



› **Noise Mitigation Measures & Low-noise Foundation Concepts – State of the Art**

Tobias Verfuß, Projektträger Jülich

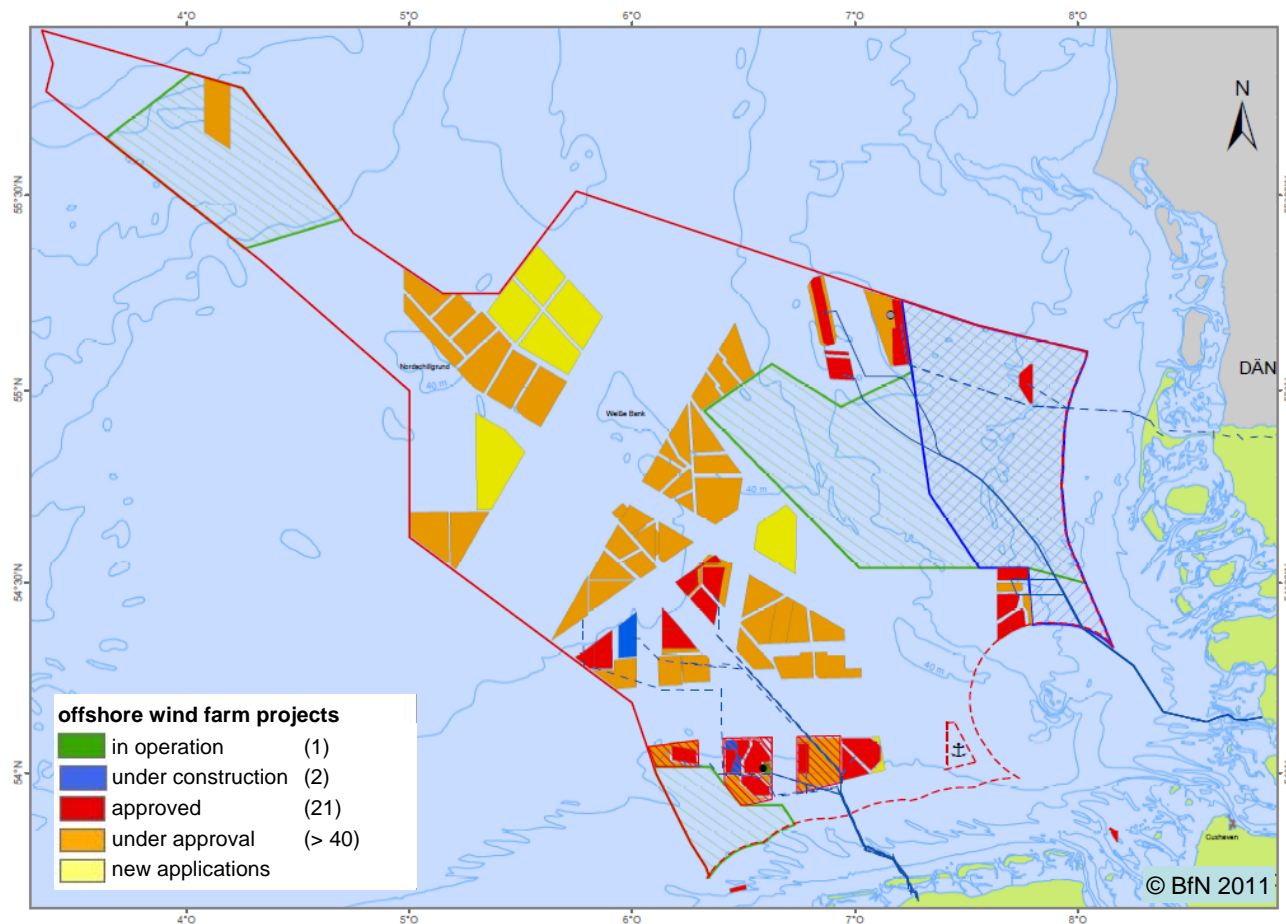
Stralsund, 25.01.2012

Structure

- › Introduction
- › Noise Mitigation Measures
 - › Characteristics of Mitigation Measures
 - › Bubble Curtains, Pile Sleeves, Hydro Sound Dampers and Others
- › Low-noise Foundation Concepts
 - › Gravity Foundations, Drilled Piles and Others
- › Summary and Outlook

Introduction

Expansion of Offshore Wind Energy in the German EEZ



Installed capacity
by 31.12.2011:
145 MW

Approved by BSH:
1,930 wind turbines
(≈ 9 GW)

