The Wind & The Waves … Renewable Energy

Developments Through Learnings From Oil & Gas

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SUT, Society for Underwater Technology

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1. Safety first : NINA

NINA NO INJURIES NO ACCIDENTS

SAFETY STATEMENT

Our people are our most valuable assets, making safety a core value. Our goal is: No Injuries No Accidents. This is embedded in our company's culture and supported through Values and Rules. All employees, including our sub-contractors, are expected to take these values and rules to heart.

VALUES

- I AM RESPONSIBLE FOR MY OWN SAFETY
- I APPROACH OTHERS ABOUT WORKING SAFELY
- I TAKE ACTION IN CASE OF UNSAFE OPERATIONS IF NECESSARY, I WILL STOP THE WORK
- I ACCEPT FEEDBACK ABOUT MY SAFETY BEHAVIOUR REGARDLESS OF RANK AND POSITION
- I REPORT ALL INCIDENTS, INCLUDING NEAR-MISSES, TO INFORM OTHERS AND BUILD ON LESSONS LEARNED

RULES

- PREPARE A RISK ASSESSMENT FOR EACH PROJECT, VESSEL OR LOCATION
- OBTAIN A PERMIT TO WORK FOR DEFINED HIGH-RISK ACTIVITIES
- MAKE A JOB HAZARD ANALYSIS FOR HAZARDOUS NON-ROUTINE ACTIVITIES
- BE INFORMED ABOUT RISK & CONTROL MEASURES
- BE FIT FOR DUTY AND WEAR THE PPE REQUIRED

HSE standards and culture in Offshore Wind should be and are at minimum the same level as in Offshore Oil & Gas

2. Renewables Developments, a personal note

Driven / motivated by:

* the need for an Energy Transition and the drive to contribute to that
* the Opportunities & Challenges in Offshore Wind
* the entrepreneurial spirit in Offshore Wind:
  - *a market becoming mature rapidly,*
  - *hardly anyone was working in Offshore 10 years ago,*
  - *people, knowledge and assets coming from Oil & Gas and other markets*
  - *many young & promising people choose to work in renewables / Offshore Wind*

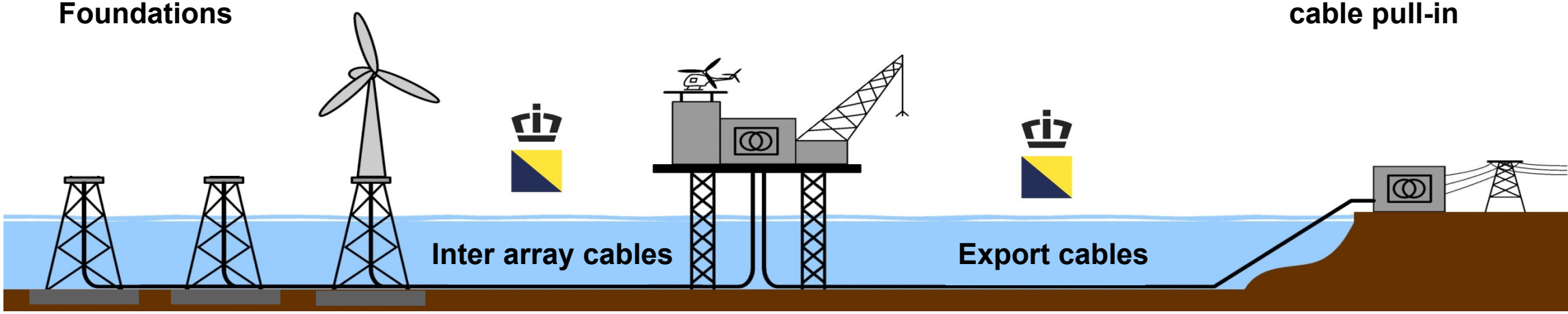
2: VARIOUS ASPECTS OF RENEWABLES DEVELOPMENTS

