EERA DEEPWIND 2018
RADISSON BLU ROYAL GARDEN HOTEL, TRONDHEIM

OO-STAR WIND FLOATER
THE FUTURE OF OFFSHORE WIND?

Trondheim, January 19th. 2018

Trond Landbø
Manager Business Area Energy/Renewable
Dr.techn.Olav Olsen AS

INTRODUCTION - MAIN MESSAGES

> We believe floating wind will beat onshore wind as well as bottom fixed offshore wind in the future

> We believe that in the future there will be three different segments within the wind industry:
> - **Onshore wind**; WTGs limited to typically **5 MW** due to transport and installation limitations on land
> - **Offshore wind, bottom fixed**; WTGs limited to typically **10 MW** due to installation cost
> - **Offshore wind, floating**; WTGs typically **20 MW**, no size limitations related to assembly and installation

> We believe Olav Olsen has developed a very cost effective floating solution with the OO-Star Wind Floater, with all the qualities required by the future floating offshore wind market

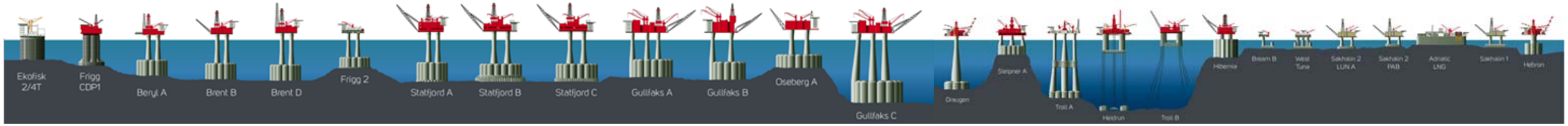
DR.TECHN.OLAV OLSEN AS INTRODUCTION

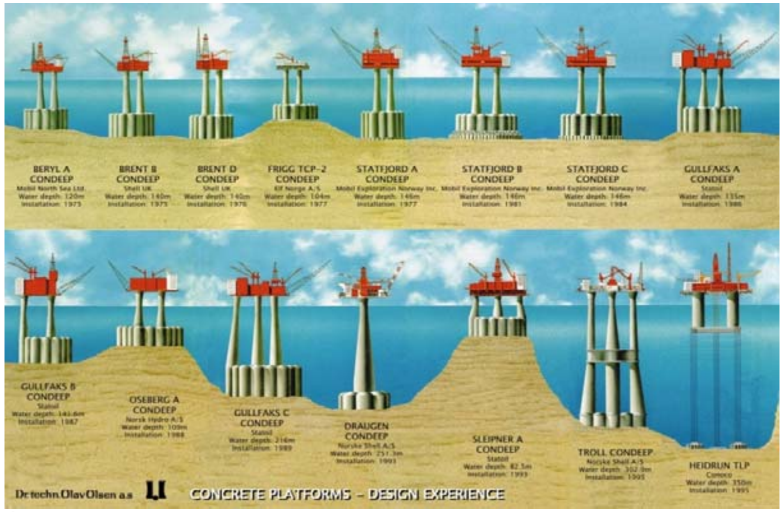
DR.TECHN. OLAV OLSEN – COMPANY PROFILE

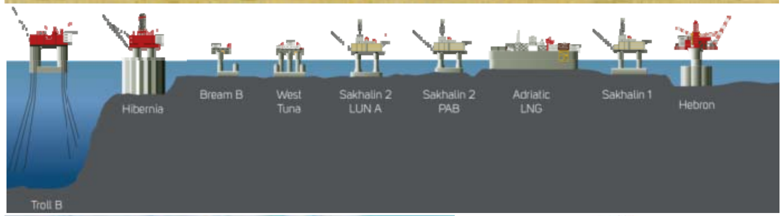
> Norwegian independent Structural and Marine consulting company founded in 1962
> Offices in Oslo and Trondheim (Norway)
> Approximately 90 employees
> Contributes in all project phases, from concept development to decommissioning
> Active in research and development projects

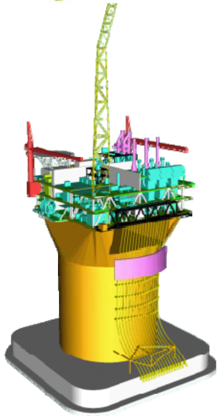
OFFSHORE CONCRETE STRUCTURES

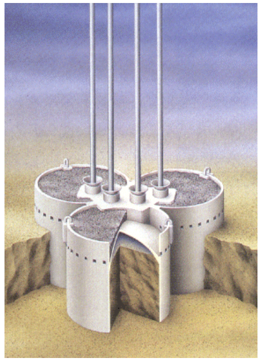
- > World leading designer of offshore concrete structures
- > Shallow to deepwater
- > Gravity Base Structures (GBS)
- > Floating concrete platforms
- > Arctic applications

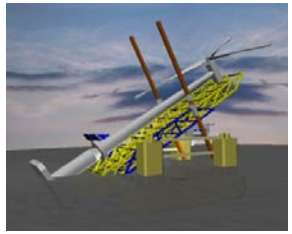


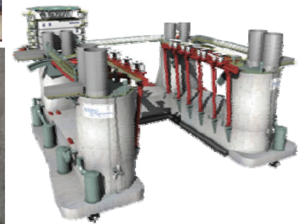

BERYL A CONDEEP
Mobil North Sea Ltd.
BRENT B CONDEEP
Shell UK
BRENT D CONDEEP
Shell UK
FRIGG TCP-2 CONDEEP
Elf Norge A/S
STATFJORD A CONDEEP
Mobil Exploration Norway Inc.
STATFJORD B CONDEEP
Mobil Exploration Norway Inc.
STATFJORD C CONDEEP
Mobil Exploration Norway Inc.
GULLFAKS A CONDEEP
Statoil
GULLFAKS B CONDEEP
Statoil
OSEBERG A CONDEEP
Norsk Hydro A/S
GULLFAKS C CONDEEP
Statoil
DRAUGEN CONDEEP
Norske Shell A/S
SLEIPNER A CONDEEP
Statoil
TROLL CONDEEP
Norske Shell A/S
HEIDRUN TLP
Conoco
Dr.techn.Olav Olsen a.s
CONCRETE PLATFORMS – DESIGN EXPERIENCE

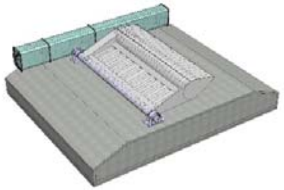

Hibernia
Bream B
West Tuna
Sakhalin 2 LUN A
Sakhalin 2 PAB
Adriatic LNG
Sakhalin 1
Hebron
Troll B

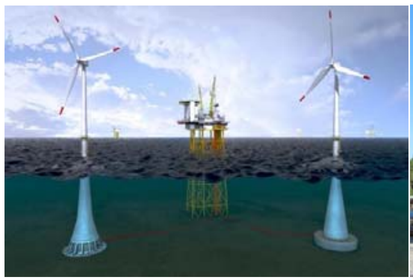


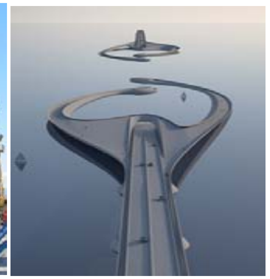








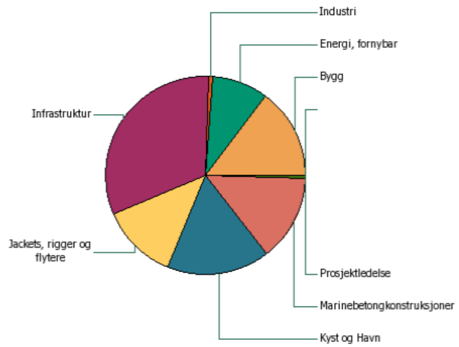




BUSINESS AREAS

- > Buildings onshore
- > Offshore Oil & Gas
- > Renewable energy
- > Infrastructures
- > Harbours and Industry
- > OO «Futurum»