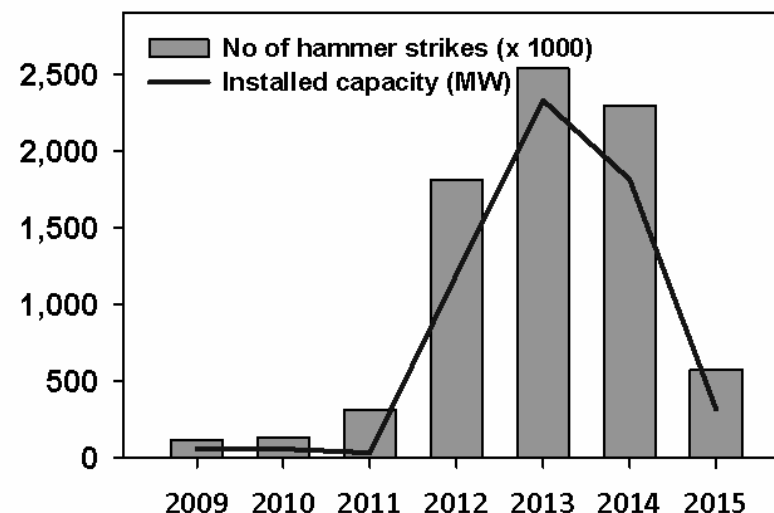
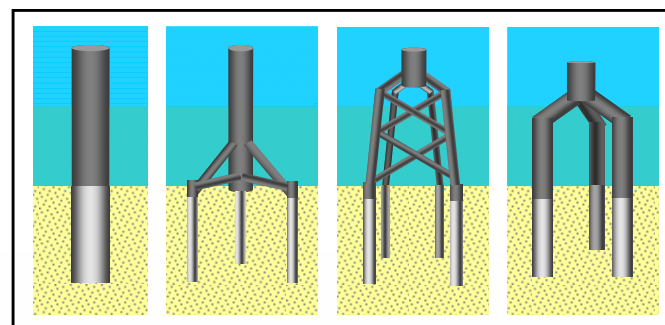
Expansion target
(German Gov.):
25 GW by 2030

Introduction

Foundation Types and Installation

- › Foundation types
 - › Monopiles
 - › Tripods/Jackets
 - › Tripiles
- › Piling noise szenario
 - › Monopile
 - ≈ 2,000 strikes
 - › Tripod/Jacket/Tripile
 - ≈ 9,000 strikes

(assumptions)

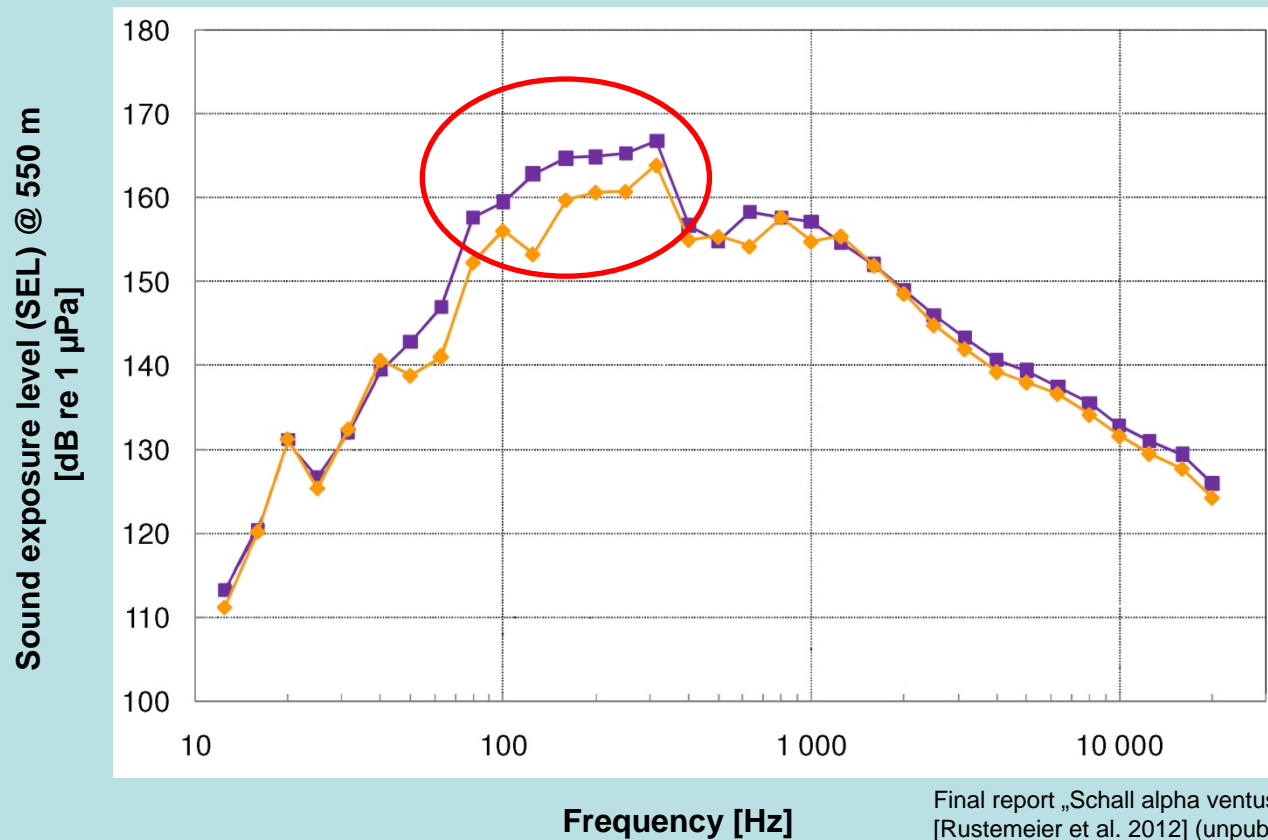


Introduction

Piling Noise

- › Frequency spectrum dependent on water depth
- › Maximum energy between 80 - 400 Hz

Tripod installation at *alpha ventus* (2009)



Final report „Schall alpha ventus“
[Rustemeier et al. 2012] (unpublished)