EPCI Foundations

WTG T&I

Substation T&I

Land- fall and cable pull-in



Scour protection

UXO Removal

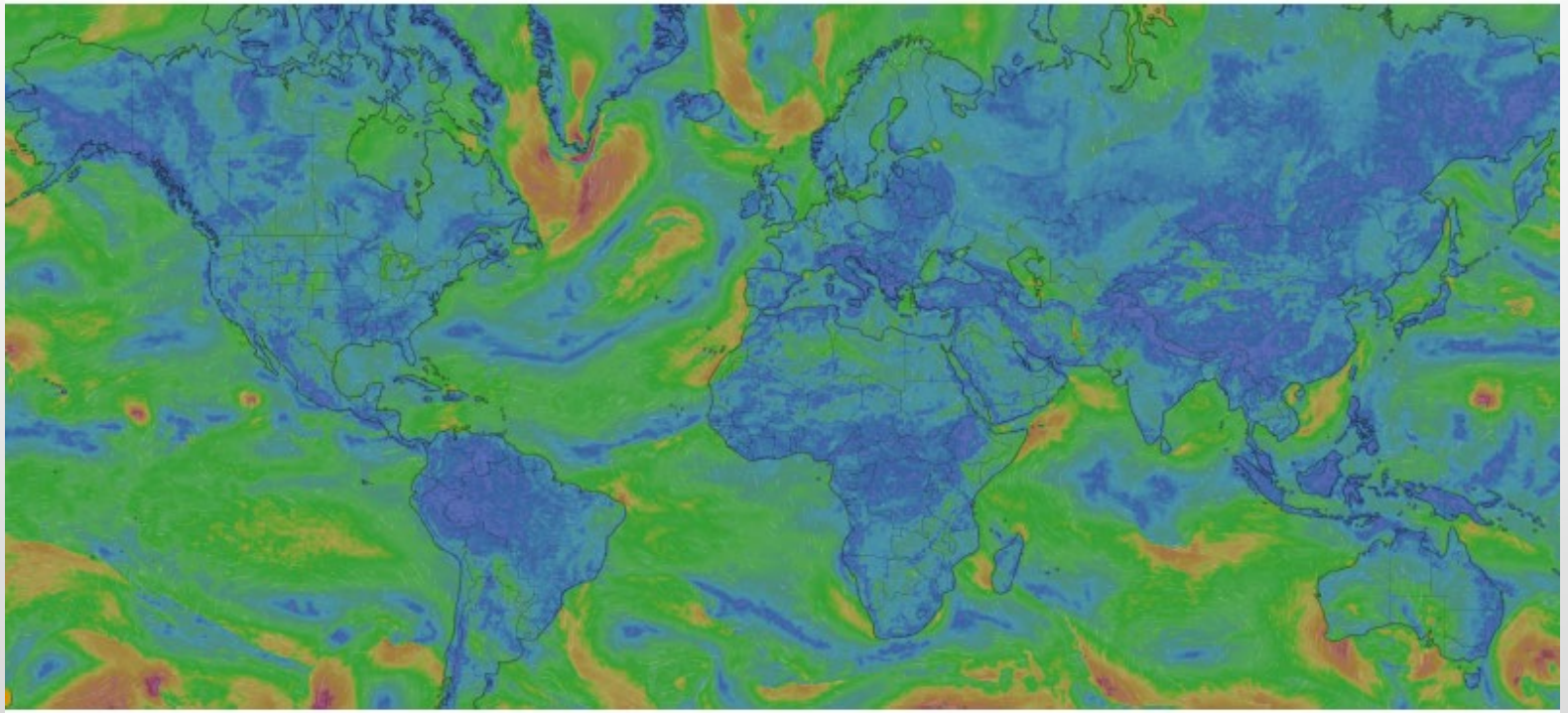
Side and geotechnical survey

3: OPPORTUNITIES AND CHALLENGES FOR OFFSHORE WIND IN THE NEAR FUTURE

3: OFFSHORE WIND OPPORTUNITIES

Source : PWC / Boskalis

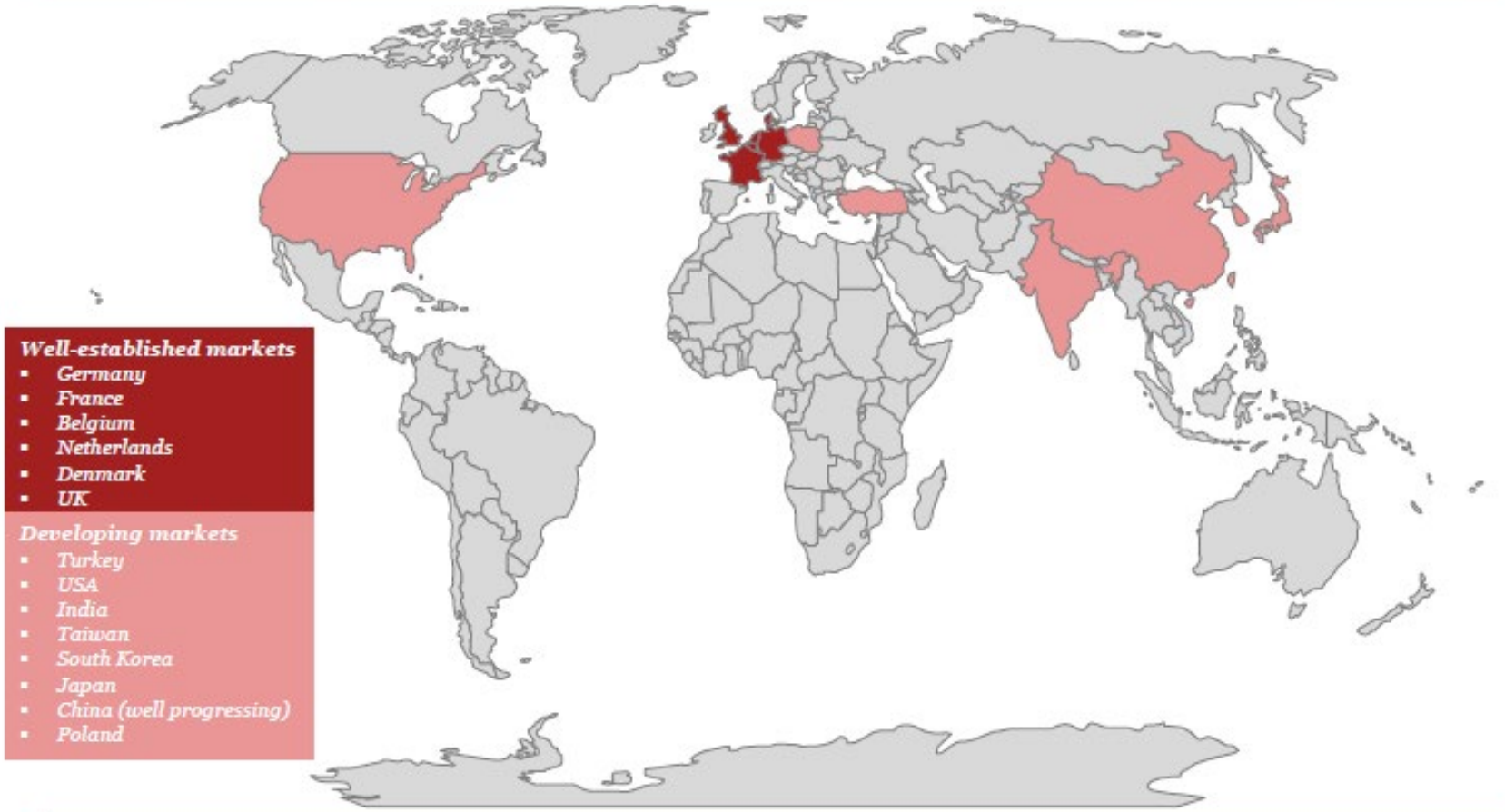
There is good wind potential around the globe, but also challenges, e.g. high water depths at the coastal line.



