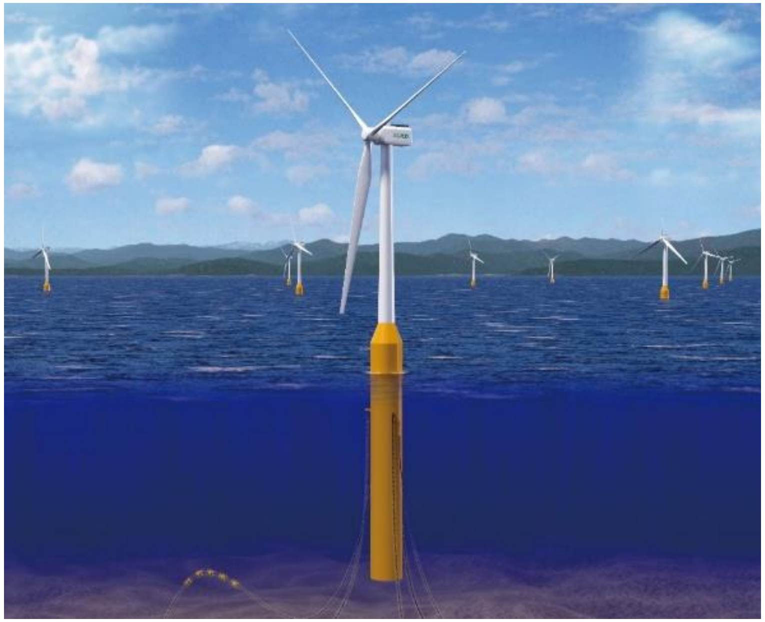
Development of low-cost technology for large floating spar



Marine Civil Engineering Group,
Tokyo Electric Power Company Holdings, Inc.

SOGAWA Yasuhiro
7th July 2022

TEPCO

Corporate profile

Holding company

TEPCO

Tokyo Electric Power Company Holdings

Wind

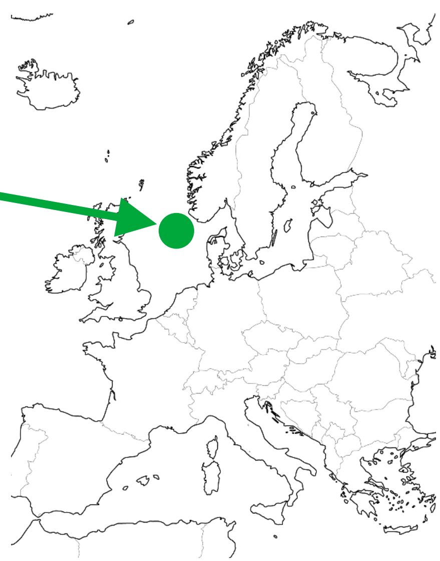
Fuel & Thermal power generation company	General power transmission & distribution company	Electricity Retail company	Renewable energy power generation company
TEPCO Fuel & Power	TEPCO Power Grid	TEPCO Energy Partner	TEPCO Renewable Power

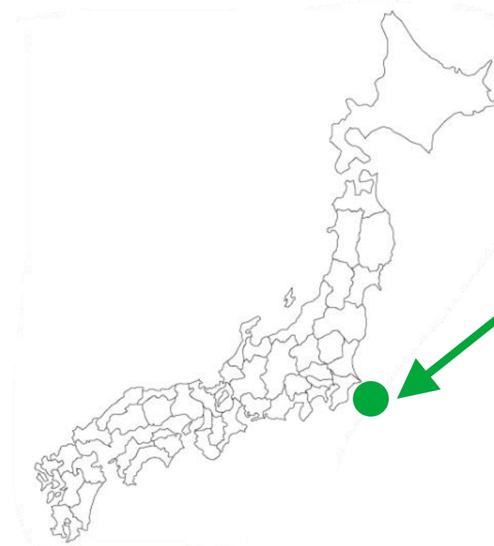
Hydro

PV

TetraSpar Demo (TEPCO/Shell/RWE)

Floating Offshore (3.6MW, 2021)