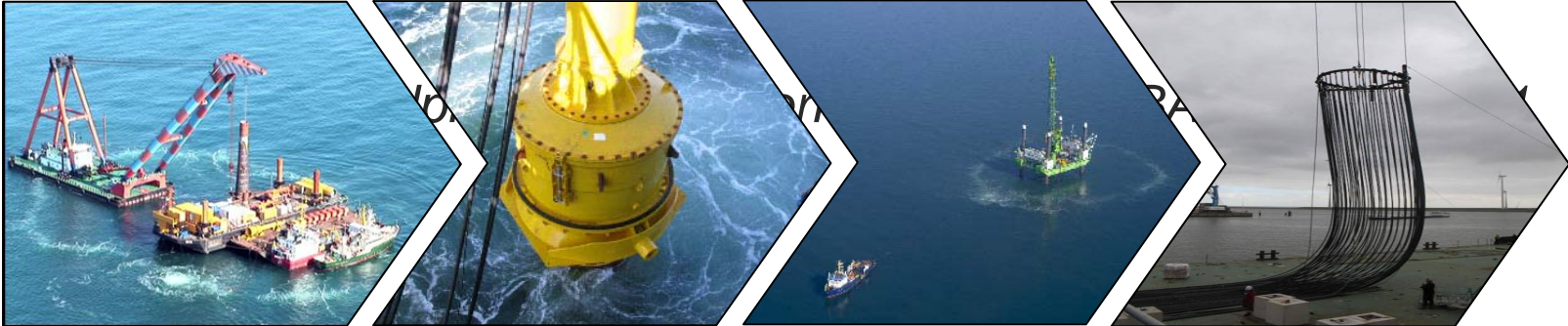
Part I: Noise Mitigation Measures

Noise Mitigation Measures should be...

- › Effective (defined threshold level)
- › Reliable
- › Non-obstructing the installation process
- › Safe and easy to handle
- › Cost-effective
- › Sustainable (reusable, eco-friendly)