3: OFFSHORE WIND OPPORTUNITIES

Source : PWC / Boskalis

There already are well-established, but also developing markets in different parts of the world.

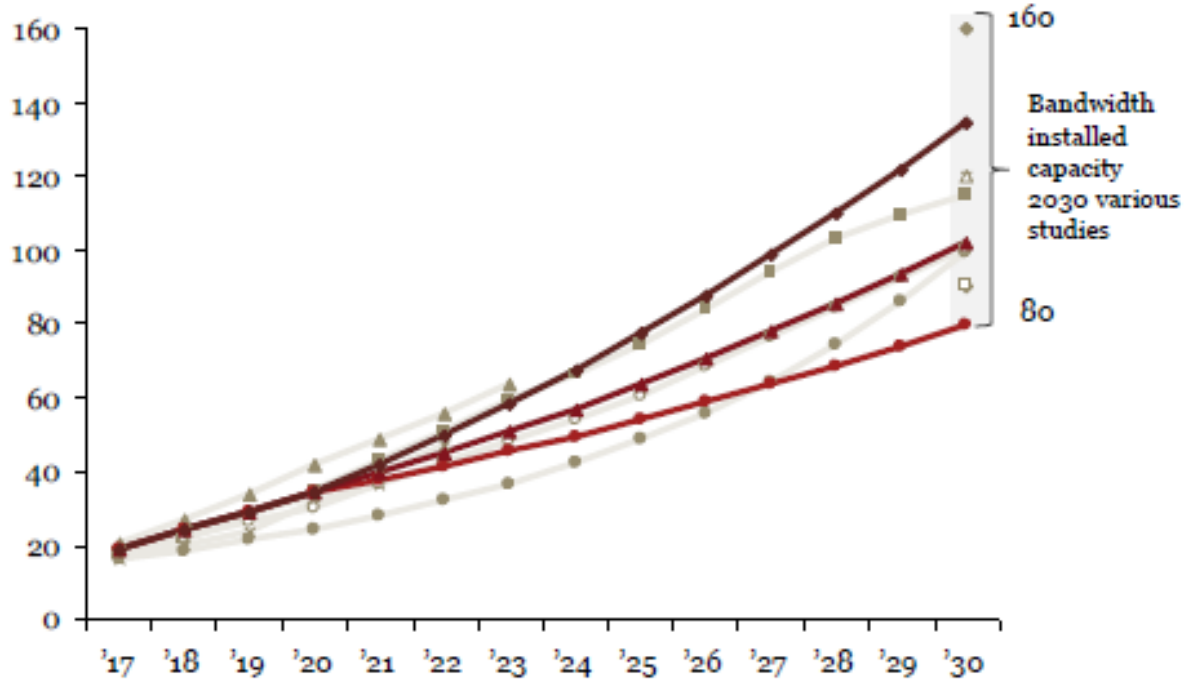


3: OFFSHORE WIND OPPORTUNITIES

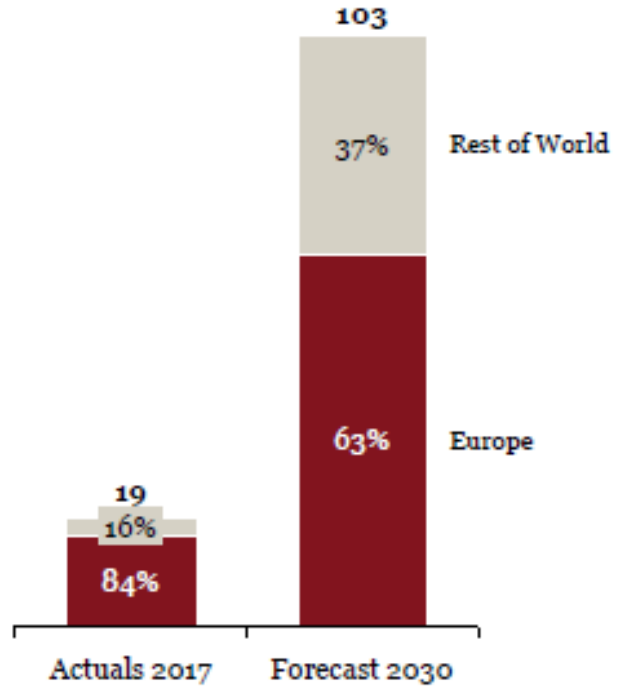
Source : PWC / Boskalis

Now that offshore wind is 'in the money', capacity is growing significantly. Up to 2030 most installed capacity probably will be in Europe, but much can be expected from Asia-Pacific and the US

Global installed capacity in GW



Installed capacity forecast in GW



BNEF
Kepler (Windeurope)
Allied Market Research
BVG associates
IEA
IEA Sustainable Development Scenario
IEA New Policy Scenario
IRENA lower bound
IRENA middle
IRENA upper bound
PwC lower roll-out speed
PwC base roll-out speed
PwC higher roll-out speed