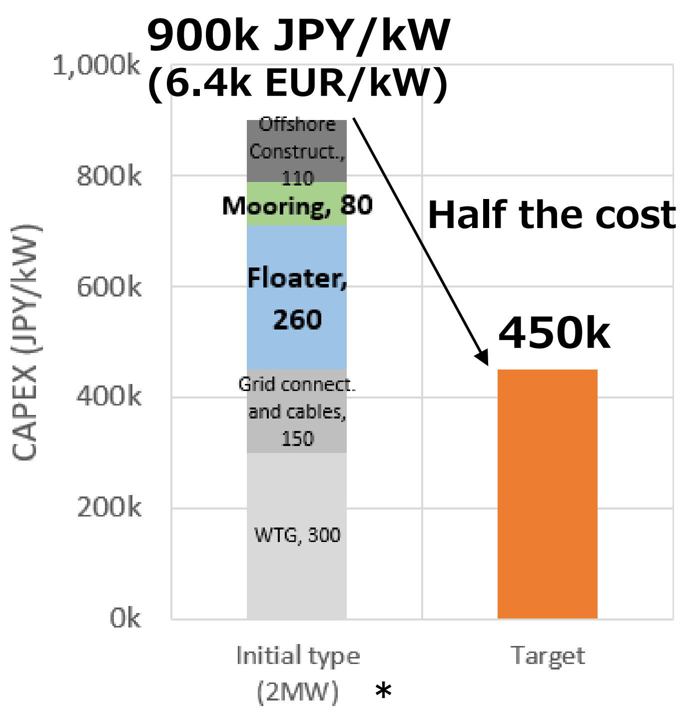
Choshi

Fixed Offshore (2.4MW, 2019)

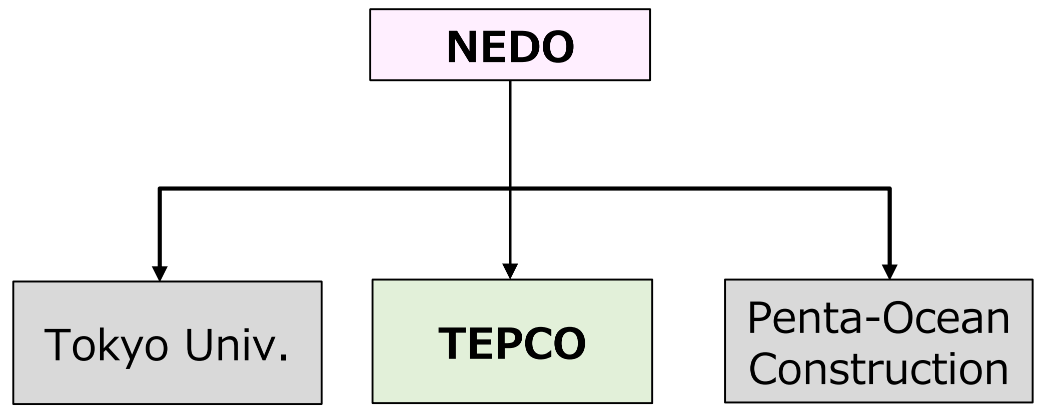
TEPCO

Background

- Working on CAPEX reduction to establish floating offshore wind at **a LCOE less than 20 JPY/kWh (CAPEX less than 450k JPY/kW)** by 2030.
- Consortium studied cost reduction technologies for **10MW spar type floater** using **NEDO subsidy** for two years from 2020.



CAPEX



Study Scope

Tokyo Univ.:
- Motion analysis
- Cost evaluation model

TEPCO:
- **Floater design and manufacturing**
- **Mooring and Anchor system**

Penta-Ocean Construction:
- Offshore construct.
- Construct. Vessel design

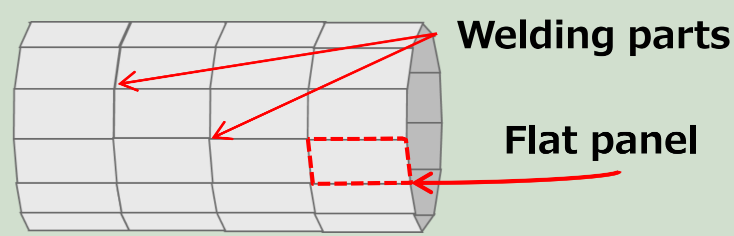
Feasibility study consortium

* Ref. : Floating Offshore Wind Market and Technology Review (Carbon Trust, June 2016)

Cost reduction technology

- ◆ Conventional cylindrical spar type floaters require the installation of many **expensive thick plate bending machines**, resulting in high manufacturing costs.
- ◆ In order to reduce the floater cost, we proposed **the flat panel floater**, which does not require the bending machine, and evaluated cost reduction effects.

