# Effects from offshore windfarms on the marine environment

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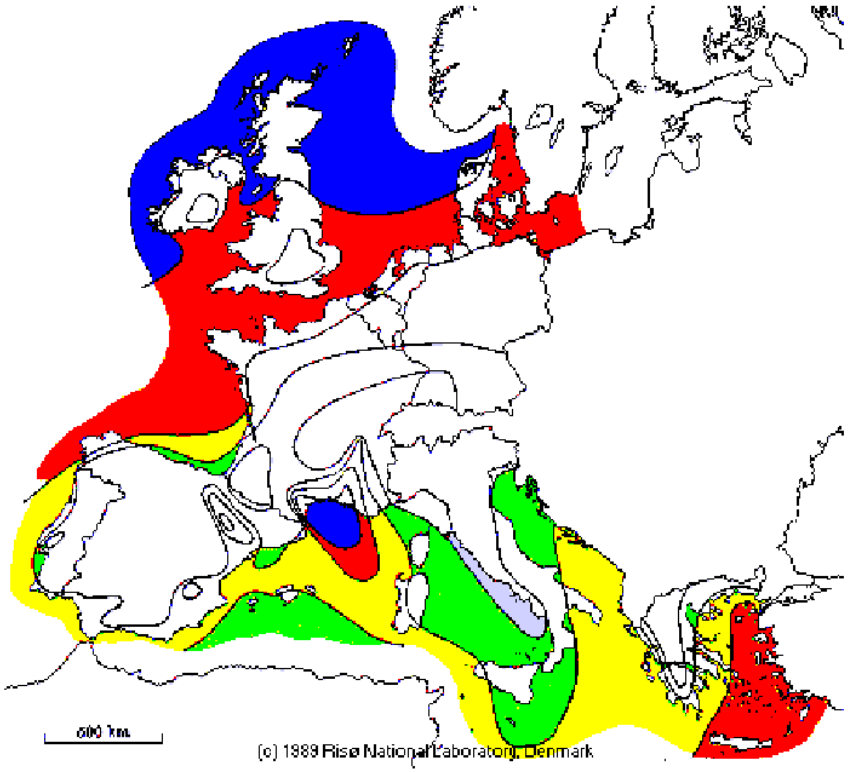
- Why going offshore
- Difficulties and challenges with offshore windfarms
- Offshore windfarms in the German North Sea
- Conflict: environmental protection vs. offshore windenergy
- Technical aspects
- Impacts on the marine environment
- Offshore windfarms as artificial reefs
- Offshore windfarms and mariculture
- Summary

# Why going offshore

- No more space on land
- Two years measurement on FINO 1:
- At 100 m heigth: Vavg = 10.4 m/s
- Profile : 9.5 – 10.0 m/s (between 35 m and 100 m)
- 4000 – 4500 hours of full load p. a. (instead 2000- 2500 h p.a. on land)




| | 10 m | | 25 m | | 50 m | | 100 m | | 200 m | |
|---|---|---|---|---|---|---|---|---|---|---|
| | m/s | W/m² | m/s | W/m² | m/s | W/m² | m/s | W/m² | m/s | W/m² |
| | > 8.0 | > 600 | > 8.5 | > 700 | > 9.0 | > 800 | > 10.0 | > 1100 | > 11.0 | > 1500 |
| | 7.0-8.0 | 350-600 | 7.5-8.5 | 450-700 | 8.0-9.0 | 600-800 | 8.5-10.0 | 650-1100 | 9.5-11.0 | 900-1500 |
| | 6.0-7.0 | 250-300 | 6.5-7.5 | 300-450 | 7.0-8.0 | 400-600 | 7.5-8.5 | 450-650 | 8.0-9.5 | 600-900 |
| | 4.5-6.0 | 100-250 | 5.0-6.5 | 150-300 | 5.5-7.0 | 200-400 | 6.0-7.5 | 250-450 | 6.5-8.0 | 300-600 |
| | < 4.5 | < 100 | < 5.0 | < 150 | < 5.5 | < 200 | < 6.0 | < 250 | < 6.5 | < 300 |

Fig. 2.1: Wind resources over open sea (more than 10 km offshore) for five standard heights [Source: RISØ, http://130.226.52.108/oceanmap.htm].

# Difficulties with offshore windfarms (overview)

- No European directive for offshore windfarms and no national
- Conflicts with other marine usings (military, navigation, protected areas, fishery etc.)
- Construction and service problem dependig on weather conditions
- Only a few offshore windfarms are already built in the North Sea, e.g. Nysted, Horns Rev => *NO* longterm experience!
- Harbours must be enlarged
- Conflicts about the pathways for the cables
- Infrastructure for service must be enlarged
- Conflicts with residents who do not want to see windmills on the horizon due to tourism