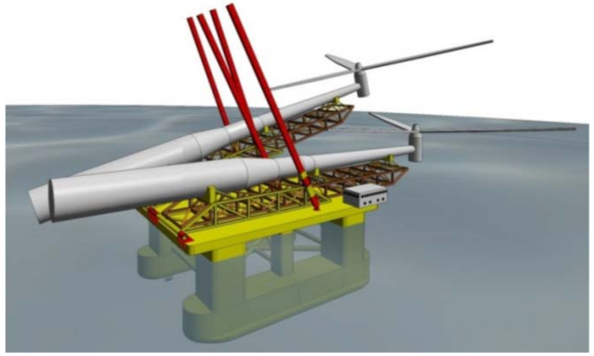
Core business: Structural & Marine engineering



Adding value to company and clients

DR.TECHN.OLAV OLSEN AS
OFFSHORE WIND

OLAV OLSEN - OFFSHORE WIND



OLAV OLSEN - CAPABILITIES OFFSHORE WIND

> Substructures
- Bottom fixed and floating
- Steel and concrete
- Concept development
- Design and analysis (ShellDesign)
- Geotechnics

> Mooring and anchors
- System configuration
- System design
- Geotechnics

> Installation
- Method development
- Installation concepts

> Fully coupled simulations:
- SIMA
- 3DFloat
- Deeplines
- (Orcaflex, Ashes, FEDEM Windpower)

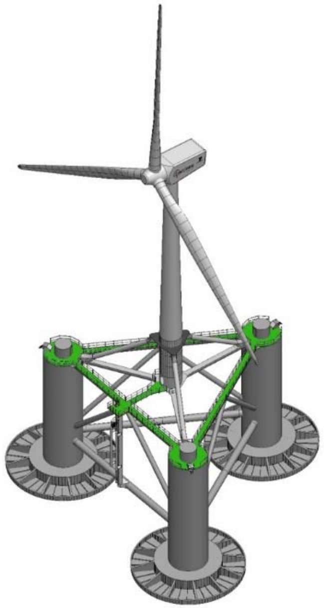
> Cost models
- Fabrication and Installation
  - Substructure
  - Mooring
  - Anchors

> Third party verification

FLOATING OFFSHORE WIND TURBINES

Hywind

Hydro/Statoil



HiPRWind

EU project

OO Star Wind Floater

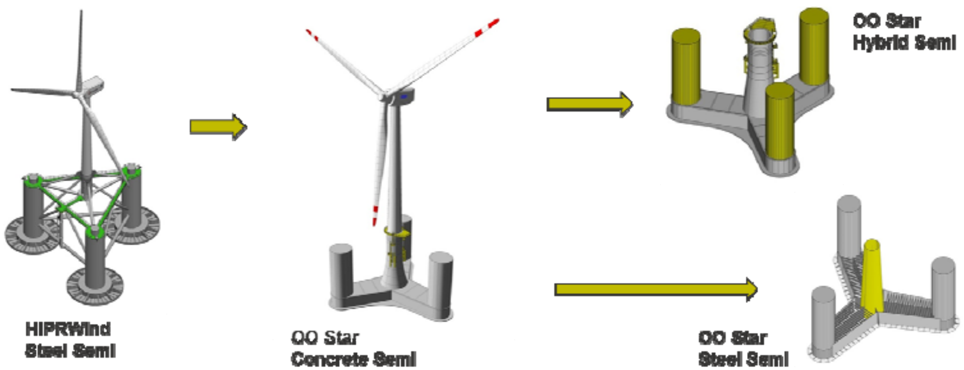
Patented concept

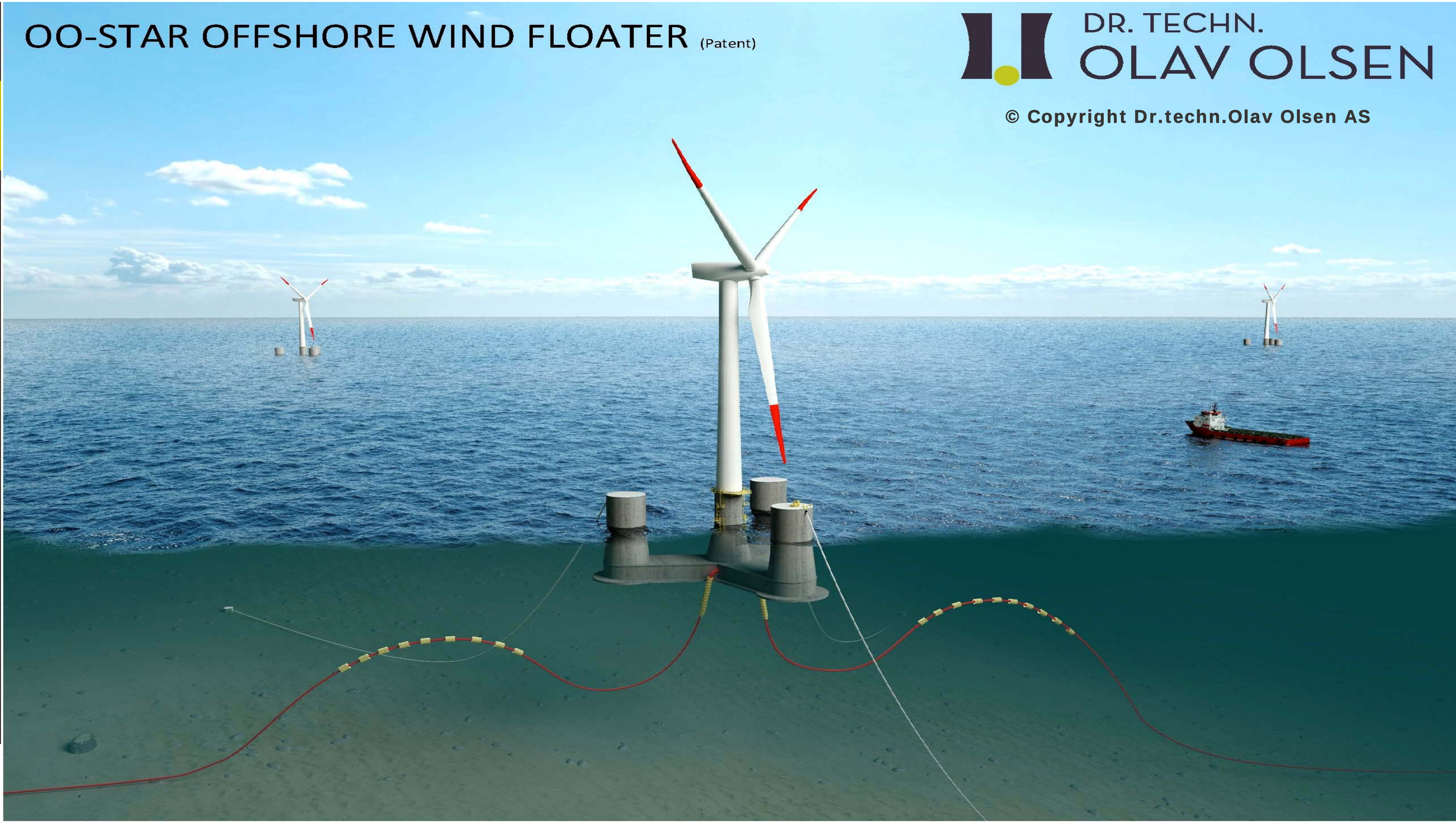
OO-STAR WIND FLOATER

THE OO-STAR WIND FLOATER HISTORY

> Few realistic WTG floaters before 2010
> Hiprwind (2010) – questions to scalability and fatigue