Pros/Cons of cylindrical floater and flat panel floater

	Cylindrical floater（Conventional）	Flat panel floater（Patent）
Pros	● Mechanically rational shape due to its circular structure	● **Can be manufactured even in plants w/o expensive thick plate bending machine**
Cons	● **Expensive thick plate bending machine** must be installed	● Reinforcement may be needed for local areas such as corners where stress concentration occurs.
Ima-ge	 Manufacturing method at Hywind Scotland	 Image of spar type floater using flat panel

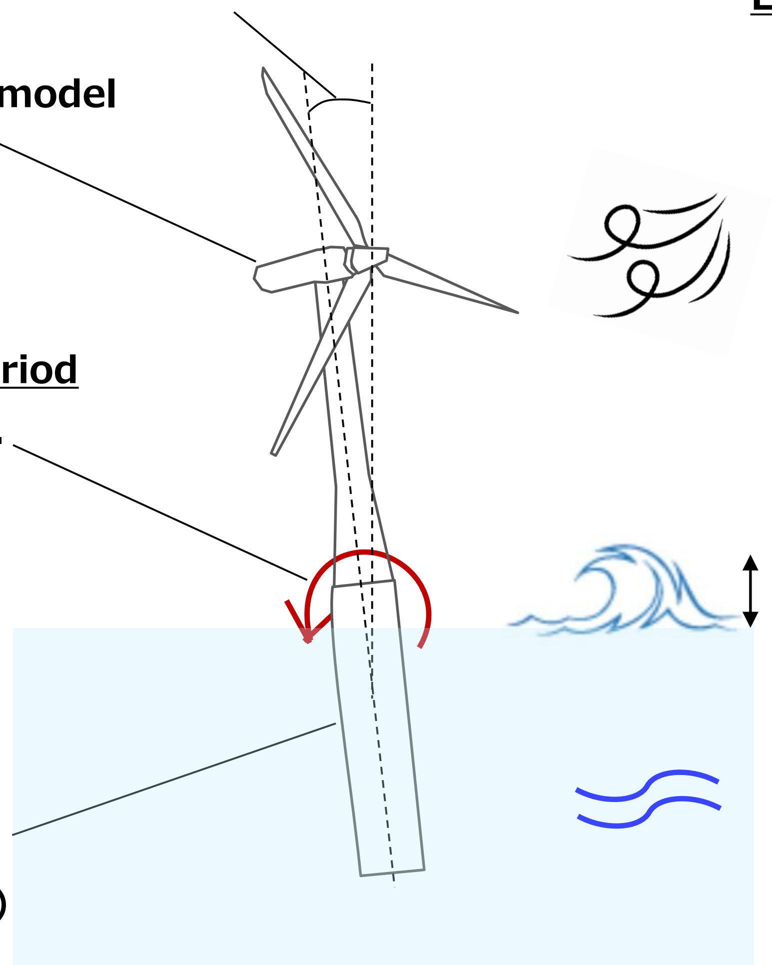
Design condition for floater and mooring

<u>Static tilt angle</u>
: Less than 5deg

<u>WTG</u>
: DTU 10MW Ref model

<u>Pitch natural period</u>
: Over 25 sec.

<u>Floater material</u>
: High-tensile strength steel
(Yield stress 315N/mm^2)



<u>Environmental condition</u>
(50-year storm)