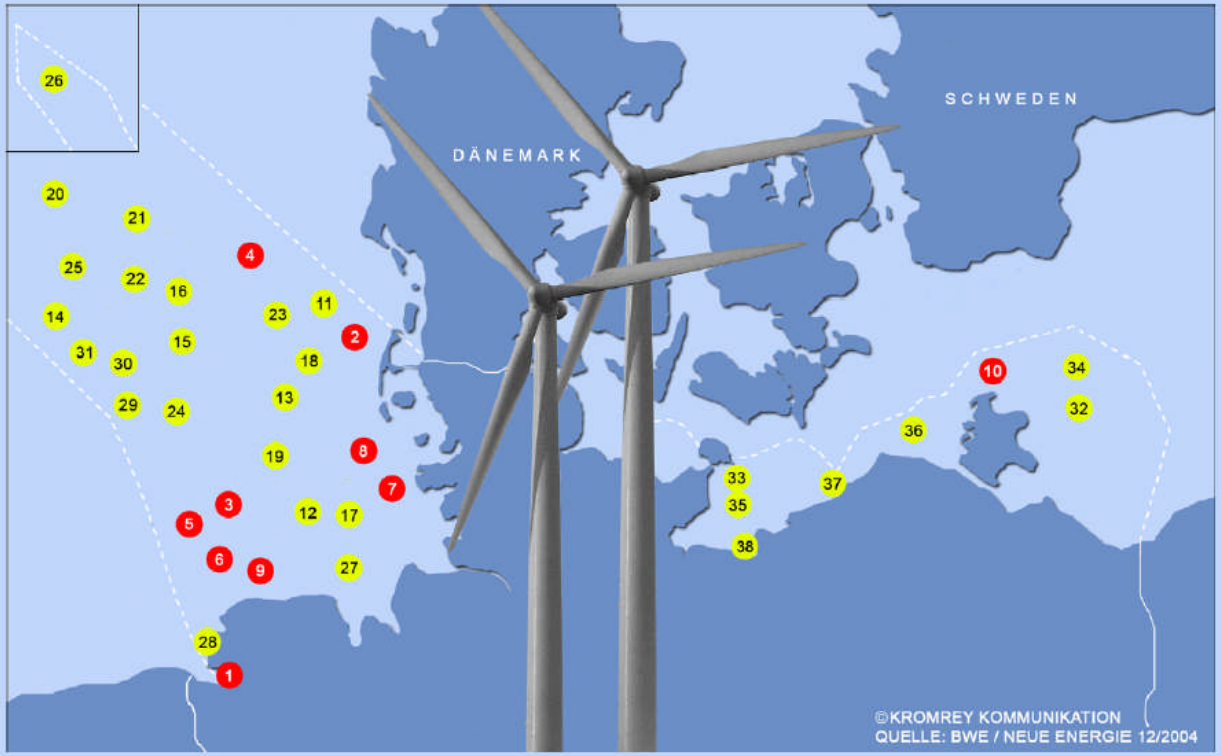
# Challenges with offshore windfarms

- High claims on the material (currency, storm, corrosion etc.)
- Foundation problems
- Transport of moduls of a windmill over land and sea from different place => partly assemblage of windmills offshore
- erection possible only during calm weather conditions
- Long distances for cables
- Survaillance of ship collision risk

# Offshore windfarms in the German part of the North Sea (1)

- firms claim areas in the EEZ (exclusive economic zone) => application to build there a windfarm & expert opinion about the biological impacts => NO law for planning
- NO uniform directive which aspects must be regarded within the expert opinion => No comparability

# Offshore windfarms in the German part of the North Sea (2)




## Die deutschen Windkraft-Projekte auf dem Meer

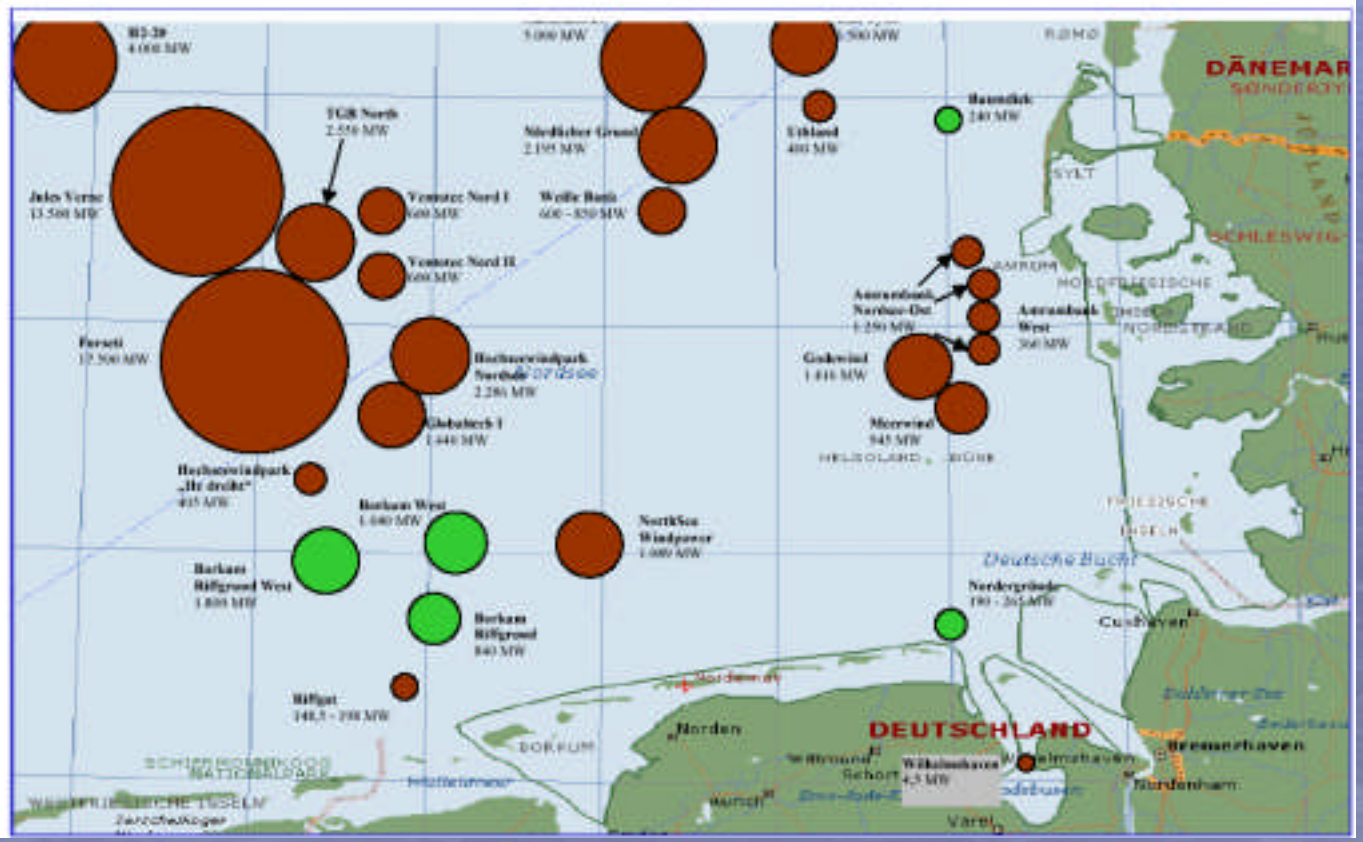
| | | |
|---|---|---|
| **Genemigte Windparks Nordsee** | | |
| 1 | Emden (Nearshore) | 4,5 MW |
| 2 | Butendiek | 240,0 MW |
| 3 | Borkum West | 1.040,0 MW |
| 4 | Sandbank 24 | bis 4.720,0 MW |
| 5 | Borkum Riffgrund West | 1.800,0 MW |
| 6 | Borkum Riffgrund | 746,0 MW |
| 7 | Amrumbank West | 400,0 MW |
| 8 | Nordsee Ost | 1.250,0 MW |
| 9 | ENOVA ONS Windpower | bis 1.255,0 MW |
| **Genemigte Windparks Ostsee** | | |
| 10 | Kriegers Flak | bis 321,0 MW |
| **Geplante Windparks Nordsee** | | |
| 11 | Dan Tysk * | bis 1.500,0 MW |
| 12 | Meerwind * | bis 819,0 MW |
| 13 | Weisse Bank 2010 | bis 2.700,0 MW |
| 14 | Forseti | 17.500,0 MW |
| 15 | Globaltech I * | bis 1.440,0 MW |
| 16 | Hochsee Windpark * | bis 2.286,0 MW |
| 17 | Godewind * | bis 896,0 MW |
| 18 | Uthland | bis 400,0 MW |
| 19 | Weisse Bank | bis 595,0 MW |
| 20 | Jules Verne | 13.500,0 MW |
| 21 | Ventotec Nord 1 | bis 600,0 MW |
| 22 | Ventotec Nord 2 | bis 600,0 MW |
| 23 | Nördlicher Grund | bis 2.195,0 MW |
| 24 | Windpark He dreiht * | 536,0 MW |
| 25 | TGB North | 2.550,0 MW |
| 26 | H 2 - 20 | bis 4.000,0 MW |
| 27 | Nordergründe | 270,0 MW |
| 28 | Riffgat | bis 220,0 MW |
| 29 | Bard Offshore * | bis 1.600,0 MW |
| 30 | Austerngrund | 400,0 MW |
| 31 | Deutsche Bucht | 400,0 MW |
| **Geplante Windparks Ostsee** | | |
| 32 | Arcona Becken Südost * | bis 1.005,0 MW |
| 33 | Beltsee | bis 415,0 MW |
| 34 | Ventotec Ost II * | bis 600,0 MW |
| 35 | Sky 2000 | bis 100,0 MW |
| 36 | Baltic I | 51,0 MW |
| 37 | Breitling | 2,3 MW |
| 38 | Wismar | 2,0 MW |