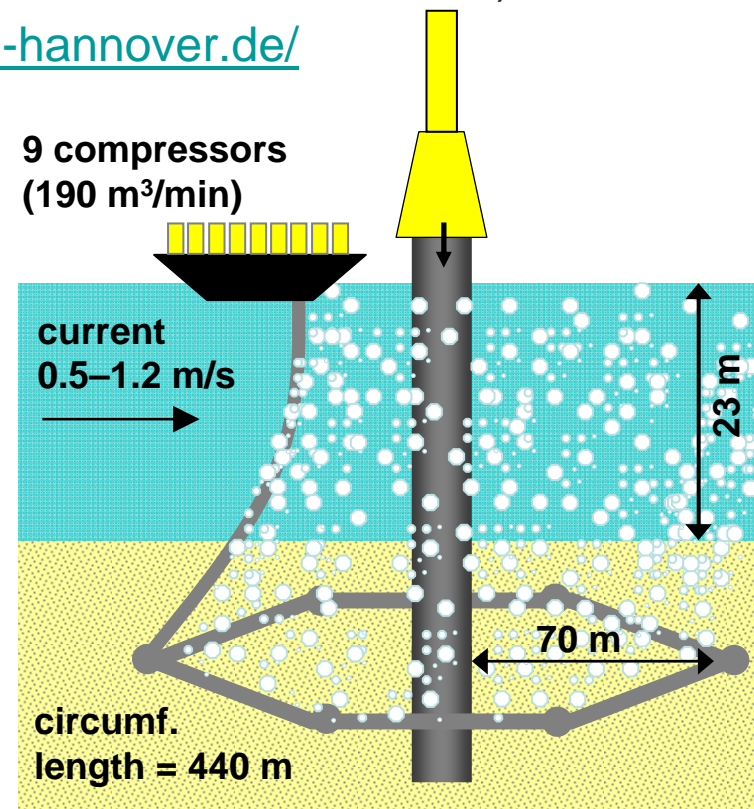
Noise Mitigation Measures

Bubble Curtains & Bubble Sticks



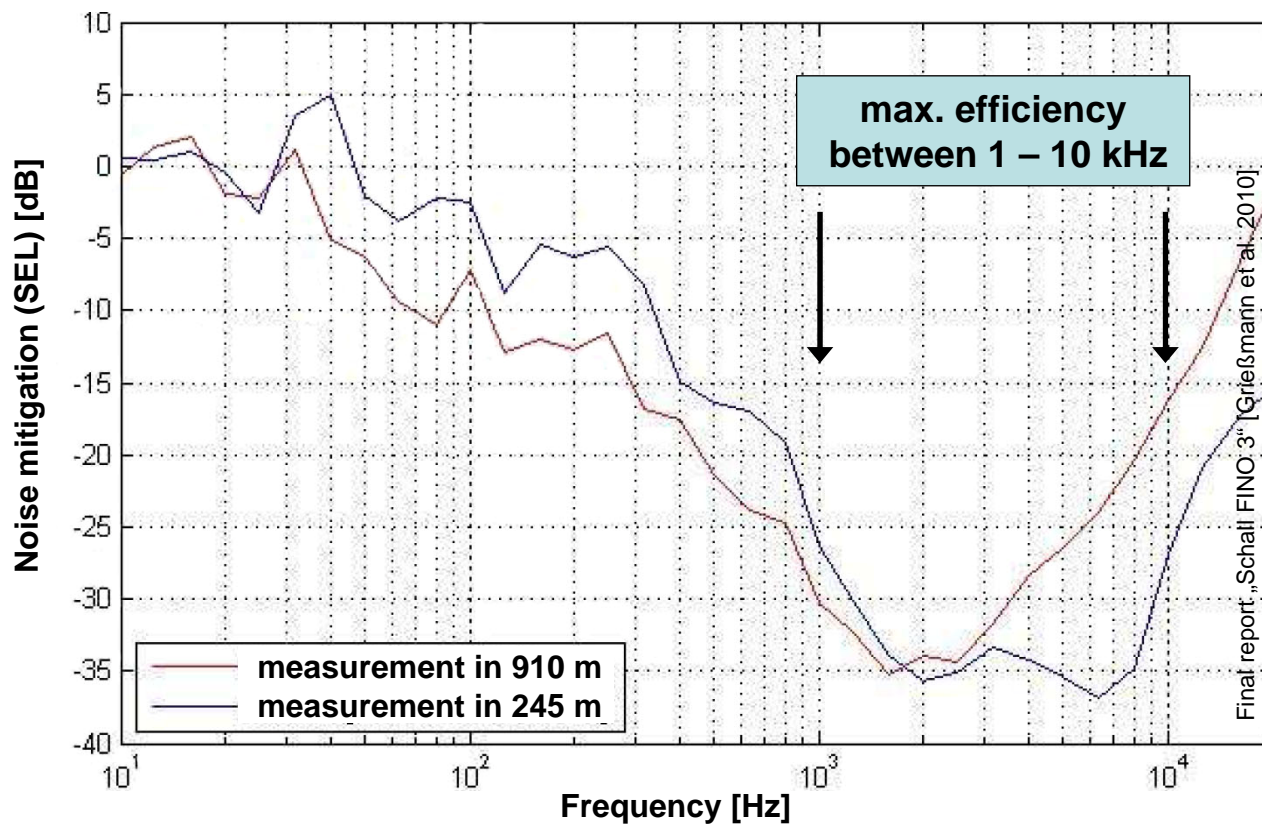
Noise Mitigation Measures Big Bubble Curtain at research platform FINO-3

- › BMU-funded project “Schall FINO-3“ (ref. no. 0325023A/0325077)
- › Final report available at: <http://www.tib.uni-hannover.de/>



Noise Mitigation Measures

Big Bubble Curtain at research platform FINO-3



Achieved noise reduction

- › SEL: 12 dB
- › L_{peak}: 14 dB

Noise Mitigation Measures

Big Bubble Curtain at OWF *Borkum West II*

- › BMU-funded project “HYDROSCHALL-OFF BWII“ (ref. no. 0325309A/B/C)



- › 40 Tripod foundations (“pre-piling”)
- › Water depth: 26 - 33 m
- › Improved BC: flexible hose coiled on a winch
- › Installation from ship before jack-up barge arrives
- › Air supply from vessel by 4 compressors (150 m³/min)



Noise Mitigation Measures

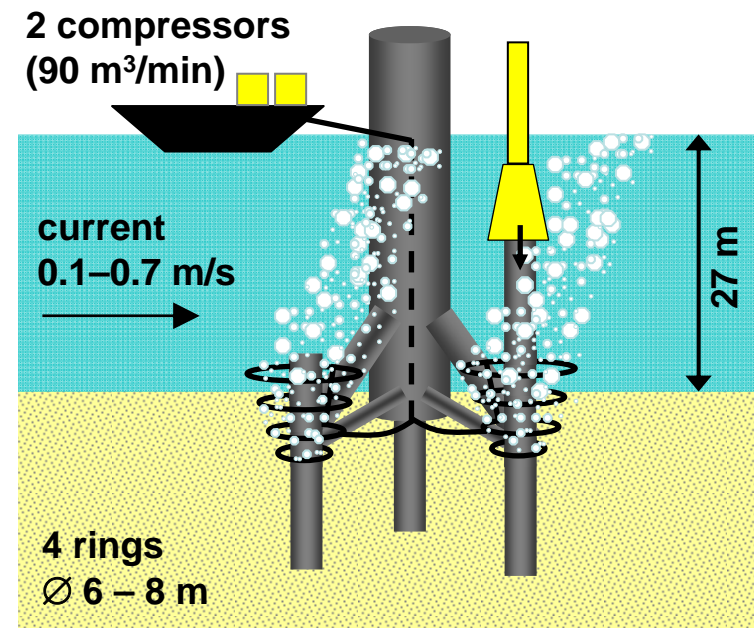
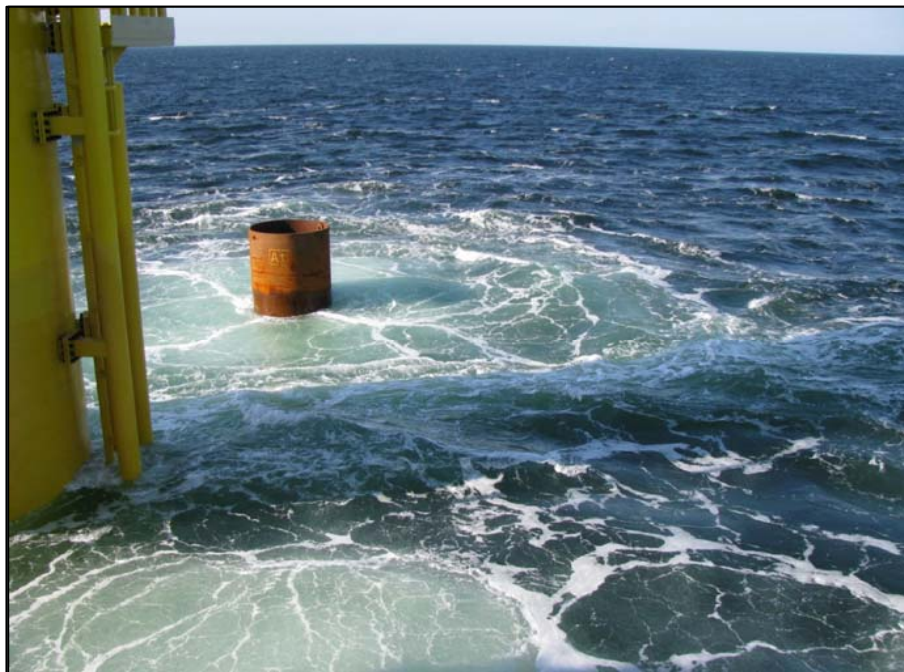
Big Bubble Curtain at OWF *Borkum West II*