①Wind speed 52m/s

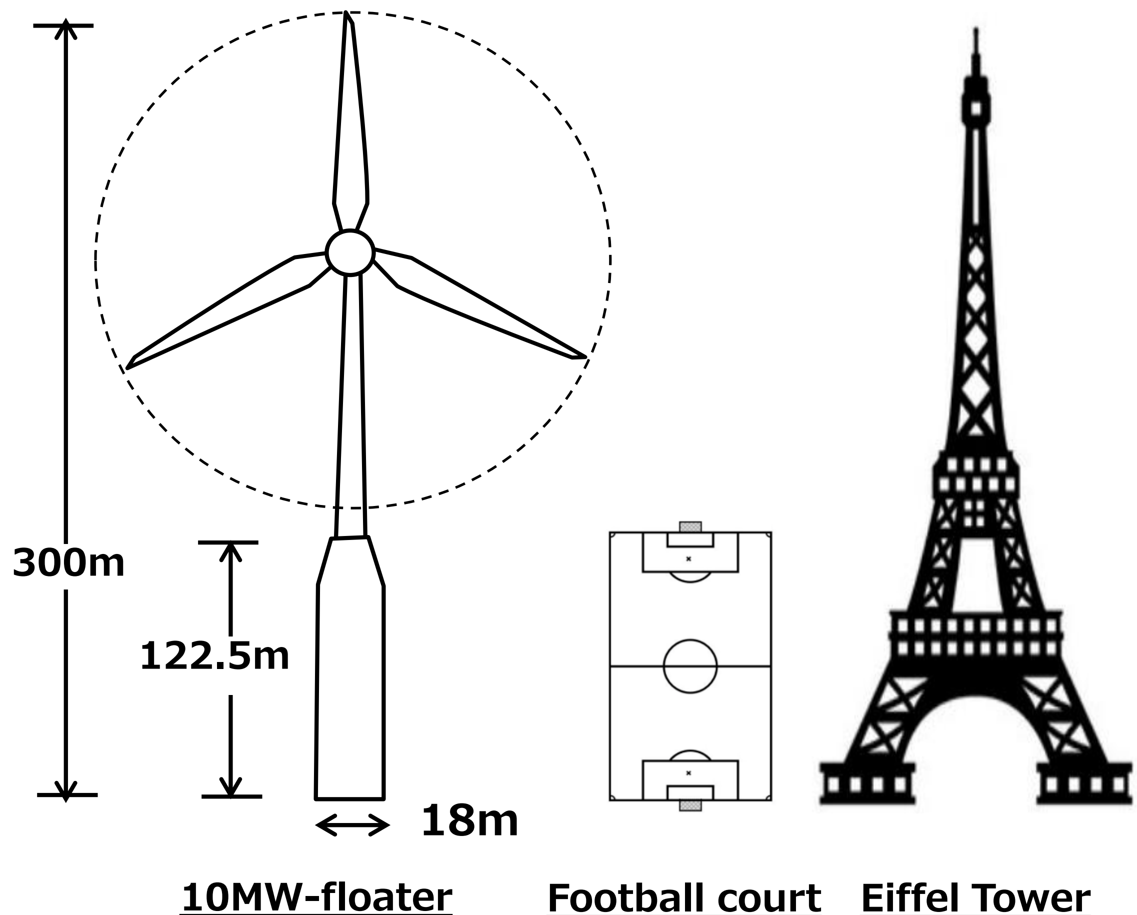
②Wave height 12m
Wave period 12-17sec

③Current 1.5m/s

10MW class floater study

◆ Floater dimensions set at **18.0m diameter and 122.5m height** in terms of natural period and static tilt angle.

	Main dimensions
Floater shape	Flat panel floater
Diameter	18.0 m
Height	122.5 m
Draft	97.5 m
Weight (incl. ballast)	22,000 ton
Pitch natural period	28.3 sec
Static tilt angle	4.7 deg