> What does the optimal floater look like?
> OO-Star Wind Floater developed 2010/11, presented at ONS2012
> Preferred concept (steel) for EU project Floatgen – Acciona part 3 MW WTG
> NFR project 2013-2014: Designed for 6MW, WD 100 m, North Sea
> LIFES50+ 2015-2018: Up-scaling to 10 MW, WD 70-130 m, Hs=7.0 -15.6 m




OO-STAR OFFSHORE WIND FLOATER (Patent)
DR. TECHN.
OLAV OLSEN
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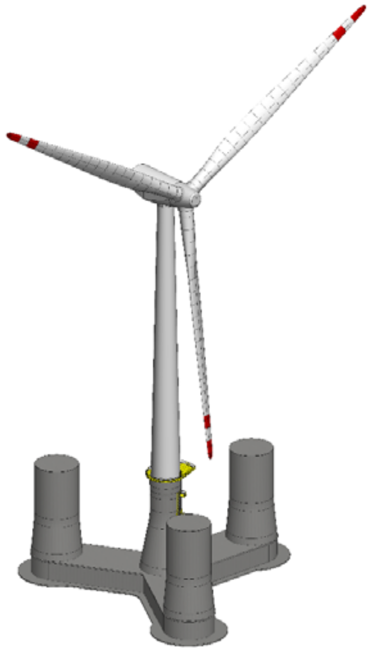
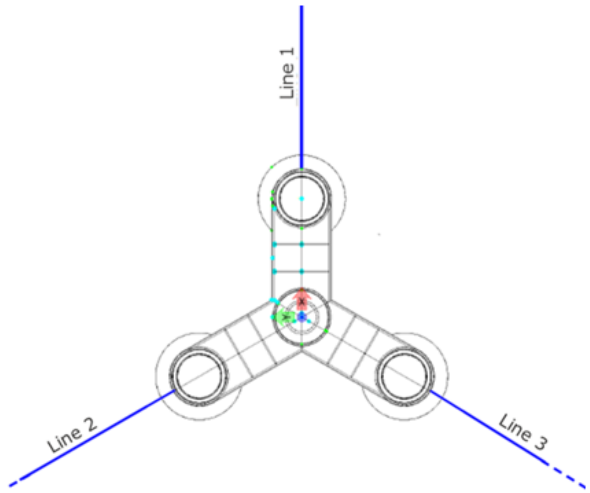
OO-STAR WIND FLOATER – GENERAL DESCRIPTION

- Robust, stable and very simple 3-leg semisubmersible floater.
- Passive ballast system
- Water depth potential from 50 m
- Concrete, steel or a combination (hybrid). Material selection according to optimal design, cost, fabrication facilities etc.
- Concrete best suited for large wind turbines. Not fatigue sensitive and long design life, 100 years +. Possible to reuse floater.
- The OO-Star Wind Floater consists of a central shaft supporting the WTG, and a tri-star shaped pontoon supporting 3 buoyancy cylinders for optimal stability.
- Permanent buoyancy in the columns and shaft. The pontoons provide structural support of the columns, weight stability, damping/added mass and temporary buoyancy for inshore assembly.
- Fabrication in a dock, on a barge or on a quay. The structure is well suited for modular fabrication.
- The substructure can float with very small draft and the unit can be fully assembled at quay-side before tow to site. No requirements for deep waters at assembly site.
- Transport to site by towing. No requirements for expensive offshore heavy lifts.



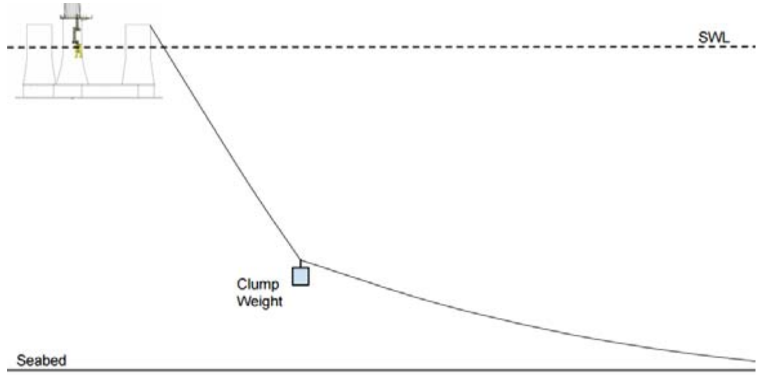
MOORING - BASIC CONFIGURATION

> 3 line system

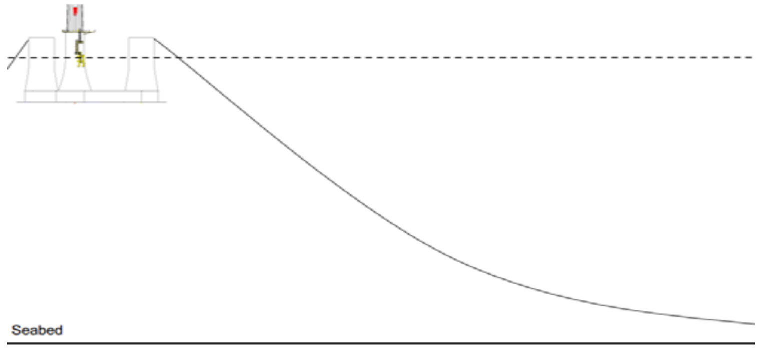


> Focus on new development
  - Line configurations
  - Number of lines
  - Line materials
  - Anchor types and sharing