Preliminary Results

- › Six successful deployments in a row during project
- › Noise reduction:
 - › 5.1 - 12.8 dB (SEL)
 - › 6.8 - 14.2 dB (L_{peak})
- › Defined threshold level (160 SEL / 190 L_{peak}) can be met
- › Re-engineered system will be tested in spring 2012

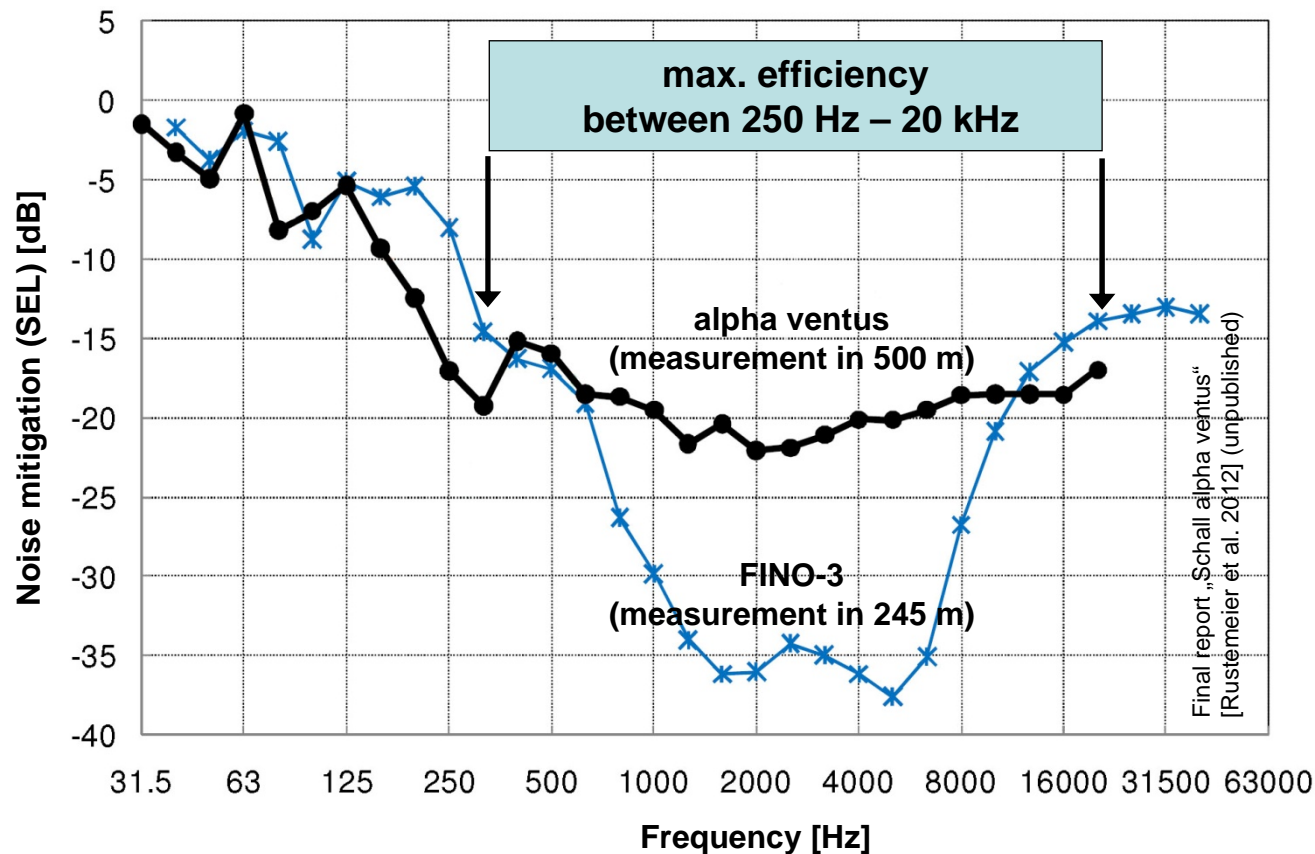
Noise Mitigation Measures Small Bubble Curtain at OWF *alpha ventus*

- › BMU-funded project “Schall alpha ventus“ (ref. no. 0325122A/B)
- › Final report available soon at: <http://www.tib.uni-hannover.de/>