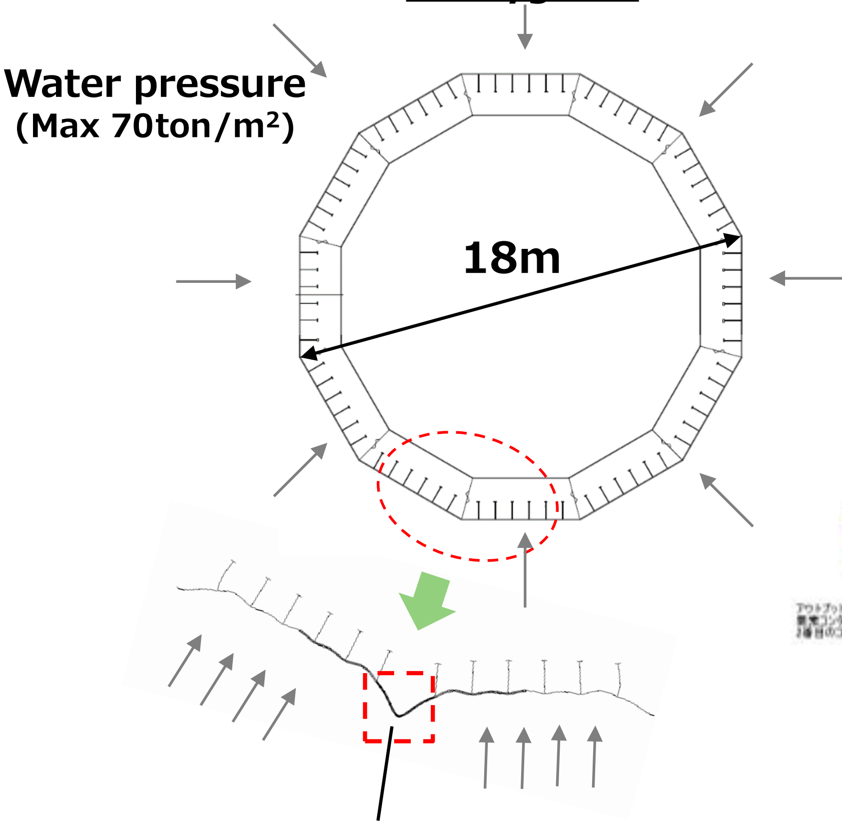


TEPCO

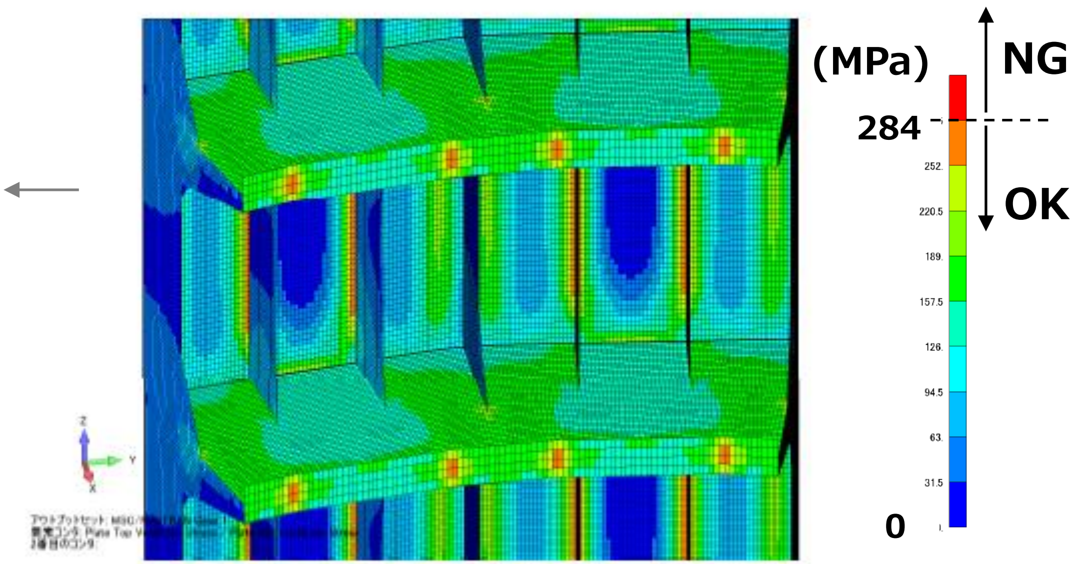
Local structure analysis

- Confirmed that the stresses were below the allowable stresses of the steel
- Floater weight is expected to be **almost the same as the cylindrical floaters**, including reinforcement against stress concentration in the horizontal corners.

Flat panel floater (Polygon)



Stress concentration tends to occur at horizontal corners.



Inside floater

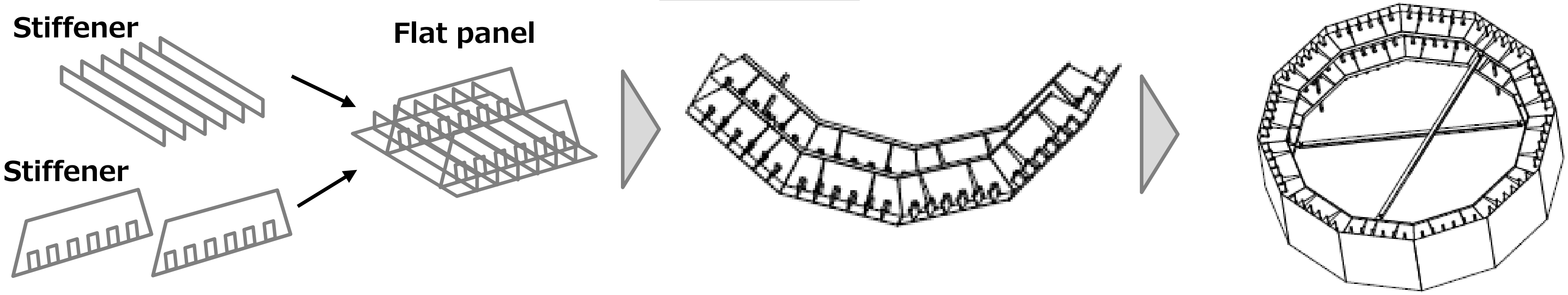
Local structure analysis results
(Generated stress illustration)