* Antrag bei BSH im Genehmigungsverfahren

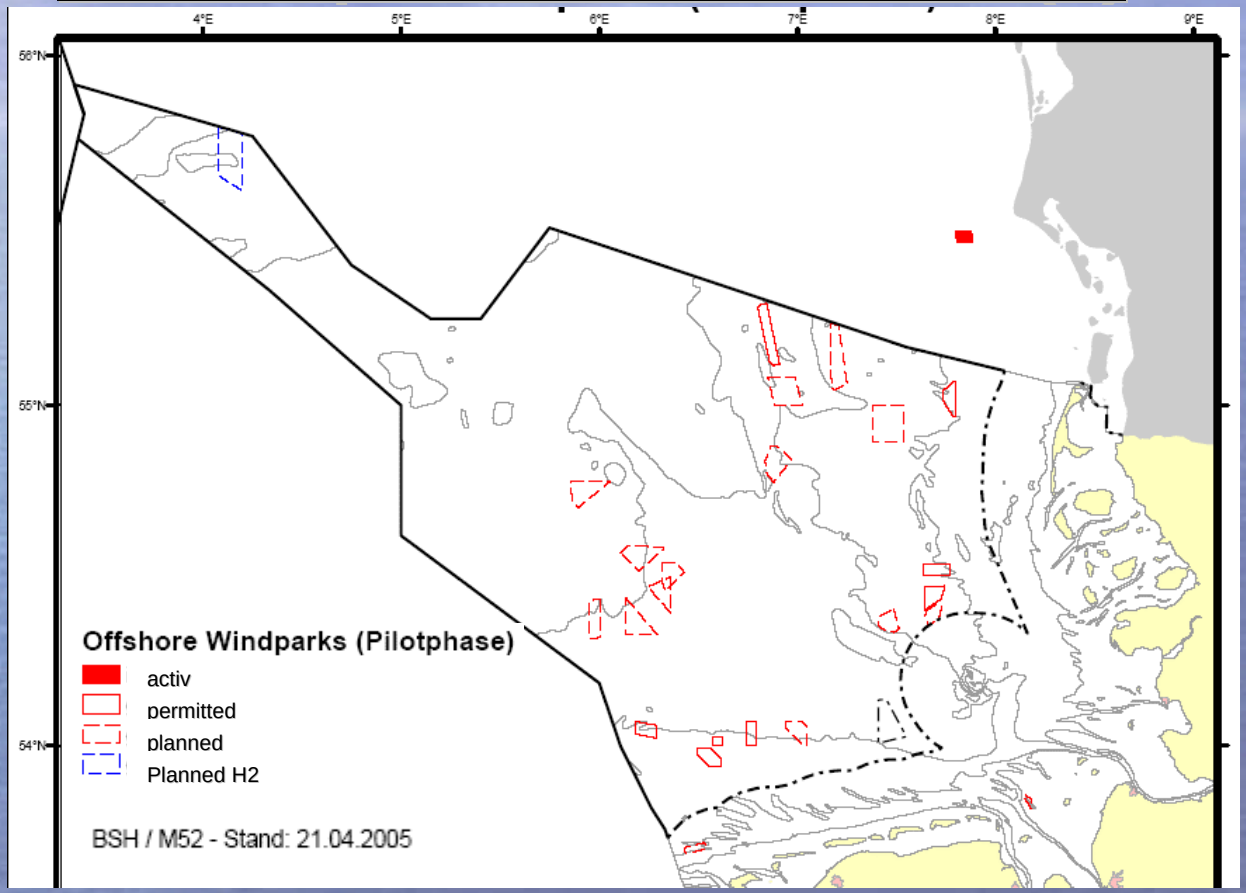
# Offshore windfarms in the German part of the North Sea (3)