Noise Mitigation Measures

Small Bubble Curtain at OWF *alpha ventus*



Achieved noise reduction

- › In direction of current:
 - SEL: 13 dB
 - L_{peak} : 14 dB
- › Against direction of current:
 - SEL: 2 dB
 - L_{peak} : 0 dB

Noise Mitigation Measures

Small Bubble Curtain at OWF *BARD Offshore 1*

- › BMU-funded project “HYDROSCHALL-OFF BO 1“ (ref. no. 0325334A/B/C/G)

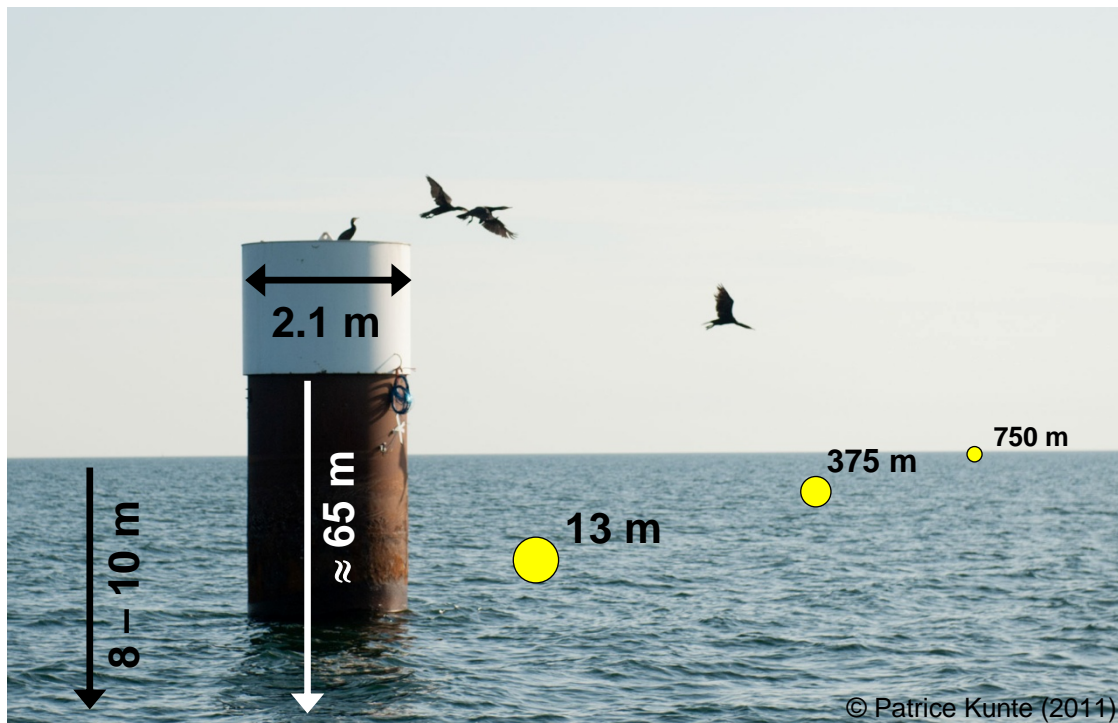


- › 80 Tripile foundations in ≈ 40 m water depth
- › BC consisting of 56 PE-tubes (length: 40.3 m)
- › 1st offshore test (November 2011)
- › Air supply from jack-up barge by up to 5 compressors (up to 190 m³/min)
- › Test of 22 different configurations
- › Noise reduction up to 15.5 dB (SEL)
- › Data analysis ongoing
- › 2nd offshore test in May 2012

Noise Mitigation Measures

ESRa: Evaluation of Systems for Ramming Noise Mitigation

- › Test under identical environmental conditions at Lübeck Bay
- › BMU-funded project (ref. no. 0325307)



Industrial Partners

- › BARD Engineering GmbH
- › DONG Energy A/S
- › EnBW Erneuerbare Energien GmbH
- › E.ON Climate & Renewables GmbH
- › EWE Energie AG
- › RWE OLC GmbH
- › Stadtwerke München GmbH
- › Vattenfall Europe Windkraft GmbH

Noise Mitigation Measures

ESRa: Noise Mitigation Screen (IHC Hydrohammer B.V.)