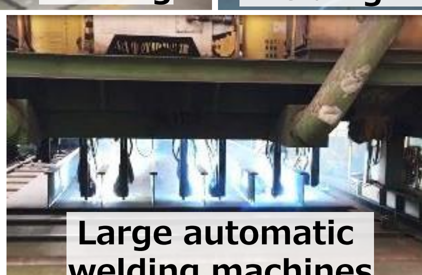
TEPCO

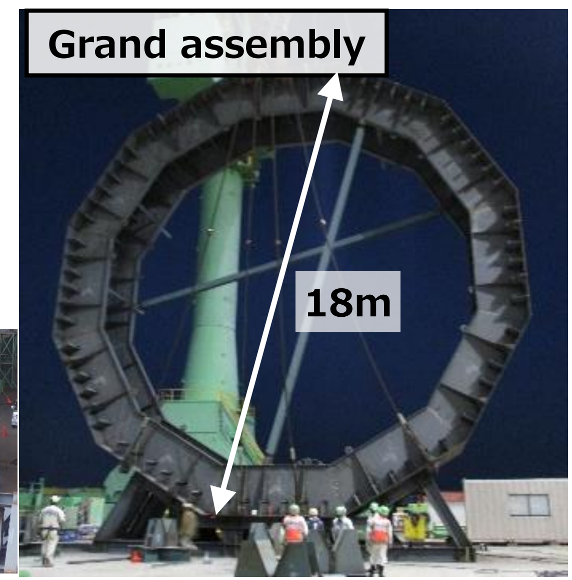
Assessment of manufacturing method (Prototype test)

- In flat sections, the use of **automatic welding machines** significantly reduces the man-made time compared to manual welding.
- The floater can be manufactured with a **0.02% difference** from the cross-sectional area of the regular shape