Offshore Technologie
Projektentwicklungsgesellschaft mbH MV

## Geplante Offshore-Windparks in dt. Gewässern



# Offshore windfarms in the German part of the North Sea (4)




- 9 permitted offshore windfarms in the German EEZ

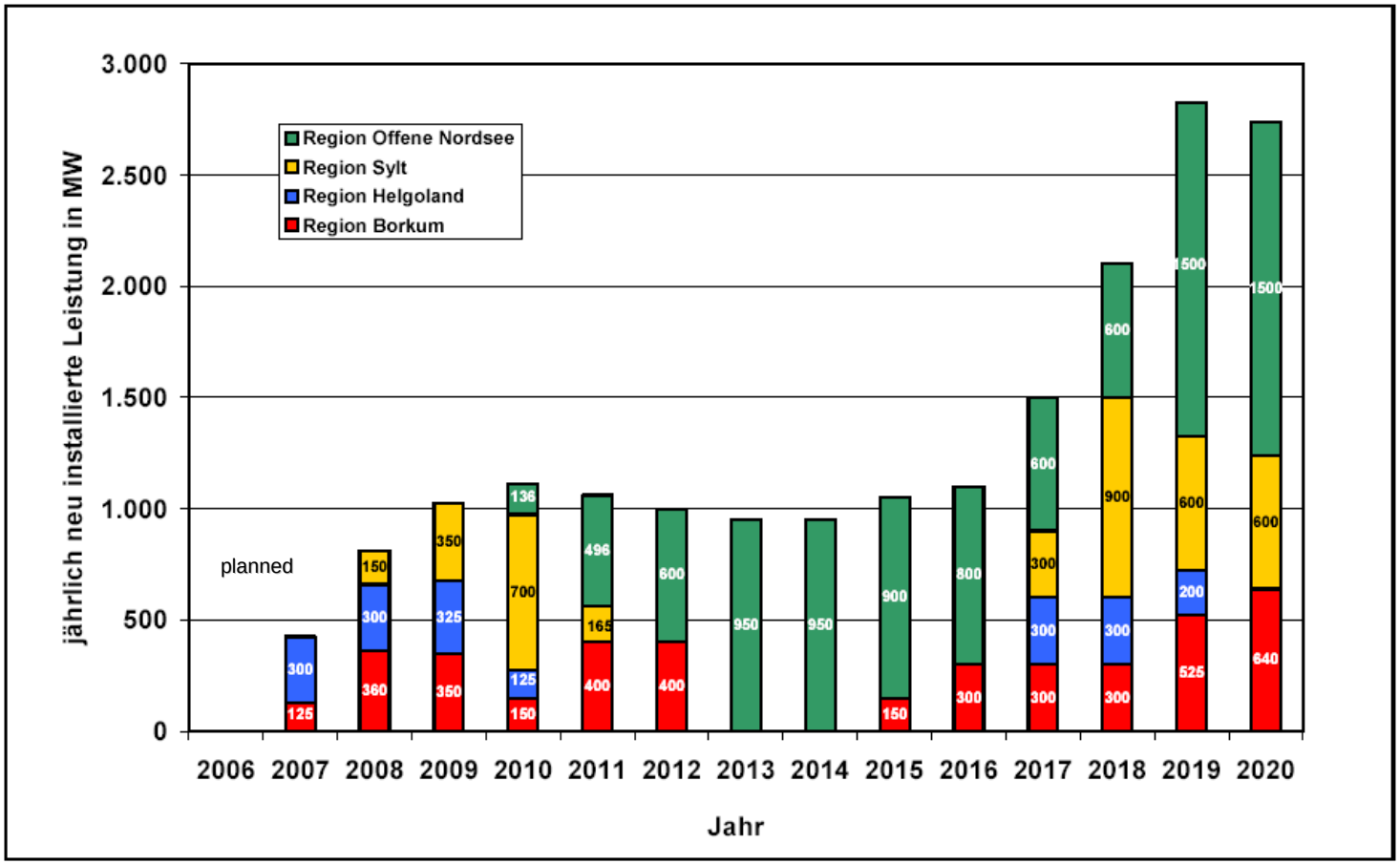
# Offshore windfarms in the German part of the North Sea (5)

| NORDSEE | Pilotphase | Endausbau | WEA | Wassertiefe | Küstenentfernung |
|---|---|---|---|---|---|
| | MW | MW | MW | | |
| **Region Borkum** | | | | | |
| Borkum West | 60 | 1.040 | 5 | 30 m | 45 km nordwestl. v. Borkum |
| Borkum Riffgrund West | 280 | 1.603 | 3,6 | 30-35 m | 50 km nordwestl. von Borkum |
| Borkum Riffgrund | 250 | 650 | 3,6 | 23-29 m | 38 km nördlich von Borkum |
| Northsea Windpower | 225 | 1.250 | 5 | 26-34 m | 39 km nördlich von Juist |
| Nordergründe | 125 | 125 | 5 | 5-18 m | 20 km nördlich von Wilhelmshaven |
| Borkum Riffgat | 198 | 198 | 4,5 | 16-24 m | 15 km nordwestlich von Borkum |
| Gode Wind | 400 | 800 | 5 | 16-24 m | 30 km nördlich von Wangerooge |
| **Summe Region Borkum** | 1.538 | 5.666 | | | |
| | | | | | |
| **Region Helgoland** | | | | | |
| Nordsee Ost | 400 | 850 | 5 | ca. 22 m | 30 km nördlich von Helgoland |
| Amrumbank West | 400 | 400 | 5 | 21-25 m | 35 km nördlich von Helgoland |
| Meerwind | 250 | 1.050 | 3,6 | 22-32 m | 22 km nordwestlich von Helgoland |
| **Summe Helgoland** | 1.050 | 2.300 | | | |
| | | | | | |
| **Region Sylt** | | | | | |
| Butendiek | 240 | 240 | 3 | 16-22 m | 35 km westlich von Sylt |
| Sandbank 24 | 360 | 4.665 | 3 | 23-35 m | 100 km westlich von Sylt |
| Dan Tysk | 400 | 800 | 5 | 23-31 m | 69 km nordwestlich von Sylt |
| Nördlicher Grund | 365 | 2.195 | 4,2 | 25-35 (40)m | 100 km (nord-)westlich von Sylt |
| *Uthland*** | *Planung ruht* | | 5 | 24-27 m | 49 km westlich von Sylt |
| *Weiße Bank*** | *Planung ruht* | | 5 | 28-35 m | 60 km westlich von Sylt |
| *Weiße Bank 2010*** | *Planung ruht* | | 5 | k.A. | k.A. |
| **Summe Sylt** | 1.365 | 7.900 | | | |
| | | | | | |
| **Region Offene Nordsee** | | | | | |
| Globaltech I | 360 | 1.440 | 4,5 | ca. 40 m | ca. 100 km nördlich von Borkum |
| Hochseewindpark Nordsee | 536 | 2.286 | 4,5 | ca. 40 m | 80 km nördlich von Borkum |
| Hochseewindpark He dreiht | 536 | 536 | 4,5 | ca. 40 m | 80 km nördlich von Borkum |
| *Forseti*** | 0 | 10.000 | 5-7 | ca. 40 m | >100 km nördlich von Borkum |
| *TGB North*** | 800 | 2.500 | 5 | ca. 40 m | 100 km nördlich von Borkum |
| *Ventotec Nord I*** | 0 | 600 | 5 | ca. 40 m | >100 km nördlich von Borkum |
| *Ventotec Nord II*** | 0 | 600 | 5 | ca. 40 m | >100 km nördlich von Borkum |
| *Jules Verne*** | 0 | 3.000 | 5 | ca. 40 m | >100 km nördlich von Borkum |
| *H2-20*** | *$H_2$-Produktion* | | 5 | 40-60 m | 250 km nördlich von Norderney |
| **Summe Offene Nordsee** | 2.232 | 20.962 | | | |
| **Summe Nordsee gesamt** | 6.185 | 36.828 | | | |

