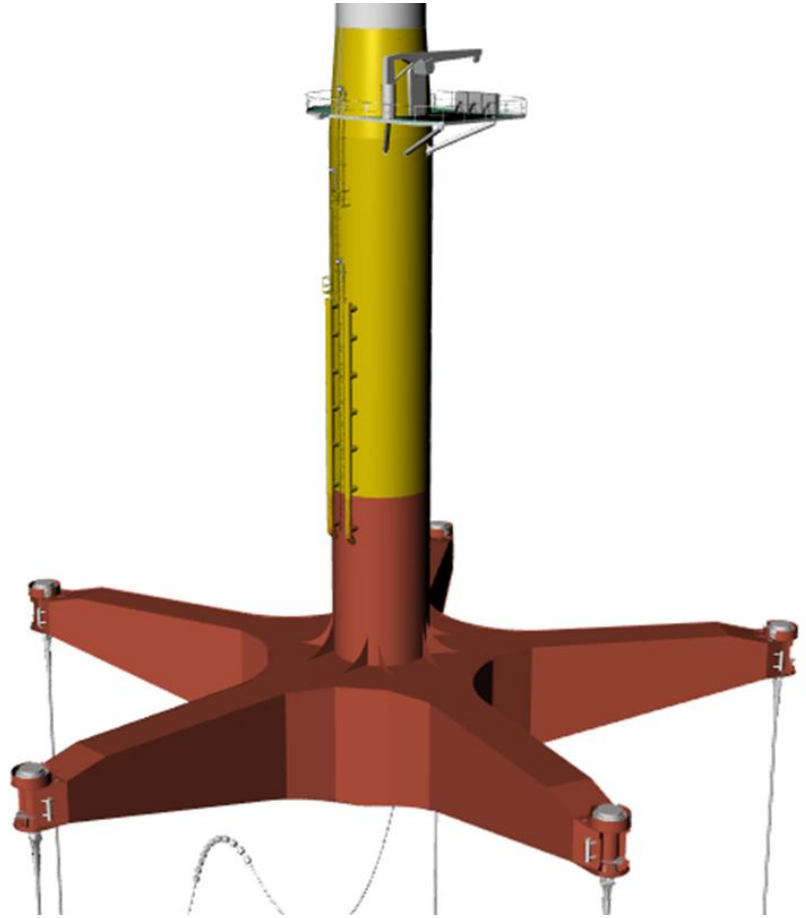
- **DEME / GeoSea's ORION – 2019 delivery – 3,000t lift at 50m reach**
  - **Enables Transport and Installation of PelaStar in Deep Water**
  - **Vessel Dynamic Positioning and Heave Compensation on the Hoist**

OUR PARTNERSHIP ADVANCED TLP TECHNOLOGY

- **Established the TLP as a viable foundation option for deep water offshore wind**
- **Generated worldwide interest in the TLP for deep water offshore wind turbine foundations**
  - **competing concepts emerging**

Today – we continue to pursue a demonstration project and commercialization of PelaStar….

- **….with confidence that the ETI vision and trust in engineering to optimize lowest-cost solutions will be realized.**



Glosten

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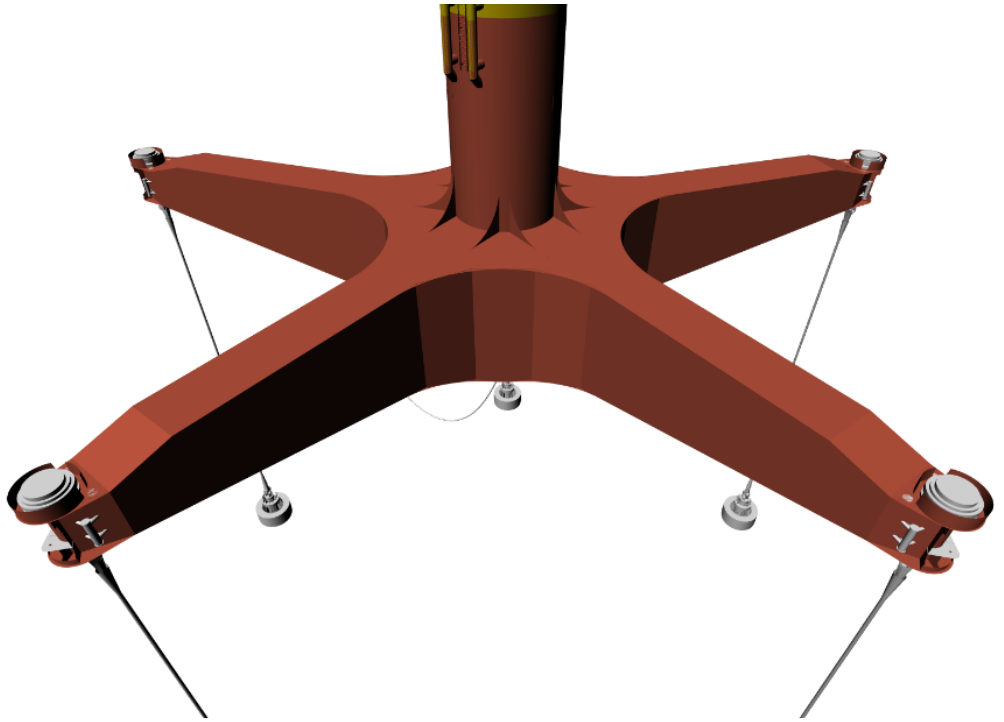
Our ETI Partnership was Extremely Beneficial for Industry, and Highly Rewarding for the Participants

Thank you.



"Scientists discover the world that exists; Engineers create the world that never was."
Theodore von Karman