Sub-assembly **Assembly** **Grand assembly**

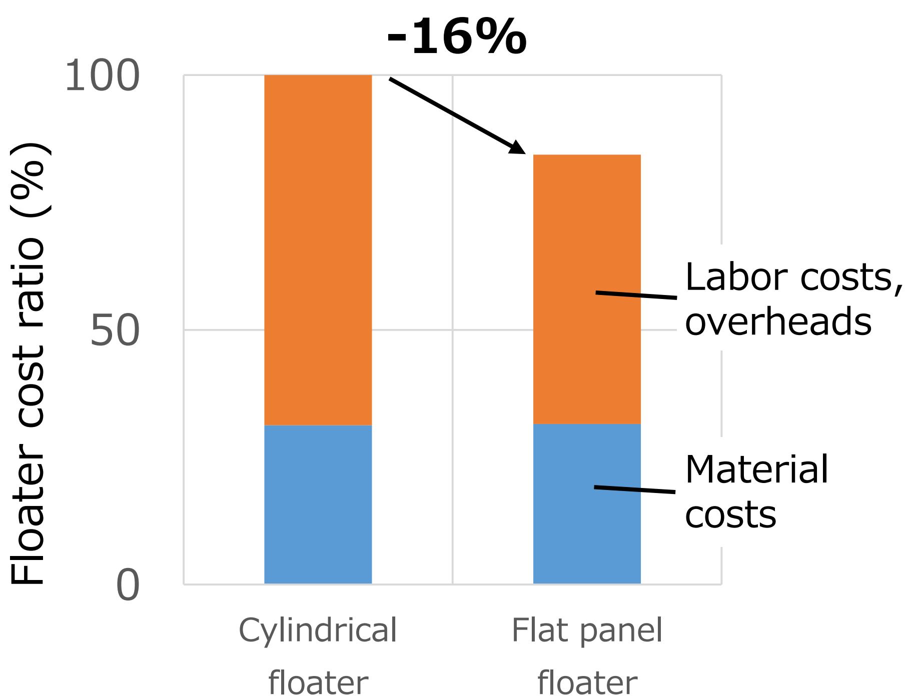






Floater cost assessment

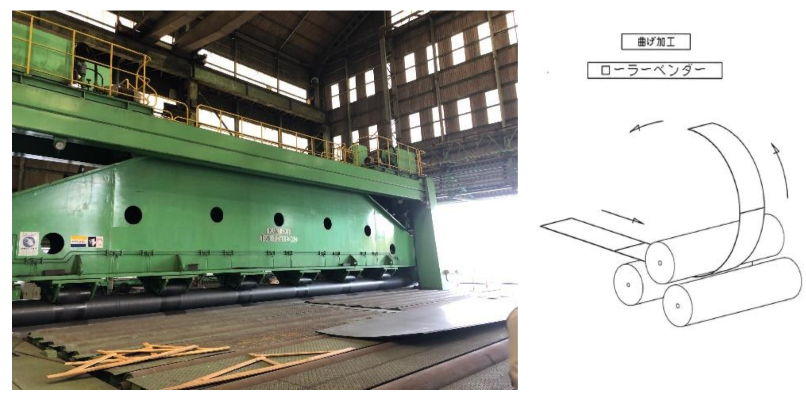
- The cost of flat panel floater is expected to be **reduced by 16%** compared to the conventional cylindrical floater.
- The main reductions are approximately **3% in labor costs** due to shorter working hours and approximately **13% in overheads** due to bending machines installation.



Comparison of floater costs

Main difference factors

- Increased work time due to bending work and **manual welding and distortion removal** of stiffeners in bending sections
- Increase in overheads due to installation of 8 bending machines (**approx. 400 million JPY/unit**).