After DENA (2005)

# Offshore windfarms in the German part of the North Sea (6)

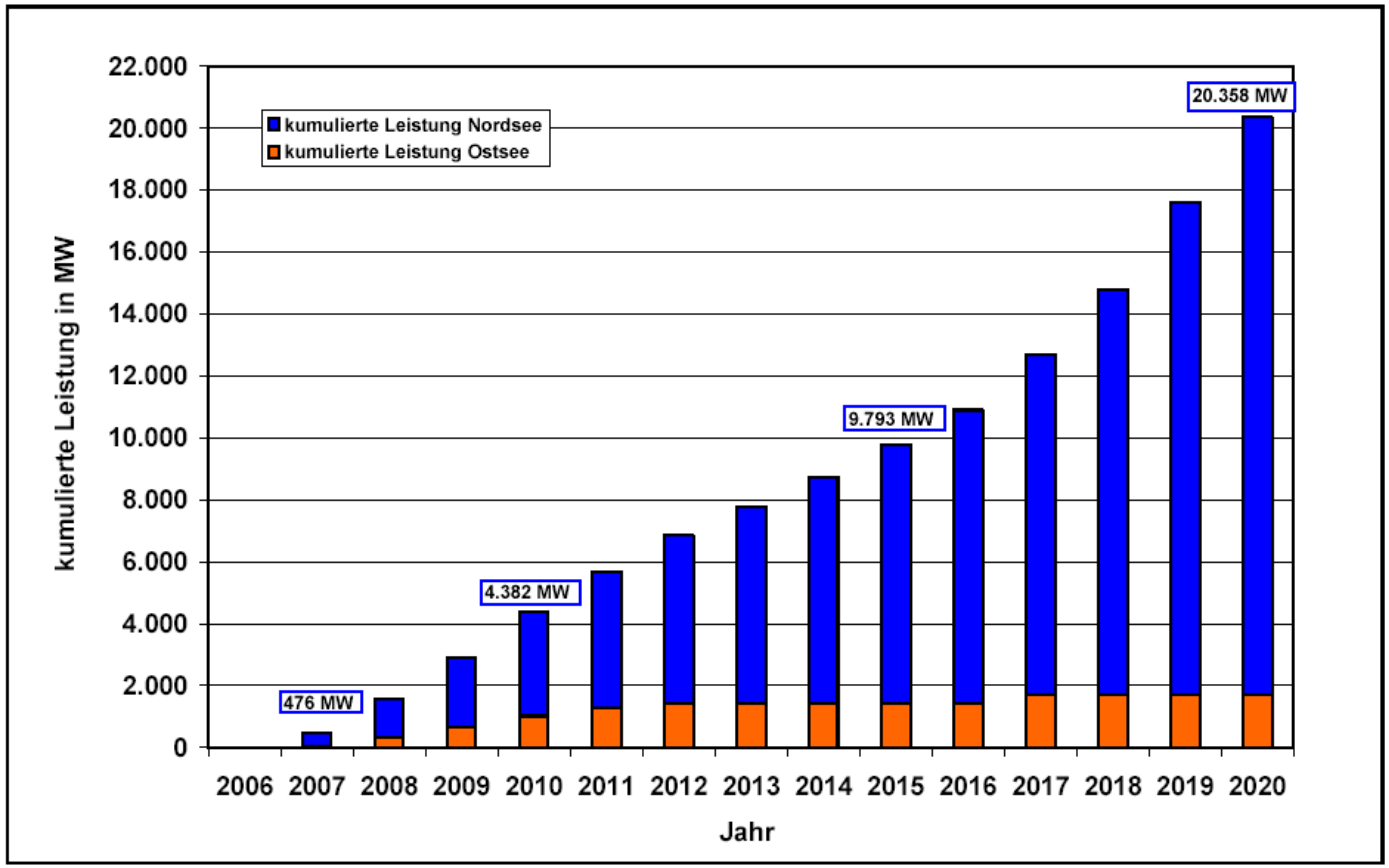
Prognosis offshore windenergy development in the North Sea




After DENA (2005)