GoF and GoM: Chain catenary with Clump weight

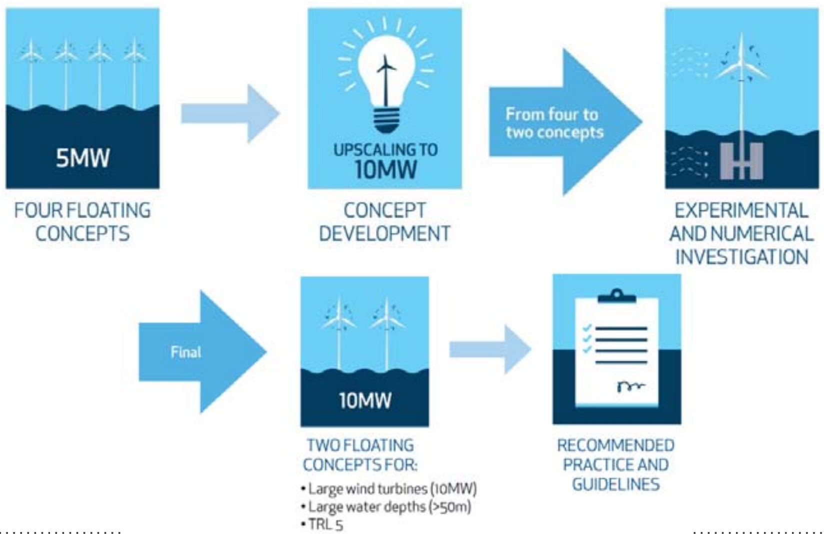


WoB: Pure chain catenary



HORIZON 2020 - LIFES 50+

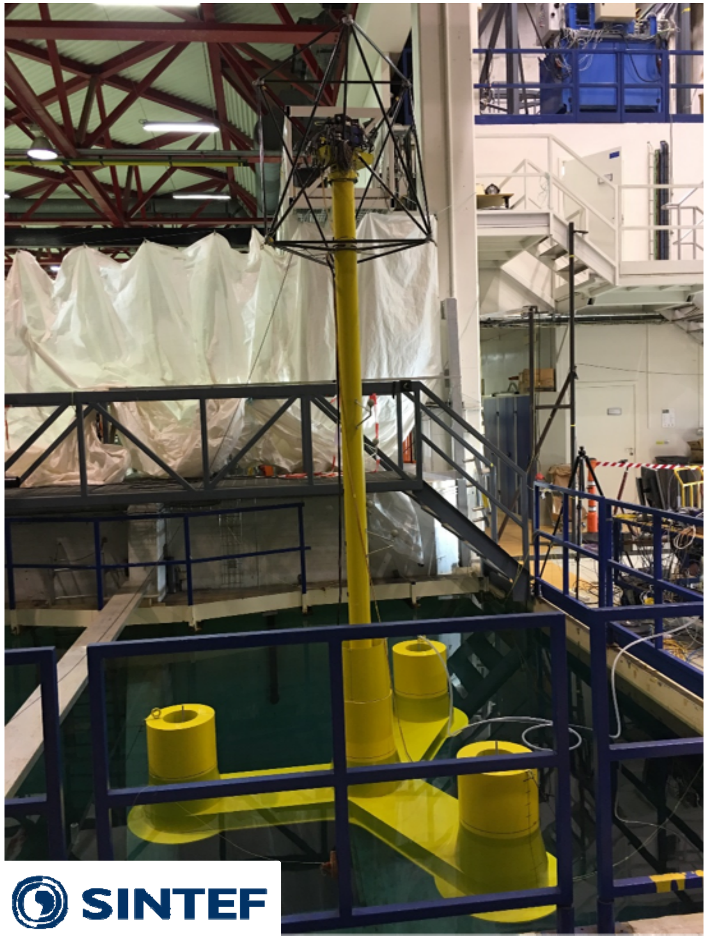
> Horizon 2020 project, total budget 7.3 MEuro
> Project lead by SINTEF Ocean
> OO Star Wind Floater selected as one of two concepts for Phase 2 (model testing and further development)
> Project web page: http://lifes50plus.eu/



DR. TECHN. OLAV OLSEN
This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 640741

LIFES 50+ MODEL TESTS

- > Modell tests planned in Phase 2:
  - Ocean Basin at SINTEF Ocean, November 2017 (Scale 1:36)
  - Wind tunnel at Polimi, Spring 2018 (Scale 1:75)



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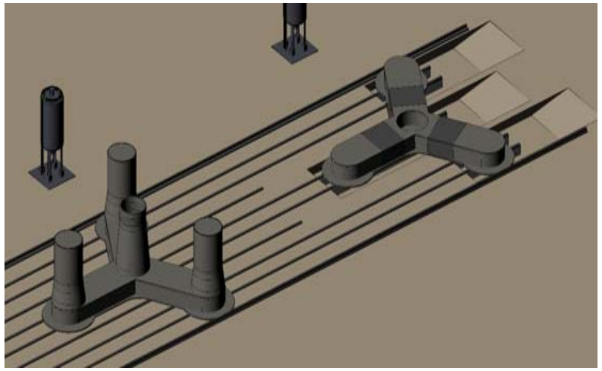
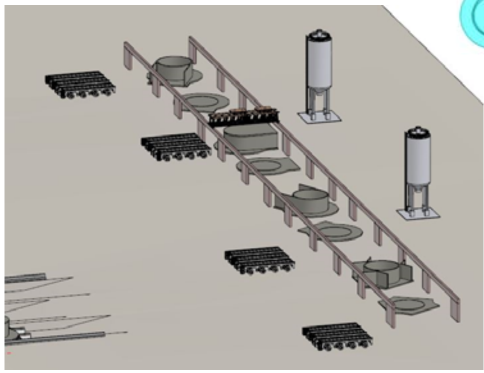
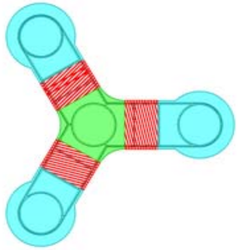
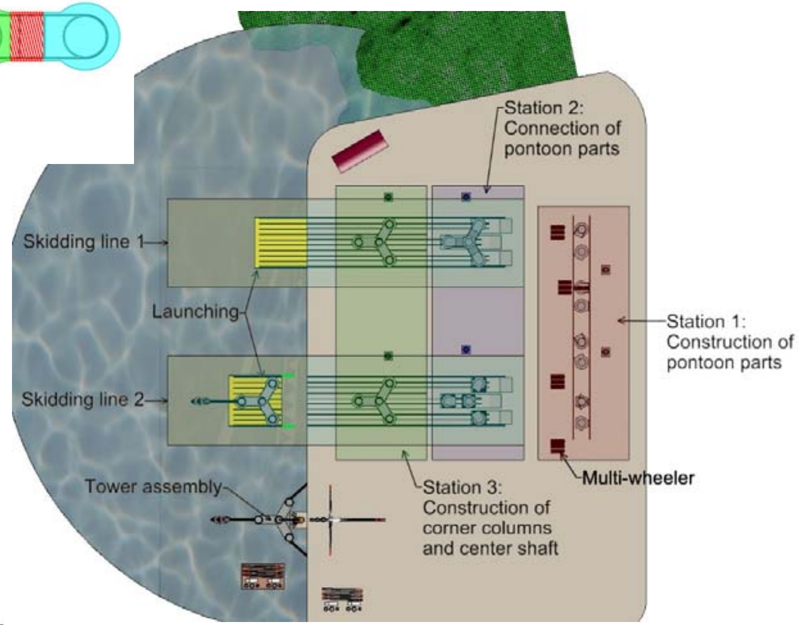
FABRICATION/INSTALLATION
OO-STAR WIND FLOATER