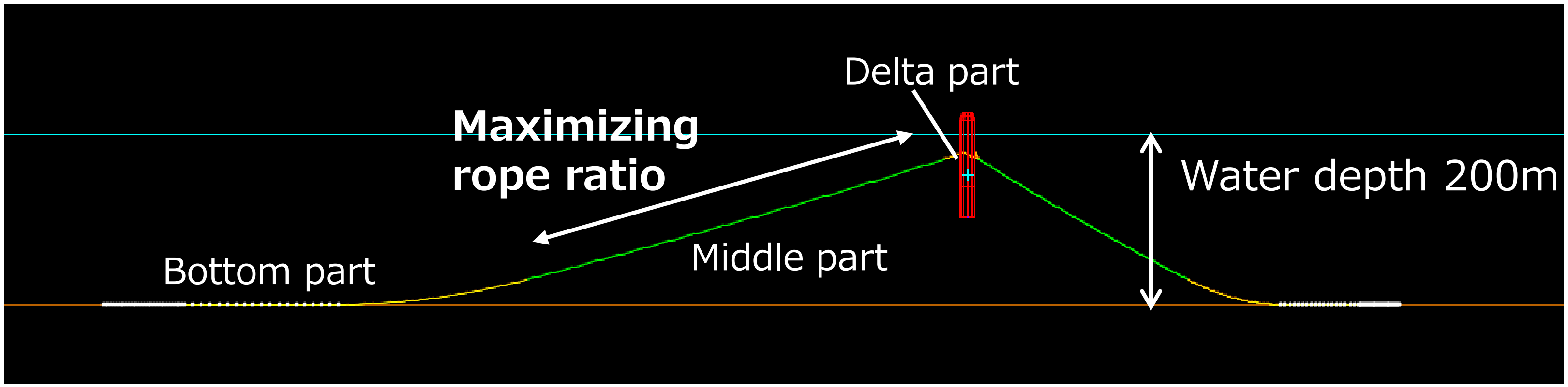
Example of bending machine

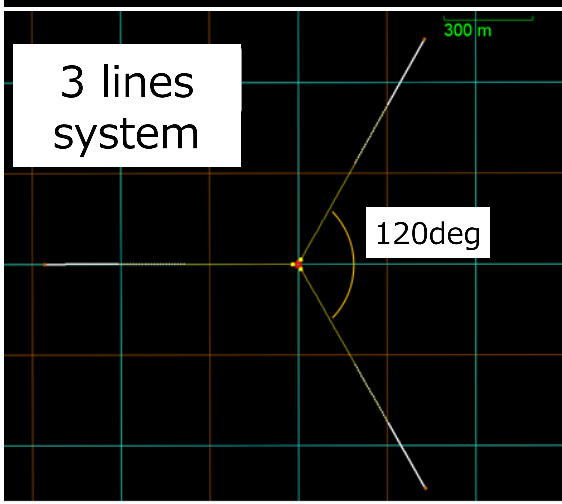
TEPCO

Study of hybrid mooring lines

The cost-reducing effect of hybrid mooring lines on an all-chain system is studied at a water depth of 200m.

Modelling and study by Orcaflex





Unit price ratio

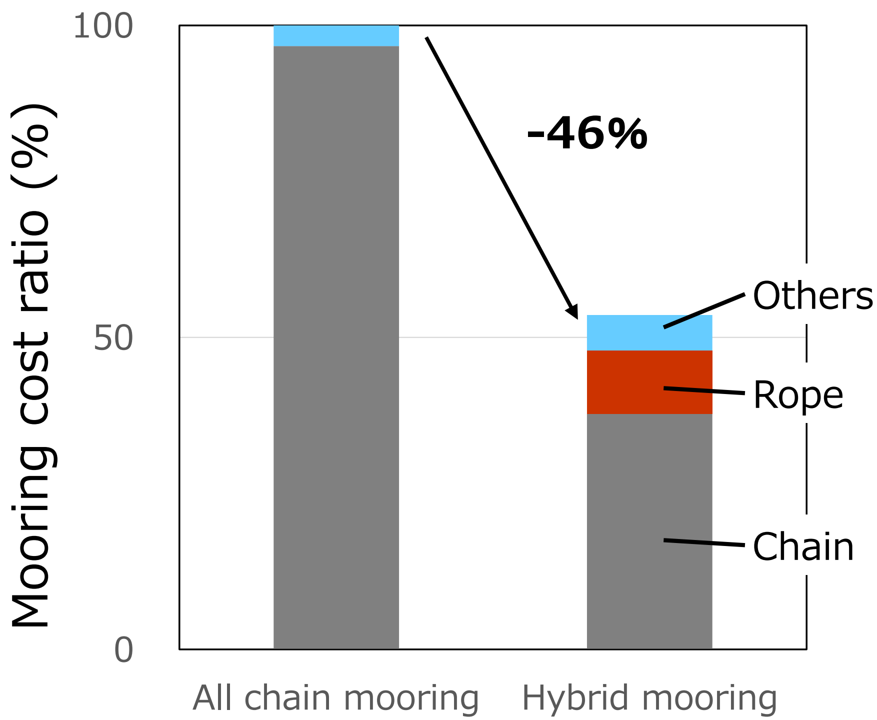
Material	Unit price ratio
Chain	4.5
Fiber rope	1

Maximizing the proportion of inexpensive rope in the composition is important.

Results and cost assessment

◆ The use of a hybrid mooring lines has resulted in a projected **cost reduction of 46%** compared to conventional all-chain lines.

	All chain	Hybrid
At middle part	R5 Chain Φ162mm	**Synthetic fiber Rope** Φ296mm
	892m	**500m**
At bottom part	Same as the middle part	R4S Chain Φ147mm
		495m
Deployment radius	**850m**	1000m



TEPCO

Conclusions and future plans

- Developed **a low-cost and fast-track flat panel floater** for a 10 MW class wind turbine, and confirmed the feasibility and manufacturing accuracy of the floater.
- The floater cost is expected to be **reduced by 16%** compared to the conventional.
- The use of a hybrid mooring lines has resulted in a projected **cost reduction of 46%** compared to the conventional.

	2022	2023	2024～
Future plans	Elemental Technology Development (Ph-1) GI Fund subsidy amount :10 bil JPY		Floating demo(Ph-2) Subsidy amount :85 bil JPY

<GI Fund Theme>

① Optimization of floating foundations
② Mass production of floating bodies
③ Optimization of mooring systems
④ Hybrid mooring system
⑤ Development of low-cost construction technology

<Ref. :「洋上風力発電の低コスト化」プロジェクトに関する研究開発・社会実装計画（概要）>

TEPCO