- › Double-wall steel tube with inner bubble curtain

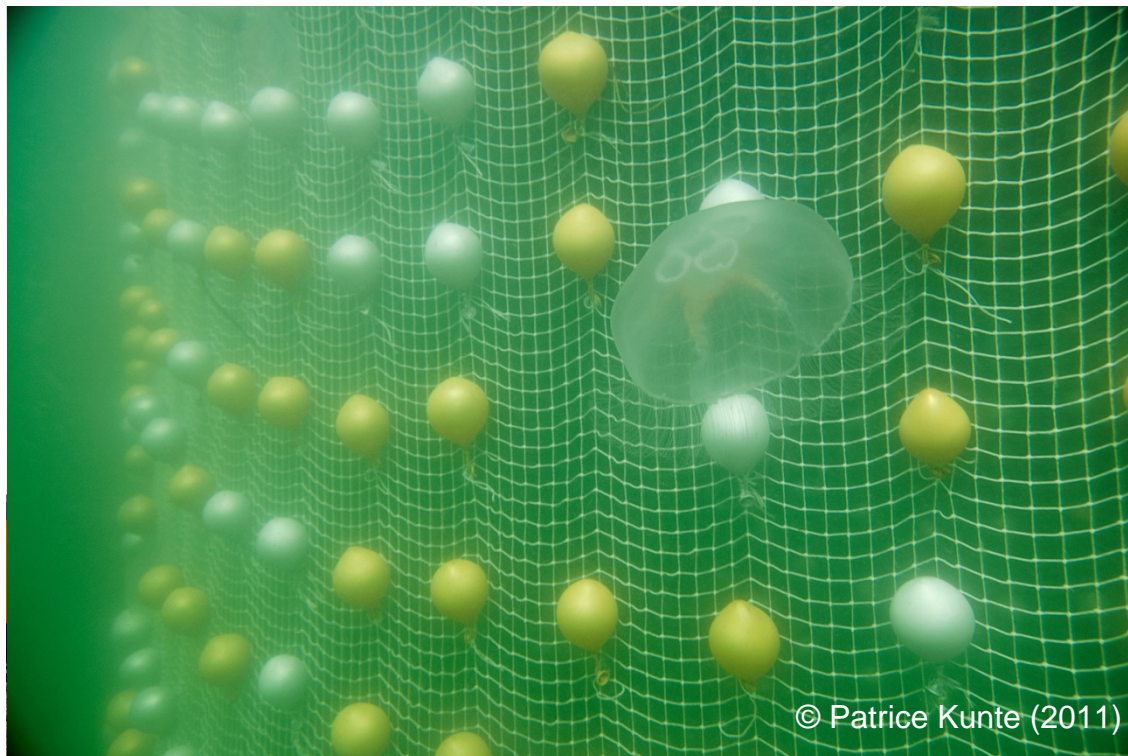


- › Maximum damping efficiency between 500 Hz – 10 kHz
- › Next step: system will be deployed at OWF *Riffgatt*

Noise Mitigation Measures

ESRa: Hydro Sound Damper (OffNoise-Solutions GmbH)

- › Latex balloons and “swim noodles” arranged on net (Braunschweig Univ.)



- › No air compressors necessary
- › Low weight
- › Maximum damping efficiency adjustable
- › Volume air in water 5 - 10%
- › Next step: will be tested at OWF *London Array* (with ABJV)

Noise Mitigation Measures

ESRa: “BEKA”-Jacket (Bernhard Weyres Offshore)

- › Two half-shells of steel and industrial sound dampers



- › Double steel wall with polymer filling
- › Inner and outer bubble curtain
- › Acoustic decoupling (vibration absorber)
- › Maximum damping efficiency between 500 Hz – 10 kHz

Noise Mitigation Measures

ESRa: Ring of Fire Hoses (MENCK GmbH)

- › Single and double wall of fire hoses filled with compressed air

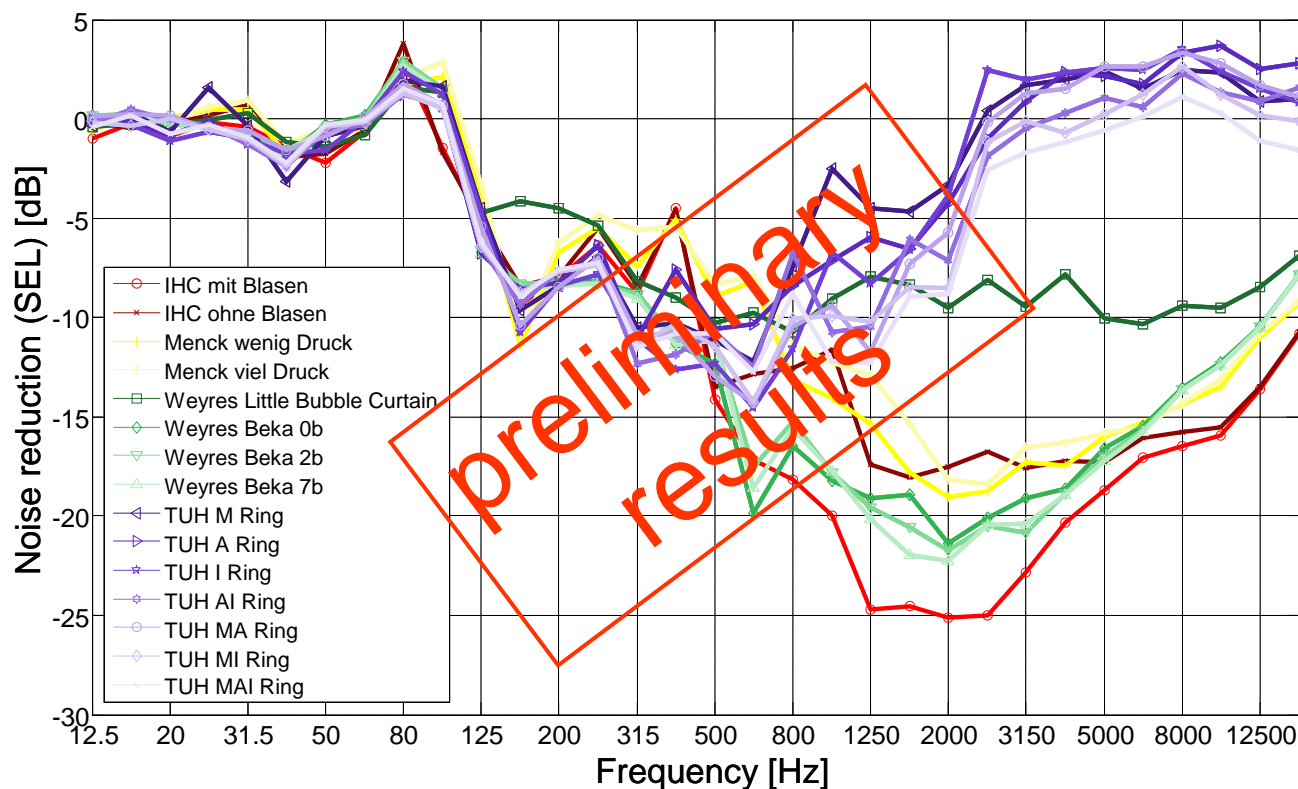


- › Small air demand to inflate system (less compressor capacity)
- › Space saving storage (foldable hoses)
- › Maximum efficiency between 1,2 - 8 kHz
- › Better results with 1 bar than with 2 bar