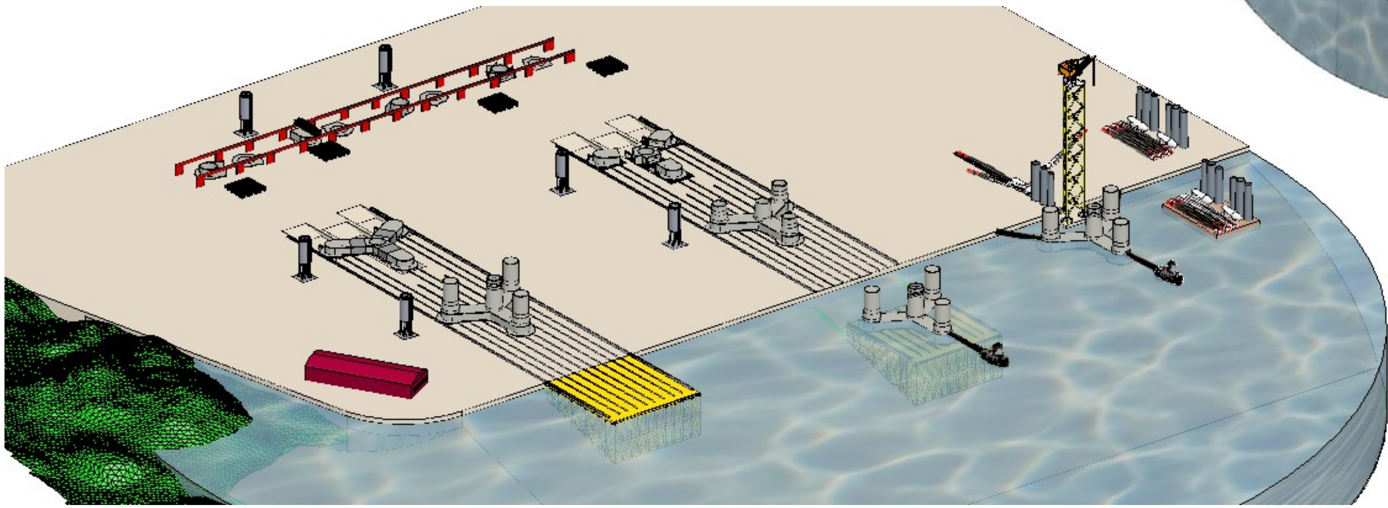
FABRICATION SET-UP

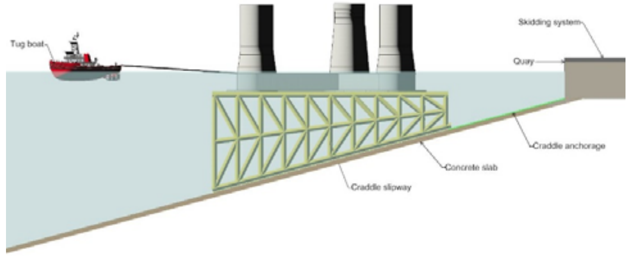








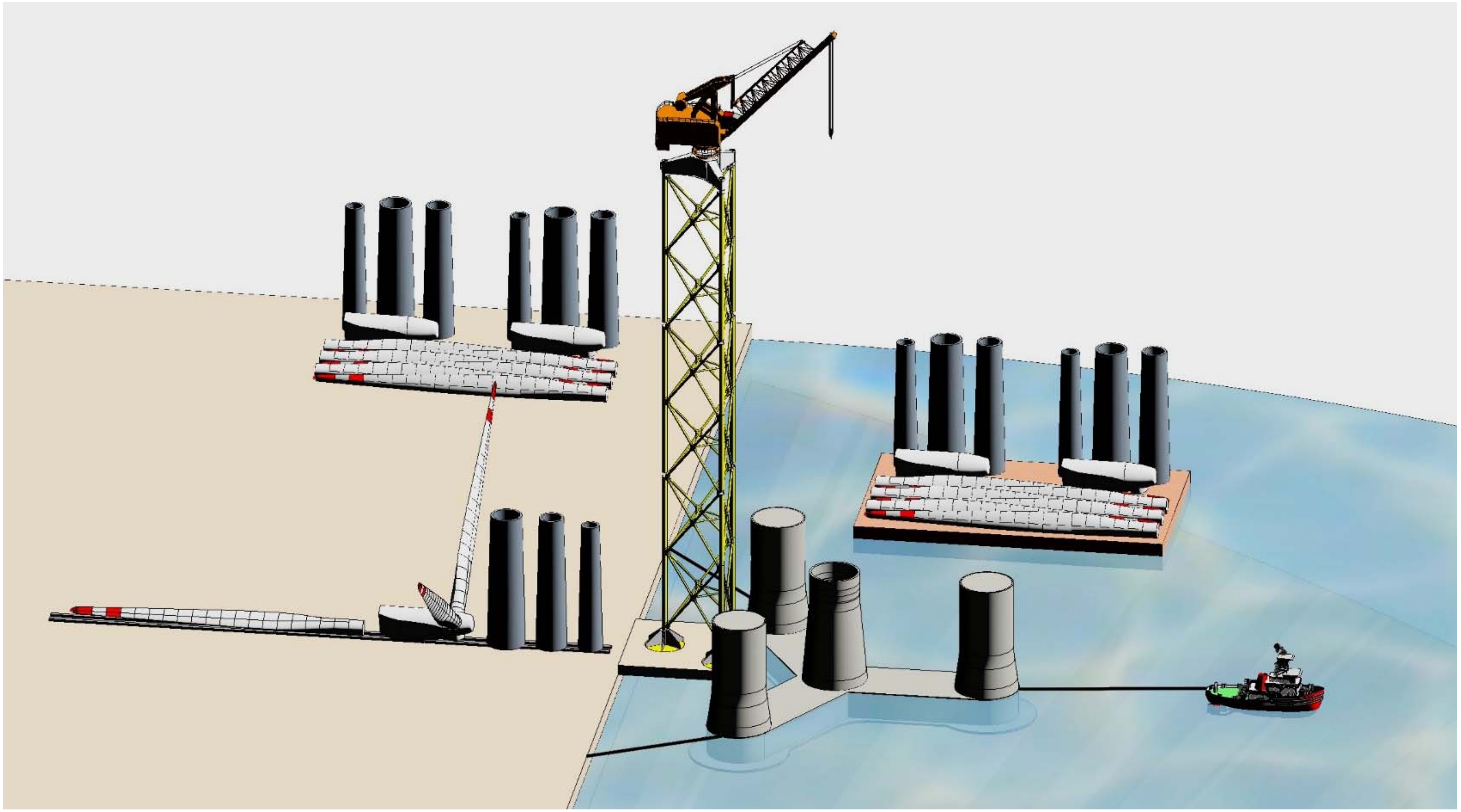




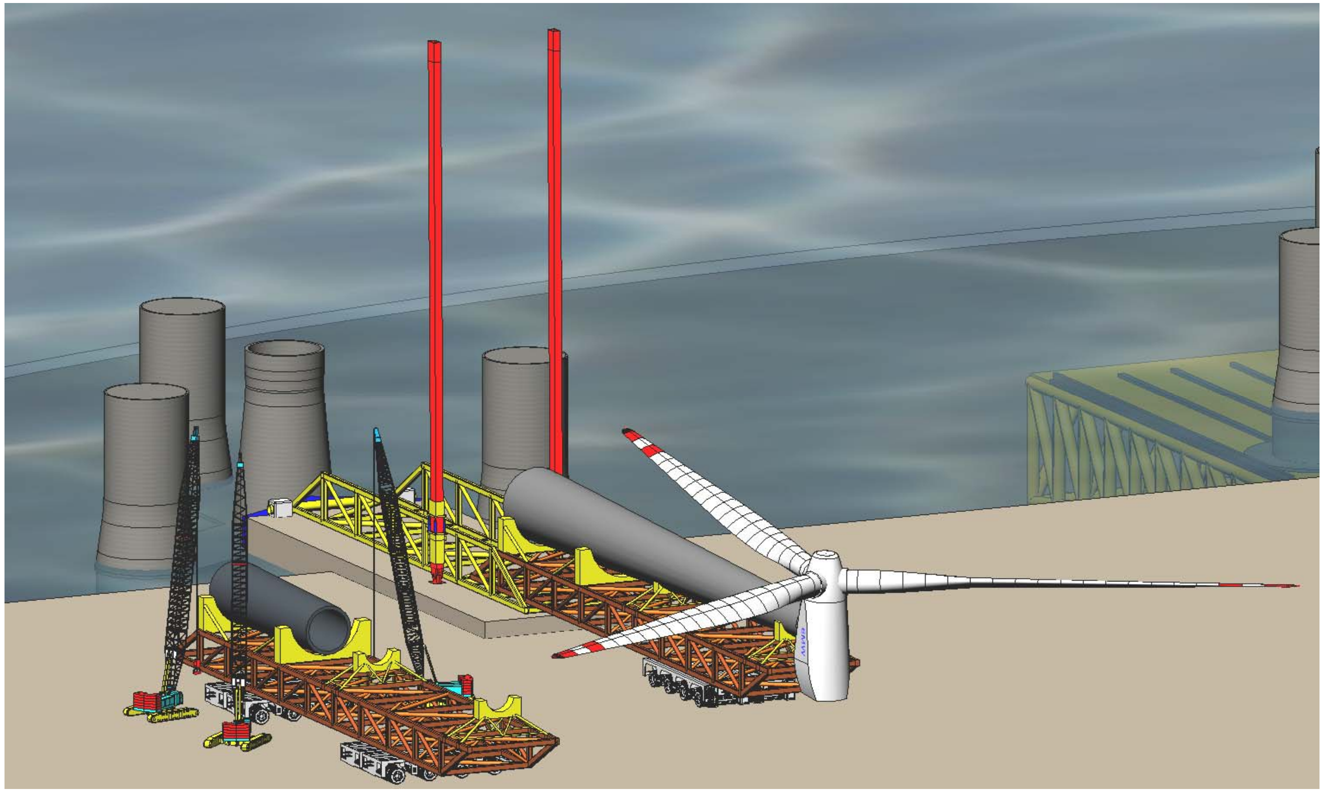
FABRICATION 25 UNITS/YEAR – TYPICAL SCHEDULE