# Offshore windfarms in the German part of the North Sea (7)

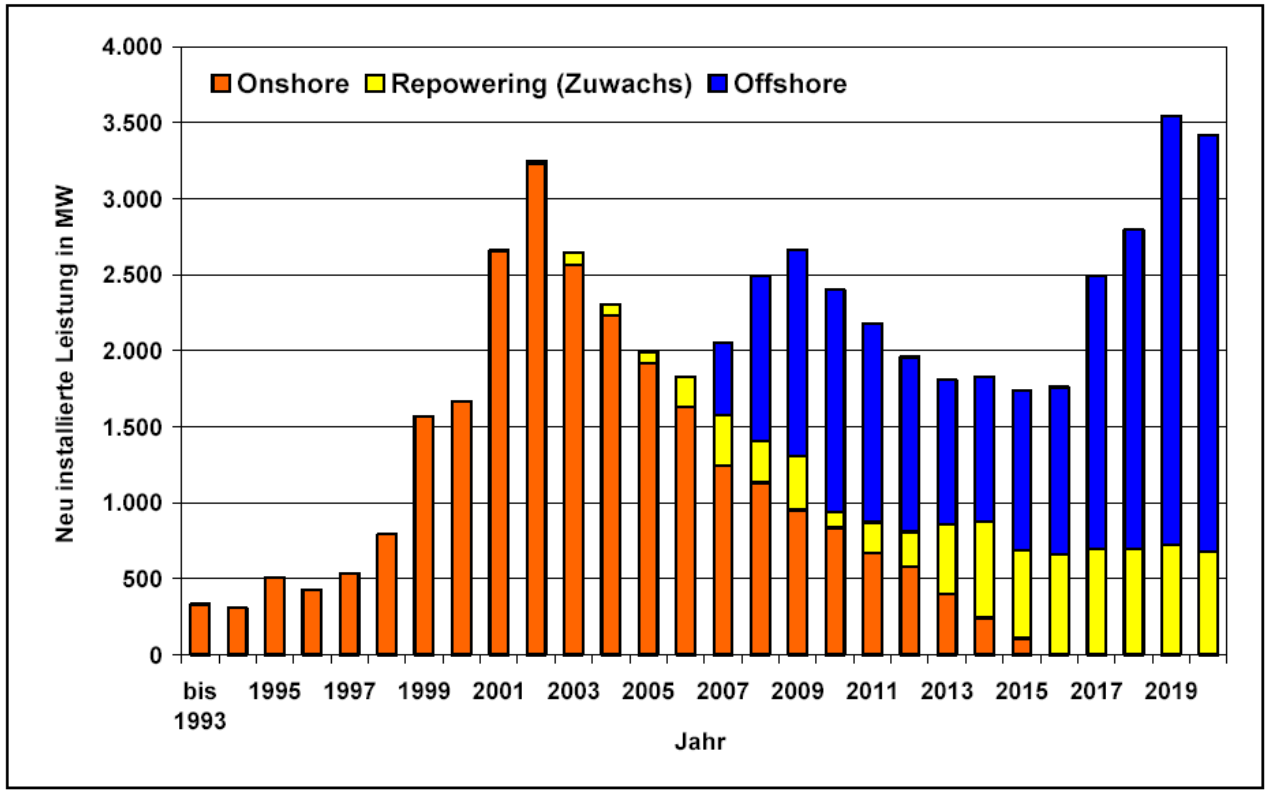
Prognosis offshore windenergy development in the North Sea and Baltic Sea




After DENA (2005)

# Offshore windfarms in the German part of the North Sea (8)

Prognosis windenergy development onshore and offshore in Germany to the year 2020 (new installation) DEWI-Scenario




After DENA (2005)

Prognosis windenergy development onshore and offshore in Germany to the year 2020 (cummulative power) DEWI-Scenario