Noise Mitigation Measures

ESRa: System Benchmark



Achieved noise reduction

- › SEL: 4.2 - 6.1 dB
- › L_{peak} : 4.5 - 7.9 dB
- › due to site specific conditions +2/3 dB
- › next step: test under real offshore conditions

Noise Mitigation Measures Cofferdam (Lo-Noise Aps)

- › Offshore test at Aarhus (Dec. 2011) in 20 - 25 m water depth



- › 4 ejector pumps to evacuate water (125 m³/h → 5 min)
- › Diaphragm seal at bottom
- › Noise reduction within 16 - 20 kHz:
 - 22 dB (SEL)
 - 18 dB (L_{peak})
- › Next steps: building Borwin2 & Helwin1 auxiliary platforms



Part II: Low-noise Foundation Concepts

Low-Noise Foundation Concepts

- › Drilled foundations
- › Gravity based foundations
- › Suction Buckets / Cans
- › Floating foundations

Low-noise Foundation Concepts

Offshore Foundation Drilling (Herrenknecht AG / Hochtief Solutions AG)

- › BMU-funded project “Further Development of VSM“ (ref. no. 0325233)



- › Concept technically and economically feasible
- › Independent from soil conditions
- › Suitable for pile diameters up to 8 m
- › Penetration rate 2-3 m/h
- › Expected noise levels:
 - 117 dB (SEL),
 - 122 dB (L_{peak})
- › Next step: prototype development (2012)

Summary and Outlook

› State of the art?

concept prototype offshore demonstration market availability

Big Bubble Curtain	✓	✓	✓	✓ ³
Small Bubble Curtain	✓	✓	(✓) ¹	(✓) ⁴
Pile Sleeve (NMS)	✓	✓	(✓) ¹	✓ ³
Hydro Sound Dampers	✓	✓	(✓) ¹	
BEKA Jacket	✓	✓	(✓) ¹	(✓) ⁴
Ring of Fire Hoses	✓	✓	(✓) ¹	
Cofferdam	✓	✓	(✓) ¹	(✓) ⁴
Drilled Foundation	✓			
Gravity Foundation	✓	✓	✓	✓ ³
Suction Bucket / Can	✓	✓	(✓) ²	

(1) **demonstration on test site only**

(2) **demonstration restricted to auxiliary platforms**

(3) **already used at or ordered for OWF projects**

(4) **offered by system manufacturer**

Summary and Outlook

- › Noise mitigation systems have been ordered for upcoming wind farm projects in German EEZ
- › Possible to meet 160/190 threshold with this systems (yet not proven for all foundation concepts)



Thank you for your attention!





Further information

- › Big Bubble Curtain at OWF *Borkum West II*:
 - › Joint research project coordinator: BioConsult-SH GmbH & Co KG; <http://bioconsult-sh.de/>
 - › System manufacturer: Hydrotechnik Lübeck GmbH, <http://www.hydrotechnik-luebeck.de/>
 - › Project homepage: <http://www.hydroschall.de>
- › Small Bubble Curtain at OWF *BARD Offshore 1*:
 - › Project coordinator: BARD Engineering GmbH; <http://www.bard-offshore.de/>
 - › System supplier: MENCK GmbH, <http://www.menck.com/>
- › Hydro Sound Dampers:
 - › Research project coordinator: TU Braunschweig; Prof. Dr. Stahlmann; <http://www.igb.tu-bs.de/>
 - › System manufacturer: OffNoise-Solutions GmbH
- › Offshore Foundation Drilling:
 - › System manufacturer/supplier: HERRENKNECHT AG and HOCHTIEF Solutions AG;
<http://www.herrenknecht.com/news/trade-fairs/bauma-2010-displays/innovative-directions.html>
http://www.hochtief-construction.com/construction_en/461.jhtml



Further information

› Research project ESRa:

- › Project website: <http://www.offshore-stiftung.com/Offshore/aktivitaeten-und-projekte/esra%3A-forschung-zur-schallminderung/144,143,60005,liste9.html>

- › System manufacturers:

“BEKA”-Jacket: Firma Bernhard Weyres; <http://www.veyres-offshore.de/>

Small Bubble Curtain: Firma Bernhard Weyres; <http://www.veyres-offshore.de/>

Ring of fire hoses: MENCK GmbH, <http://www.menck.com/>

Hydro Sound Dampers: OffNoise-Solutions GmbH

Noise Mitigation Screen: IHC Merwede; <http://www.ihcbeaverdredgers.com/about/news-archive/single-news-item/article/ihc-offshore-systems-provides-worlds-biggest-noise-mitigation-system-to-protect-sea-life/>