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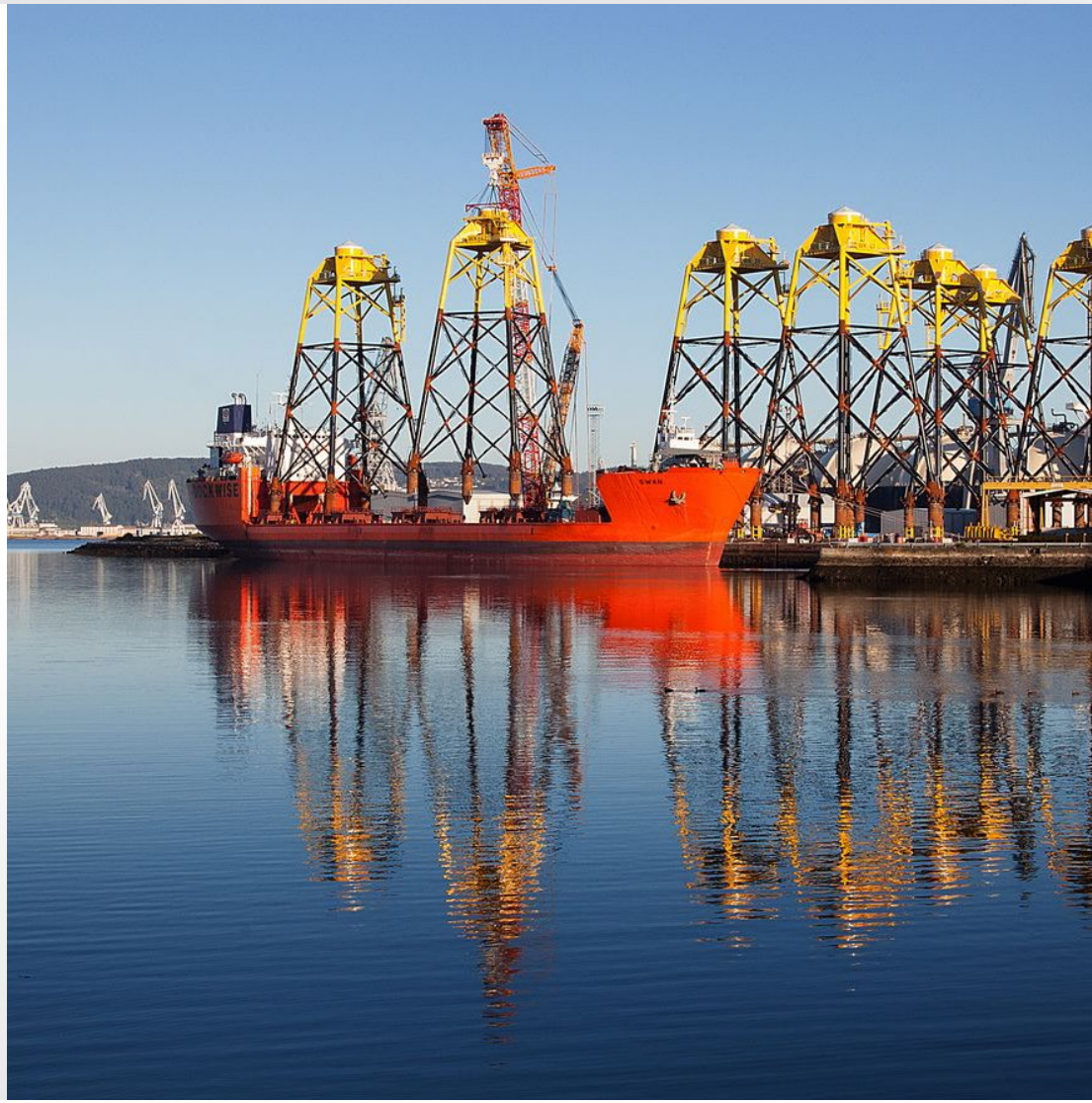
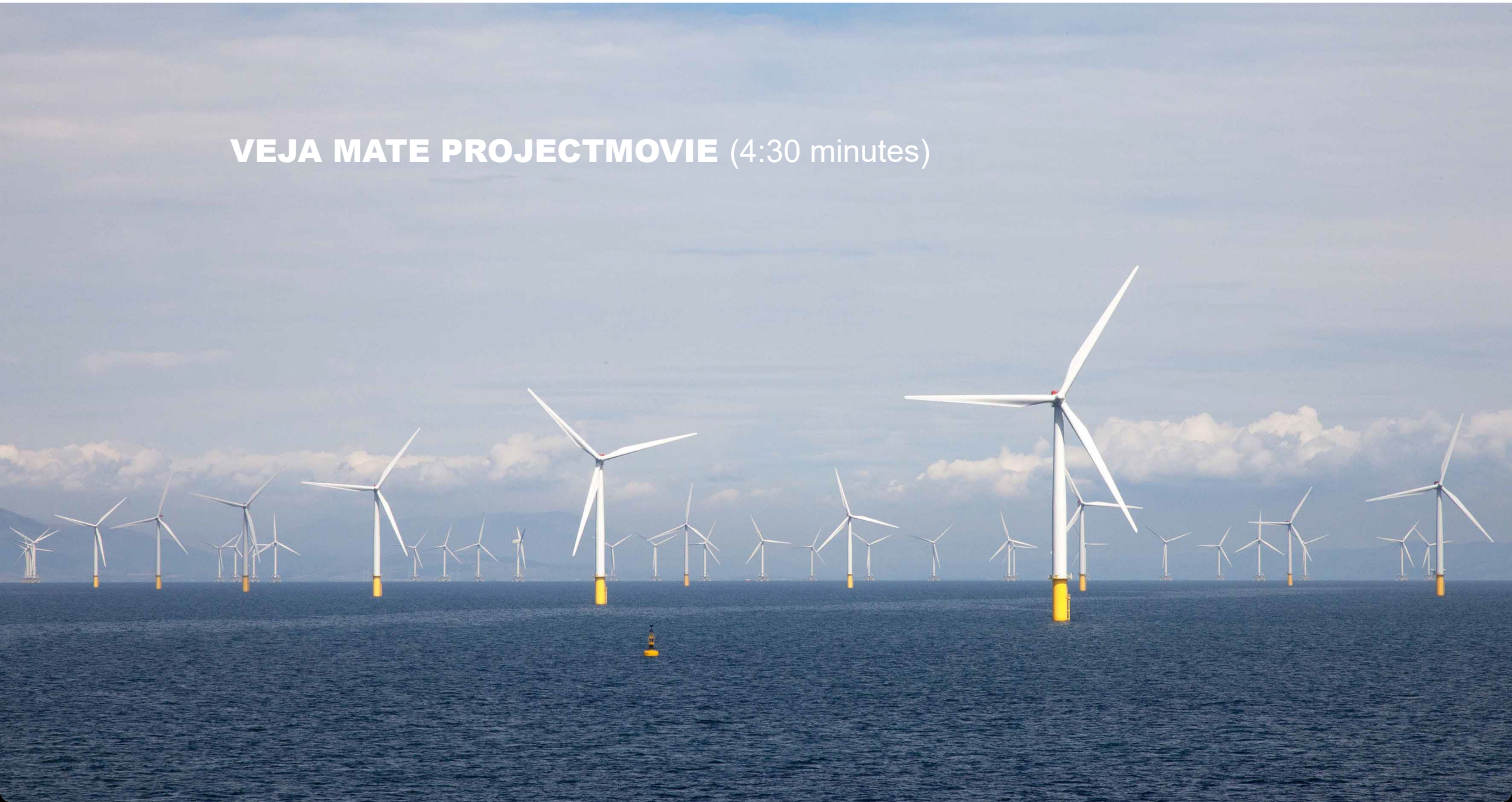
3: OFFSHORE WIND CHALLENGES

- **(IN EU) MOST FAVORABLE SITES USED:**
  - Water depths increasing
  - More challenging Soil & Wave parameters
  - Distance to shore increasing
- **INSTALLATION ON WINDY LOCATIONS**
- **WIND TURBINE SIZE & POWER INCREASING**
- **NEW MARKETS -> LOGISTICS**
  - Taiwan / United States (Jones act) / Australia
- **FLOATING FOUNDATIONS**
- **PRICES / SUBSIDY PER MW DECREASING**
- **MARKET CAPACITY**
  - Shortage of Fabrication & Installation capacity foreseen after 2020 *(especially when oil price picks up as well)*