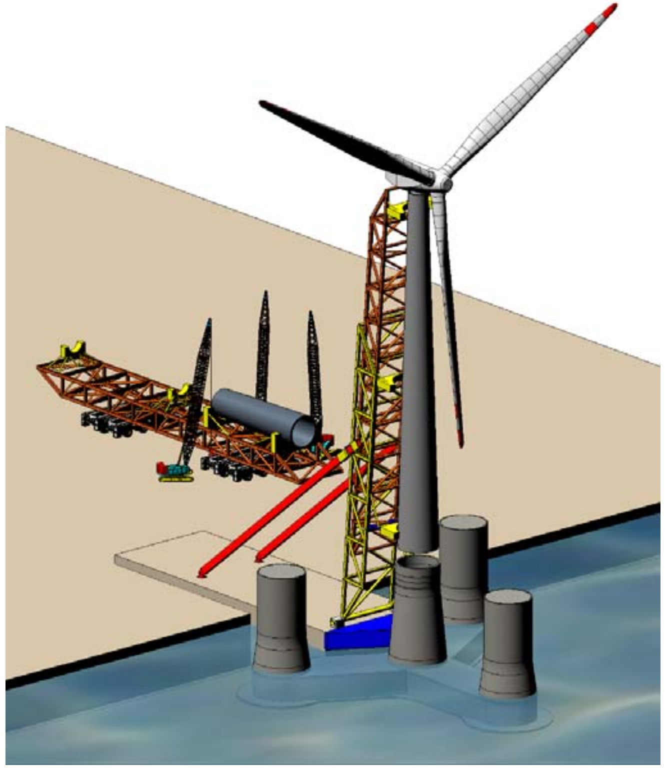
		...	W 1	W 2	W 3	W 4	W 5	W 6	W 7	W 8	W 9	W 10	W 11	W 12	W 13	W 14	W 15	W 16	W 17	W 18	W 19	...
For sk. line 1	Construction of pontoon parts	...	4 weeks				4 weeks															...
For sk. line 2		...			4 weeks				4 weeks													...
Skidding line 1	Connection of pontoon parts	...					4 weeks				4 weeks											...
	Columns construction	...									4 weeks				4 weeks							...
	Central shaft construction	...									4 weeks				4 weeks							...
	Launching	...																				...
Skidding line 2	Connection of pontoon parts	...							4 weeks				4 weeks									...
	Columns construction	...											4 weeks				4 weeks					...
	Central shaft construction	...											4 weeks				4 weeks					...
	Launching	...																				...
Total launched units		...	L1		L2		L1		L2		L1		L2		L1		L2		L1		L2	...

ASSEMBLY AT QUAYSIDE – CURRENT WTG's



ASSEMBLY AT QUAYSIDE – FUTURE LARGE WTG's

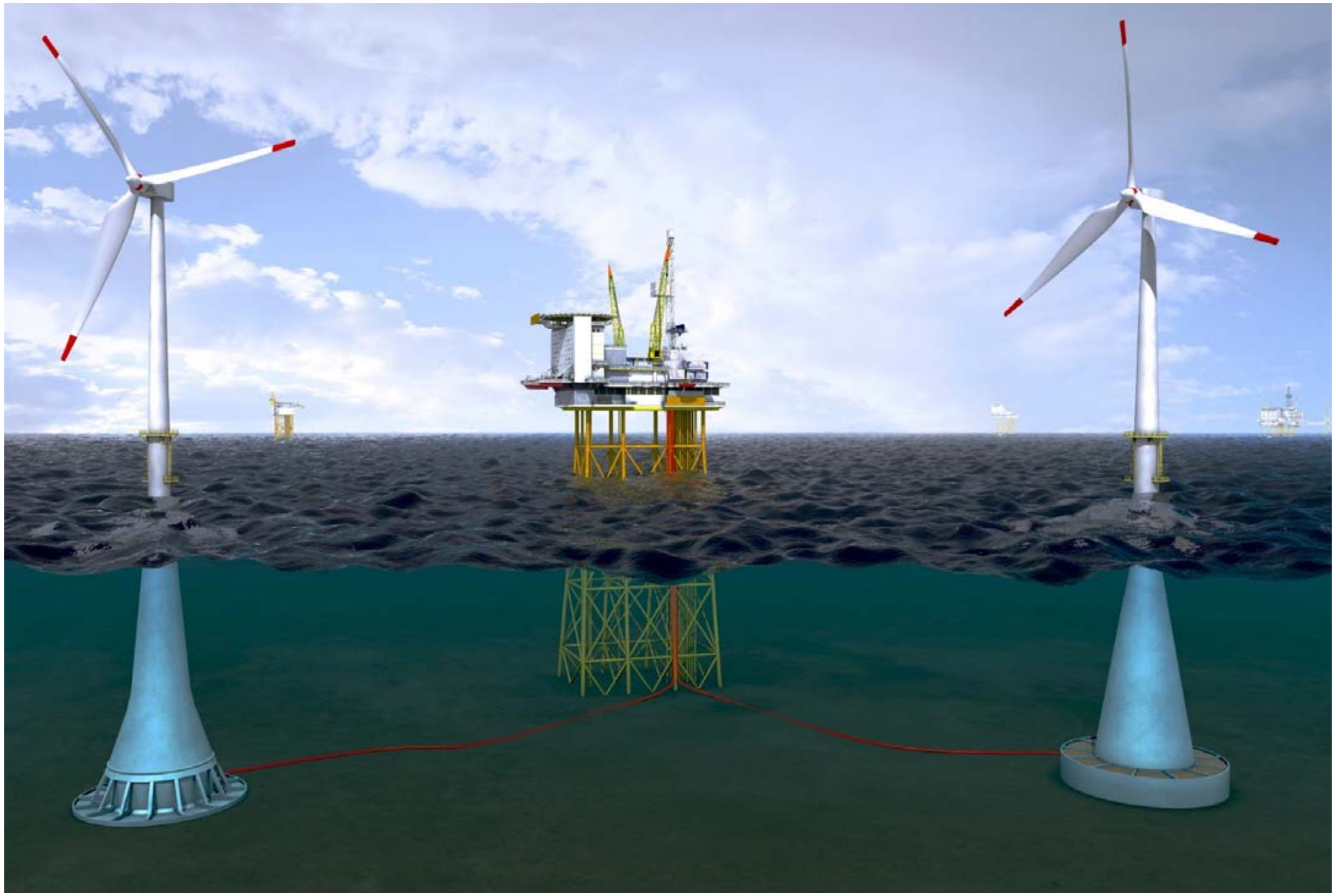




BOTTOM FIXED WTGs (FOR COMPARISON)