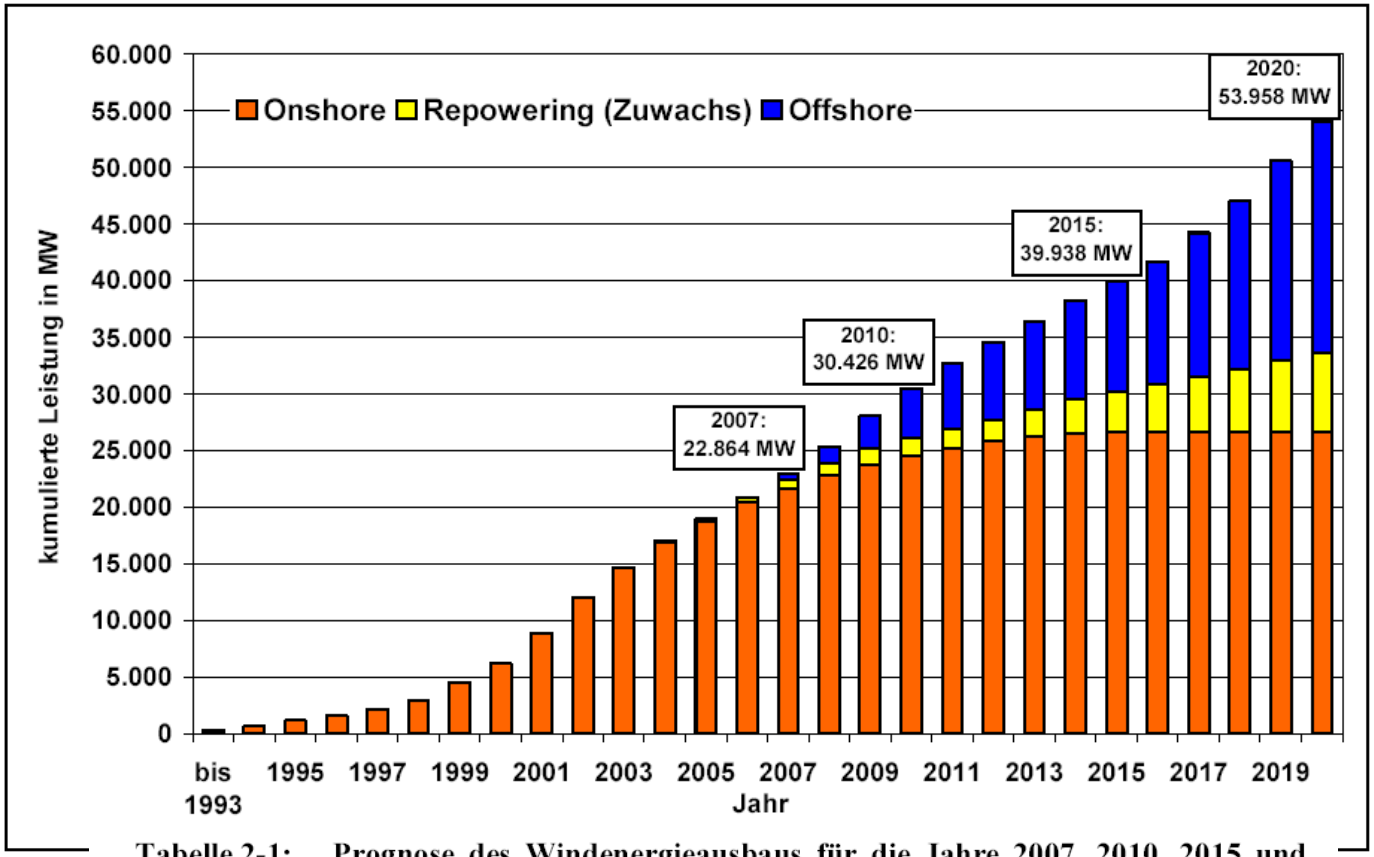


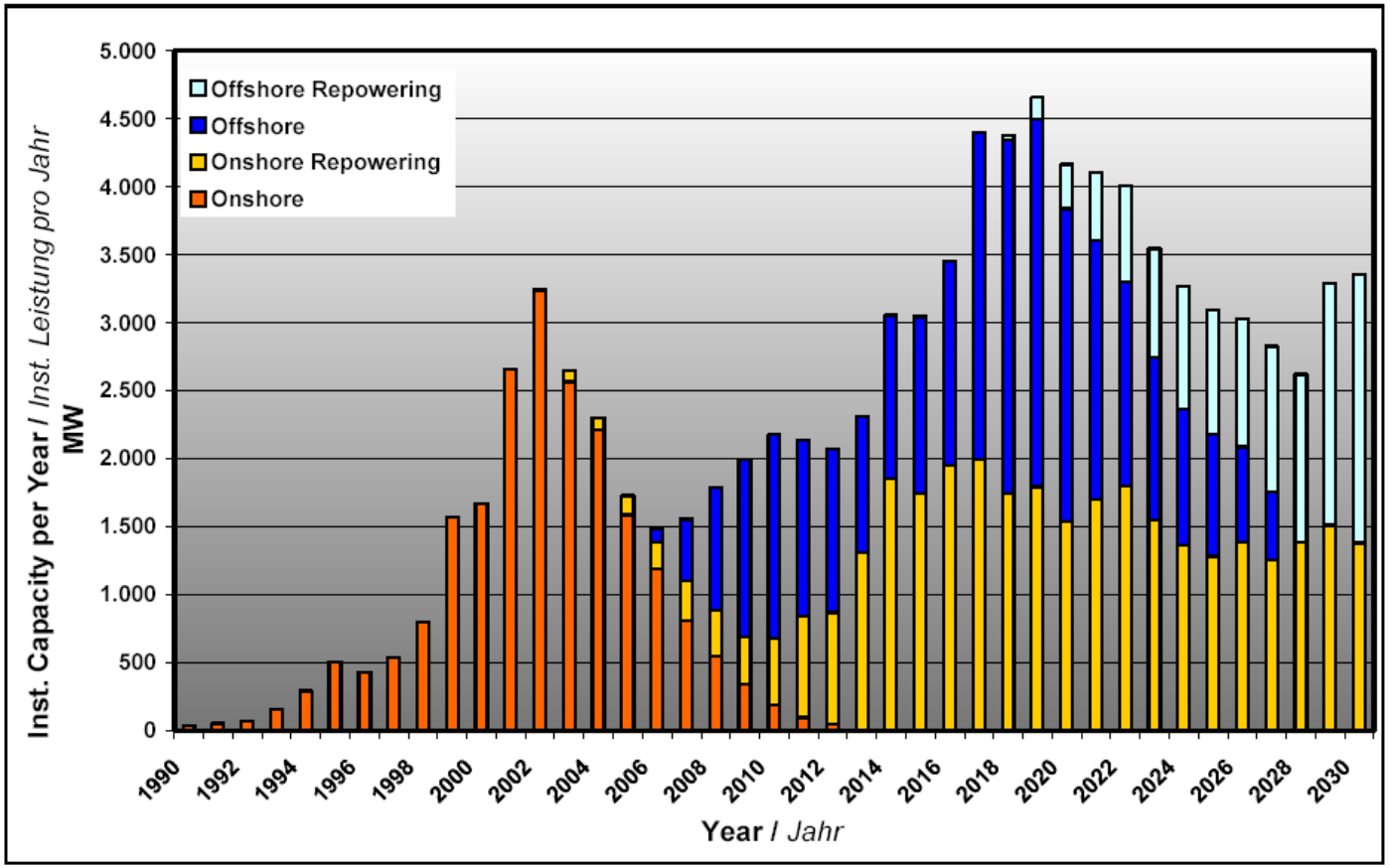

**Tabelle 2-1: Prognose des Windenergieausbaus für die Jahre 2007, 2010, 2015 und 2020 gemäß DEWI-Szenario (kumuliert, Angaben in MW)**

| Jahr | Onshore | Repowering (Zuwachs) | Offshore | Summe |
|---|---|---|---|---|
| 2007 | 21.620 | 768 | 476 | 22.864 |
| 2010 | 24.540 | 1.503 | 4.382 | 30.426 |
| 2015 | 26.544 | 3.601 | 9.793 | 39.938 |
| 2020 | 26.544 | 7.056 | 20.358 | 53.958 |

After DENA (2005)