4: VEJA MATE OFFSHORE WIND FARM (402 MW)

EPCI-contract for 67 XXL Monopile Foundations in the German Bight



5: MONOPILE DESIGN (VEJA MATE PROJECT)

Mono Piles	Length : MAX 84.8 m MIN 76.2 m Weight : MAX 1304 T MIN 1157 T Diameter : MAX 7,8 m MIN 6,5 m
Pile Penetration	Max. 41m
Water Depth	-38.5 till -39.8m LAT
Transition Pieces	Length 22.2 m, Weight 350 T Diameter 6.81 m
MP-TP Connection	**Bolted** with **Grout** Skirt Flange @ +4.5 LAT
Scour Protection	Double Layer (Rock) Pre-installed

Scope	**EPCI 67 Wind Turbine Foundations** **(6MW Siemens SWT-6.0-154)**

5: INSTALLATION – MONOPILES

MAIN INSTALLATION VESSEL

- SeaJacks Scylla (new build)

OUTFITTING

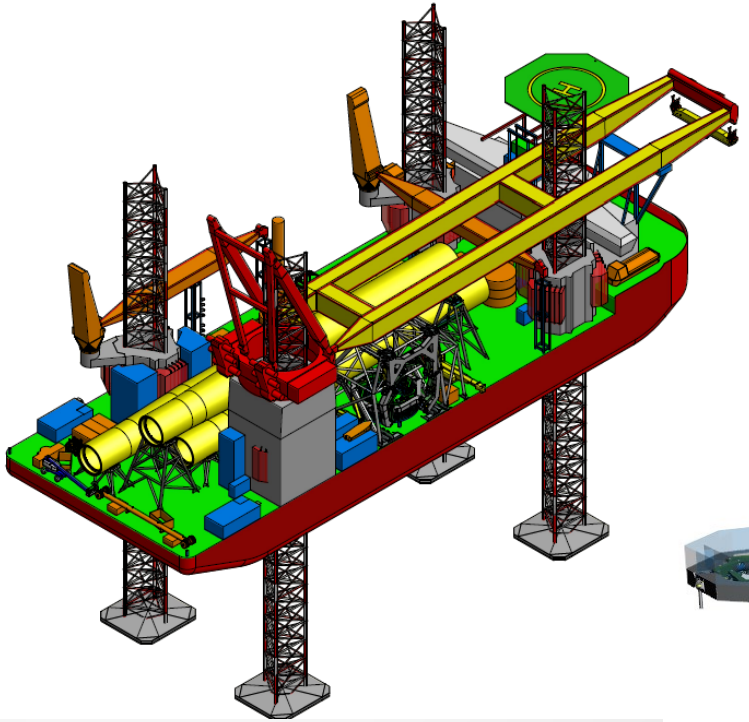
- 1540T crane
- Stacked MP storage line
- Upending line with bucket on SPMTs
- MP lifting tool (FMUT)
- Pile Gripper Frame (PGF)
- S-4000 Hydro-hammer spread
- Hydro Sound Damper Noise Mitigation