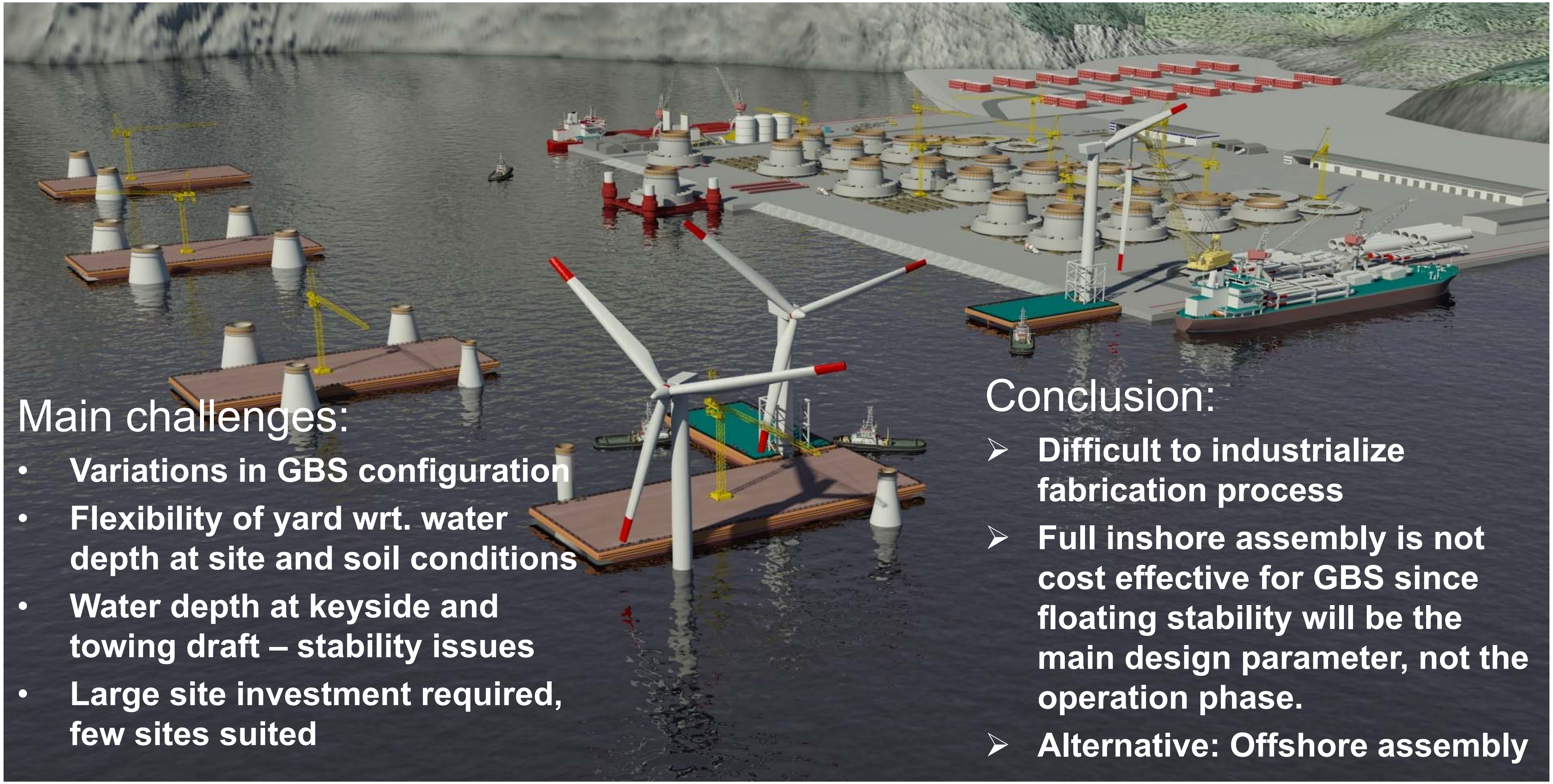
FABRICATION/INSTALLATION - CHALLENGES

OFFSHORE WIND - BOTTOM FIXED



GBS Production Facilities – Large Scale

vici ventus



Main challenges:

- Variations in GBS configuration
- Flexibility of yard wrt. water depth at site and soil conditions
- Water depth at keyside and towing draft – stability issues
- Large site investment required, few sites suited

Conclusion:

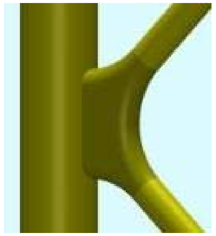
- ➢ Difficult to industrialize fabrication process
- ➢ Full inshore assembly is not cost effective for GBS since floating stability will be the main design parameter, not the operation phase.
- ➢ Alternative: Offshore assembly

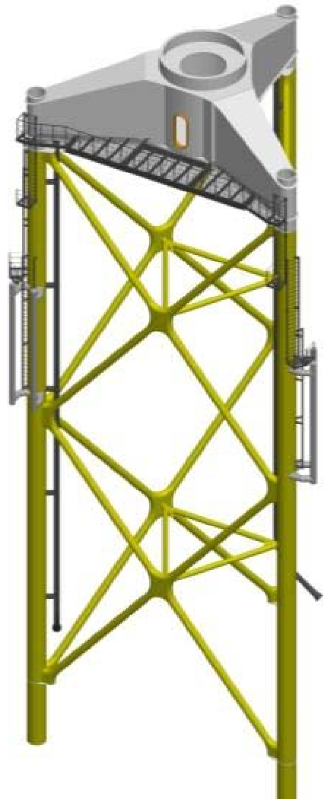
SPACE FRAME TOWER (SFT)

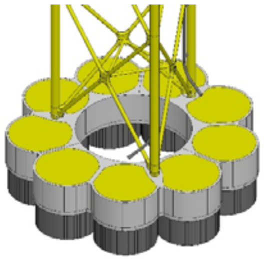
> Foundation - different solutions
  - Gravity base
  - Suction buckets
  - Piles

> 3 main element types:
  - Vertical legs, constant diameter
  - X and K nodes with uniform design. Cost effective fabrication, superior fatigue capacity.
  - Uniform X-bracing system

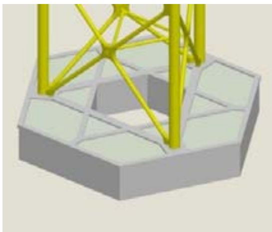
> Transition structures are standardized for turbine type







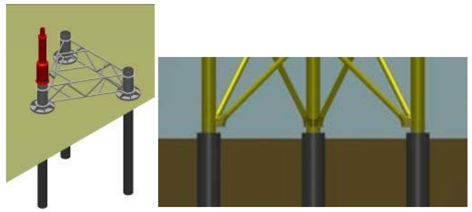
Gravity/Skirt piles



Gravity Base

Piled foundation frame

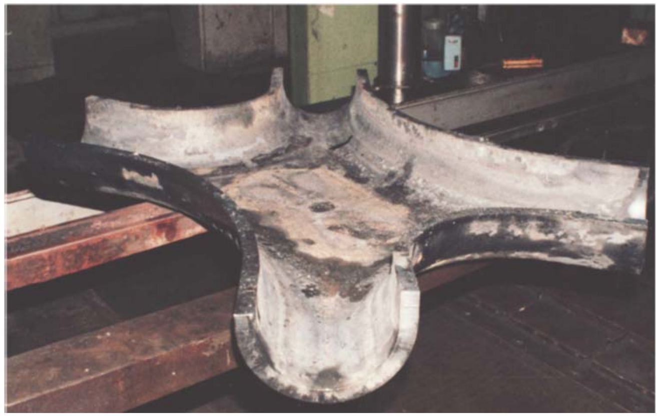
Suction buckets



Pre installed piles

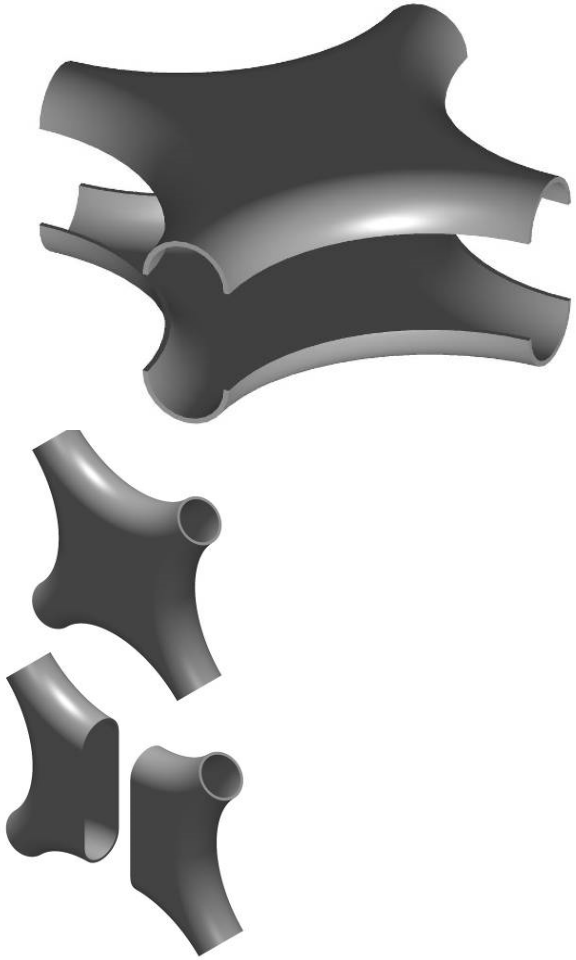
SFT - NODE FABRICATION

Hot forming with hydraulic press



Welding two halves together to an X-node

Splitting X-node into two K-nodes



Proposed Fabrication scheme for SFT substructure

Transition Piece

Nodes

Precut legs

Precut braces

Sub Contractor Fabrication

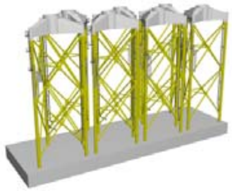
Possible Preassembly

Reception and temporary storage

Assembly and temporary storage

Load out to transport barge

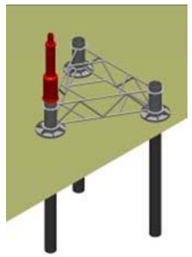
Assembly Yard



Installation on preinstalled piles

Piles

Installation of piles



Conclusion:

- Easier (than GBS) to industrialize the fabrication process
- Will depend on offshore assembly or special installation vessels

SUMMARY BOTTOM FIXED

> Monopiles have been dominating the market for bottom fixed offshore wind – highly industrialized

> Jacket structures becoming more popular for deeper water and larger WTGs, less steel than monopoles give potential for cost savings.

> Use of concrete can increase the operational life of substructures

> Difficult to standardize bottom fixed substructures due to variation in water depth, soil conditions and environmental loading

> Monopiles and jackets have higher potential for standardization and industrialization than concrete GBS

> Installation of bottom fixed WTGs requires offshore assembly or costly measures to solve temporary conditions.

> Future large WTGs (20 MW) will require expensive new installation tools. Likely that bottom fixed WTGs will be limited in size.

OFFSHORE WIND CHALLENGES

DR. TECHN. OLAV OLSEN

OFFSHORE WIND CHALLENGES

> The main and overall challenge is to reduce cost of energy (LCOE) – cannot rely on subsidies in the future

> *Requirements:*

> Consistent frame conditions (political, consenting, tendering process, environment etc.)

> Development of consistent rules and regulations

> Development of business tools (financing, insurance etc.)

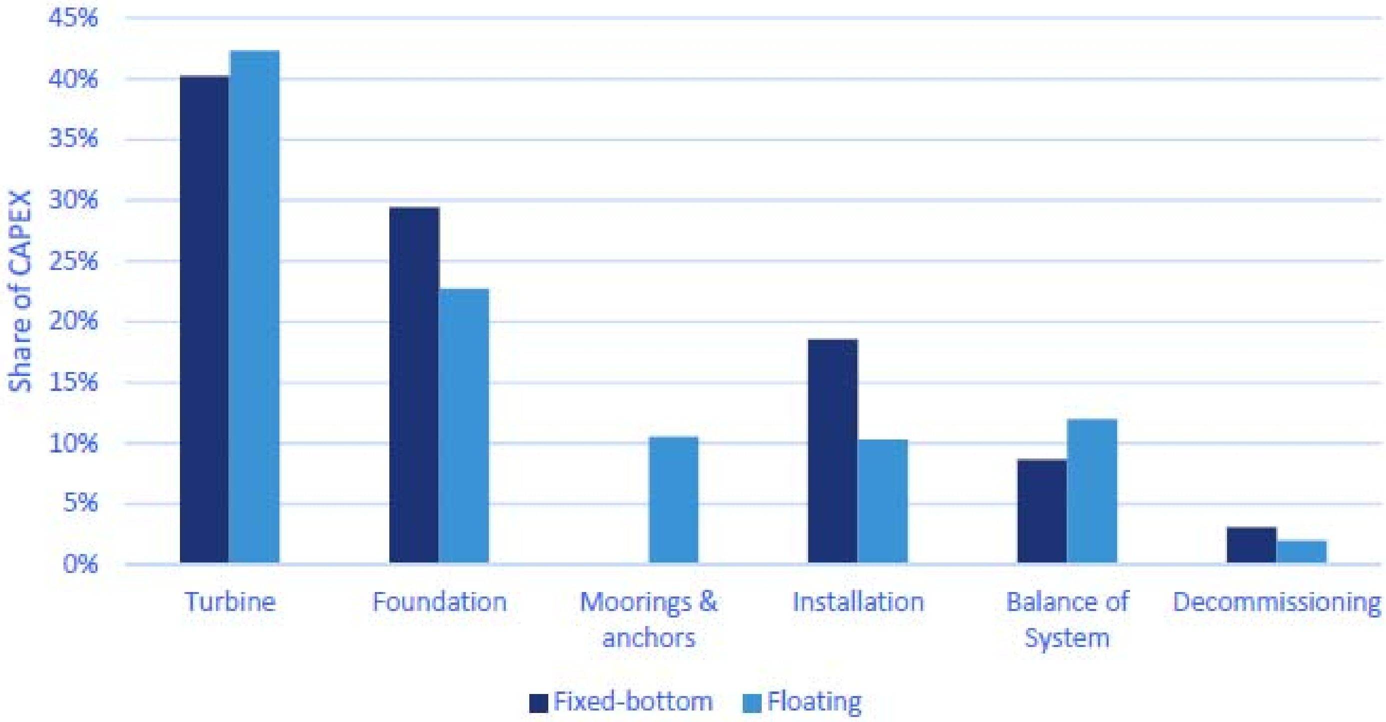
> Development of supplier industry (competition, effectivity, market stability)

> Development of new and better technology

- Economy of scale, larger turbines
- Increase effectivity, robustness and operation life
- Reduce CAPEX, OPEX

> Development of fabrication and installation methods (reduce CAPEX, risk)

OFFSHORE WIND CHALLENGES



Source Carbon Trust 2015

WHY

FLOATING OFFSHORE WIND

WILL OUTBEAT

BOTTOM FIXED OFFSHORE WIND

IN THE FUTURE

FLOATING WIND – KEY ADVANTAGES

- Floating wind has larger energy potential than bottom fixed.
- In some areas floating wind is the only way to go. This will ensure development of a floating market.
- Floating substructures have higher potential for standardization than bottom fixed (not very sensitive to water depth and soil conditions). Efficient and cost effective mass fabrication of substructures
- Shallow draft floaters - Quayside assembly and testing prior to tow out
- Installations without offshore heavy lift – tow to site
- Simple removal – reverse installation
- Large potential for reuse – 2nd hand value of floater will reduce energy cost
- Large potential for efficient supply chain and significant cost reductions

- Robust execution program suitable for future large WTGs
- Next generation 20 MW floating WTGs can be assembled without expensive new offshore cranes

- Specific for Norway:
  - Norway do not have suitable sites for bottom fixed offshore wind (with a couple of exceptions).
  - Floating wind has a significant future potential in Norway

WHY

OO-STAR WIND FLOATER

HAS THE QUALITIES REQUIRED BY THE

FUTURE OFFSHORE WIND MARKET

OO-STAR - ADVANTAGES

- OO-Star Wind Floater is a simple and robust floater concept, with favourable motions for WTG and cable
- Adaptive to «all» environmental conditions and WTG sizes
- Very good «scalability-factor» for increase of WTG size
- Concrete is less sensitive to fatigue than steel (WTGs are fatigue machines) and requires minimum maintenance
- Concrete substructure has long design life, 100+ years with minor cost increase (concrete cover, cathodic protection and outfitting)
- Concrete is fabricated in all countries, limited number of skilled workers required
- Shallow minimum draft - can be fully assembled and tested at quayside
- No offshore heavy lifts – WTG assembly by land cranes onto fixed substructure (resting at seabed)
- Mooring connections above water – easy access and «artificial» increase of water depth (benefit for mooring in shallow water)
- Fixed mooring points at 2 columns, fairlead/chain stopper at 3rd column. Tensioning from vessel, no winch.
- Possible to improve cost and durability by lifting interface between concrete and steel and to reduce steel tower fatigue (crucial for future large WTGs)

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