SUPPORT VESSEL

- Noise Mitigation vessel operating DBBC

PROGRESS

- Started in April 2016, last MP installed in August 2016



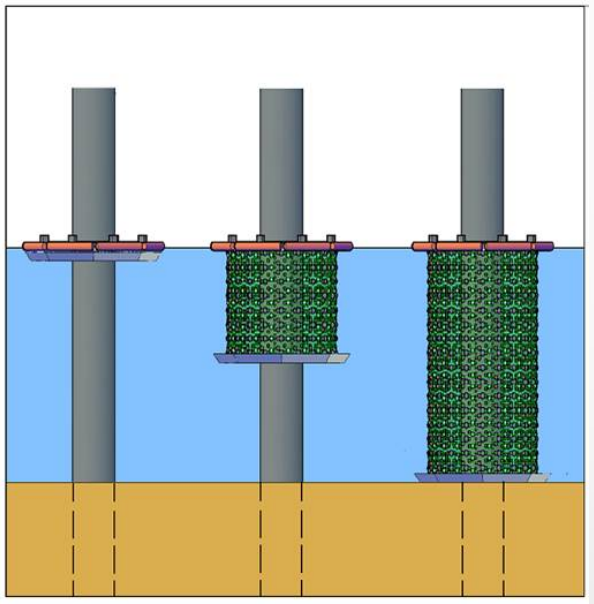
5: INSTALLATION – MONOPILES

6: MP-INSTALLATION : NOISE MITIGATION

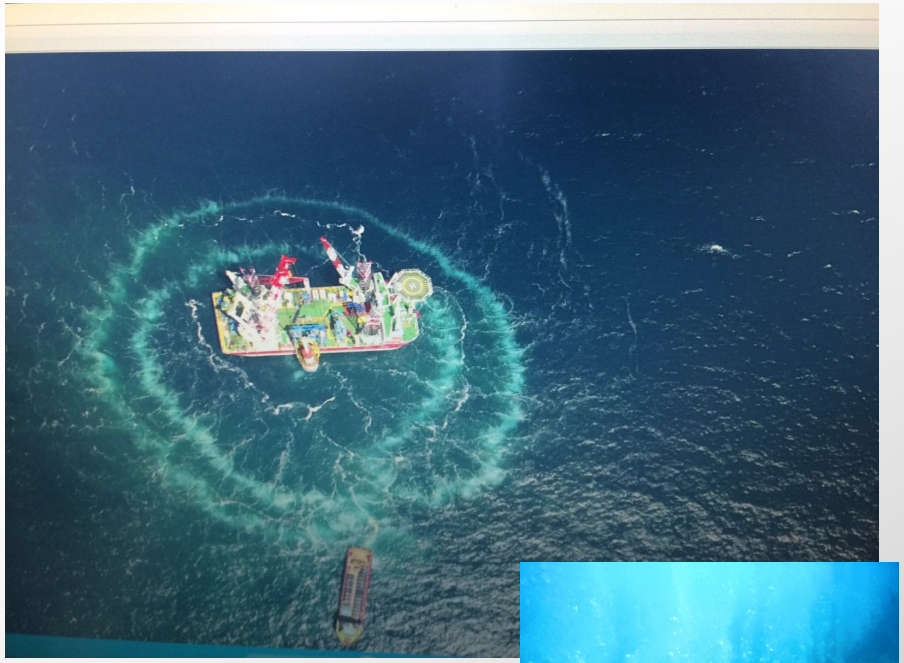
Requirement for underwater noise at 750 m in Germany (BSH):

- L_{Peak} ≤ 190 dB
- SEL_{05} ≤ 160 dB

1: HYDRO SOUND DAMPER (HSD)



2: DOUBLE BIG BUBBLE CURTAIN (DBBC)



3: ACTIVE HiLo PILING

Controlling piling energy based upon direct monitoring of SEL_{05} development during piling
HiLo: Hight Frequency / Low Energy

7: INSTALLATION – TRANSITION PIECES

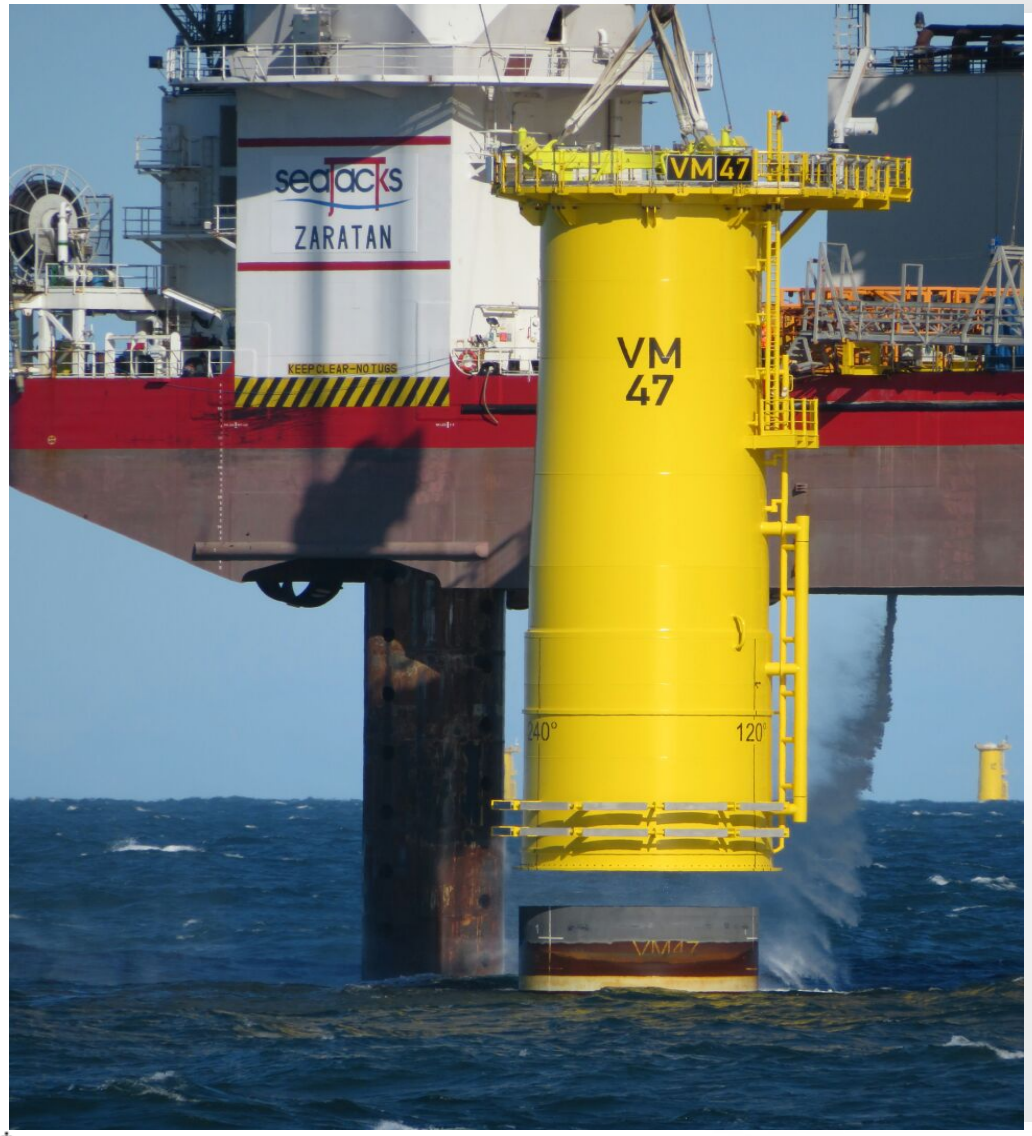
VESSEL:

- Sea Jacks JU Zaratan (subcontract)

OUTFITTING:

- TP Lifting Tool
- TP Access System
- Grout spread
- Bolting Tools

7: TP-INSTALLATION



7: BOLTING AND GROUTING IN PROCESS

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BOLTING AND GROUTING CONSIDERATIONS

- Connection between jacket / TP or MP/TP is a weak link and has caused major challenges in the early days.
- Choice for bolted, grouted or hybrid is strongly depending on project specific circumstances
- Bolted connections:
  - require a flange (piling on the flange challenging w.r.t. very strict margins)
  - bolting protocol and pre-tensioning techniques challenging
  - relaxation possible
  - easy to retension, replace bolts and decommission
- Grouted connections:
  - create a fixed solution, no flange required
  - mix in place offshore: very strict quality and temperature requirements
- Hybrid connections:
  - best of both worlds, reducing MP and TP wall tickness
- Recent design solutions : MP or jacket without separate Transition Piece (requiring alternative piling methods for MP's)


50
VM 50
VM
50

8: JACKET INSTALLATION

DIFFERENT CONCEPT JACKETS COMPARED TO MONOPILES

- In deeper water jackets become more economic than monopiles
- Design of jackets is more challenging (more elements, fatigue on nodes)
- Fabrication complexity is different:
  - Monopiles require large can rolling equipment and welding robots (diameter up to 10 m, wall thickness up to 120 mm)
  - for jackets 3D construction within margins and corrosion protection is more challenging
- Fabrication time for a jacket is longer due to complexity and more elements
- Piling for jackets produces less underwater noise (Suction Buckets produce hardly any noise)
- More challenging lifting, transport and seafastening requirements for jackets (jackets mostly transported in vertical position, monopiles horizontally)

8: JACKET INSTALLATION

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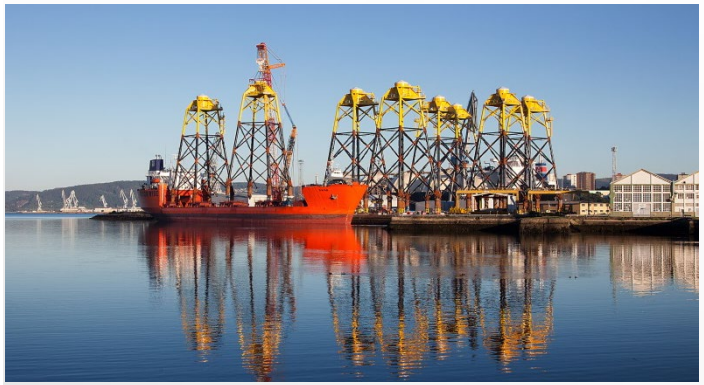
8: EXAMPLE: WIKINGER PROJECT DRILLED PIN PILES



Transport

Pile Installation

In pile Dredging

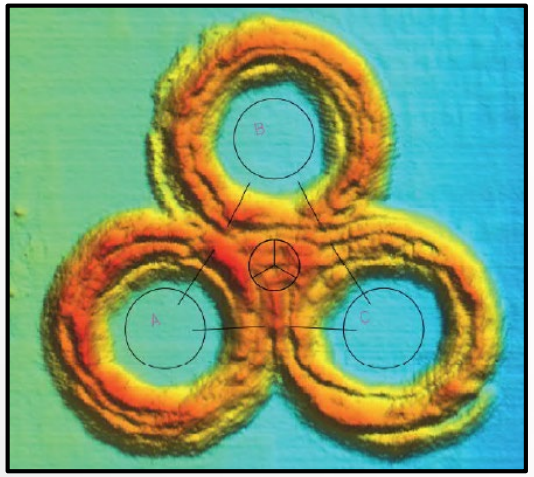
Jacket Installation

Jacket-Pile Grouting

Motion compensated Drilling

8: EXAMPLE: ABERDEEN BAY SUCTION BUCKET FOUNDATIONS

Design and fabrication



Pre-lay scour protection

Transport of jackets

Installation of jackets

WTG installation

Export and array cable installation

Grouting and post scour protection

Secondary works and hand over

9: DISCUSSION & QUESTIONS