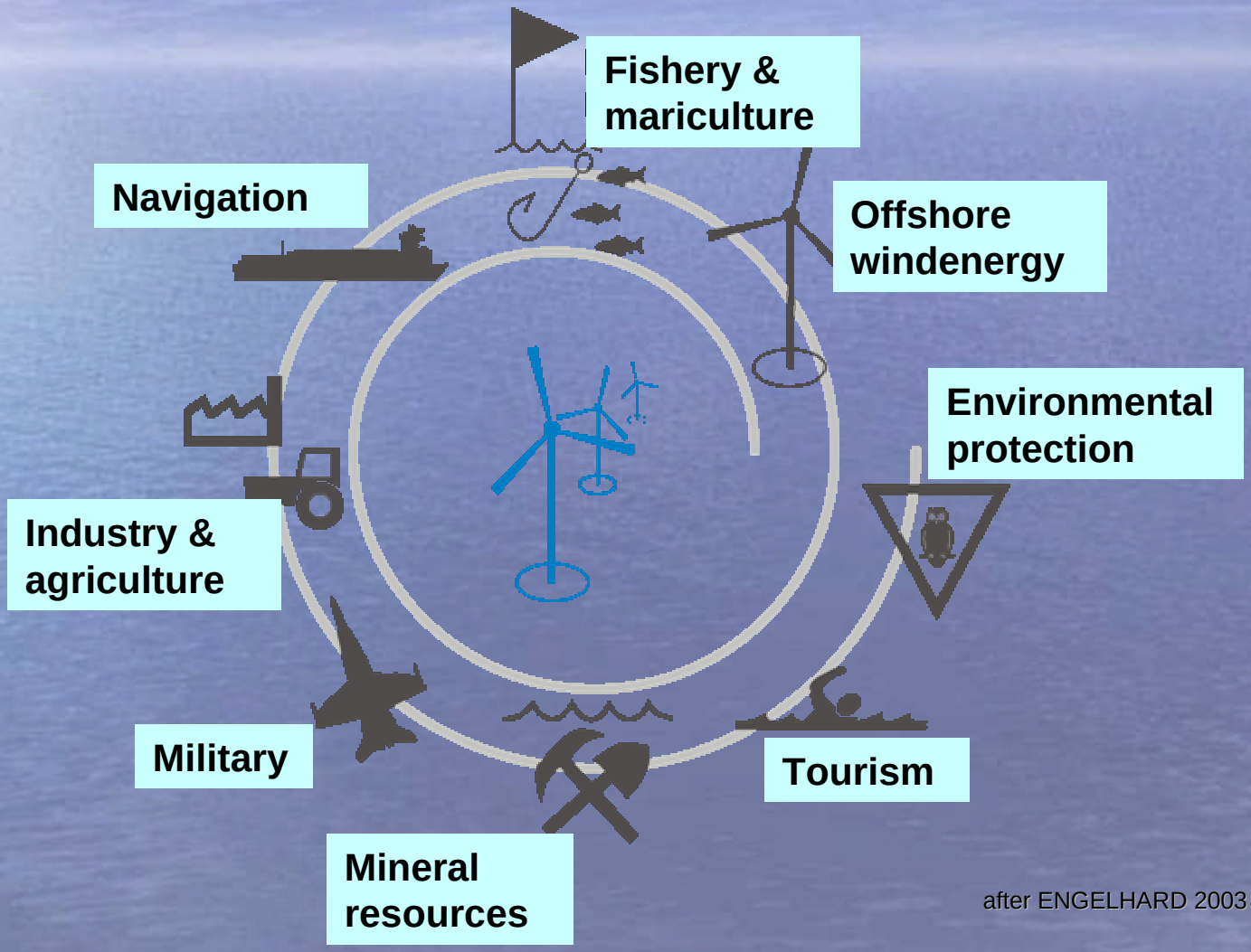
# Offshore windfarms in the German part of the North Sea (10)

Prognosis windenergy development in Germany to the year 2030 including onshore-installations and repowering and offshore-installation and repowering (DEWI 2004a)



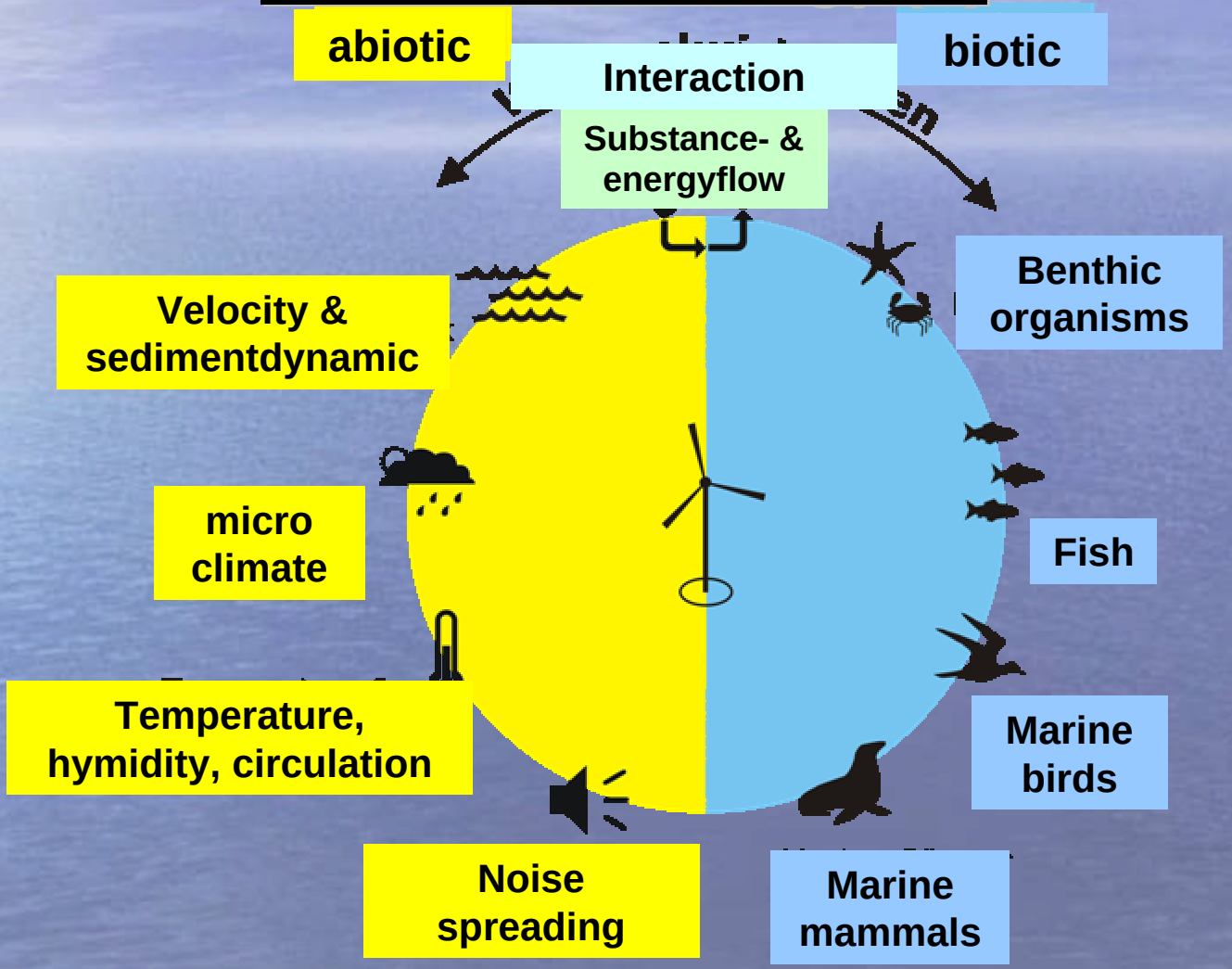

After DENA (2005)

# Conflict: environmental protection vs. offshore windenergy (1)




after ENGELHARD 2003

# Conflict: environmental protection vs. offshore windenergy (2)



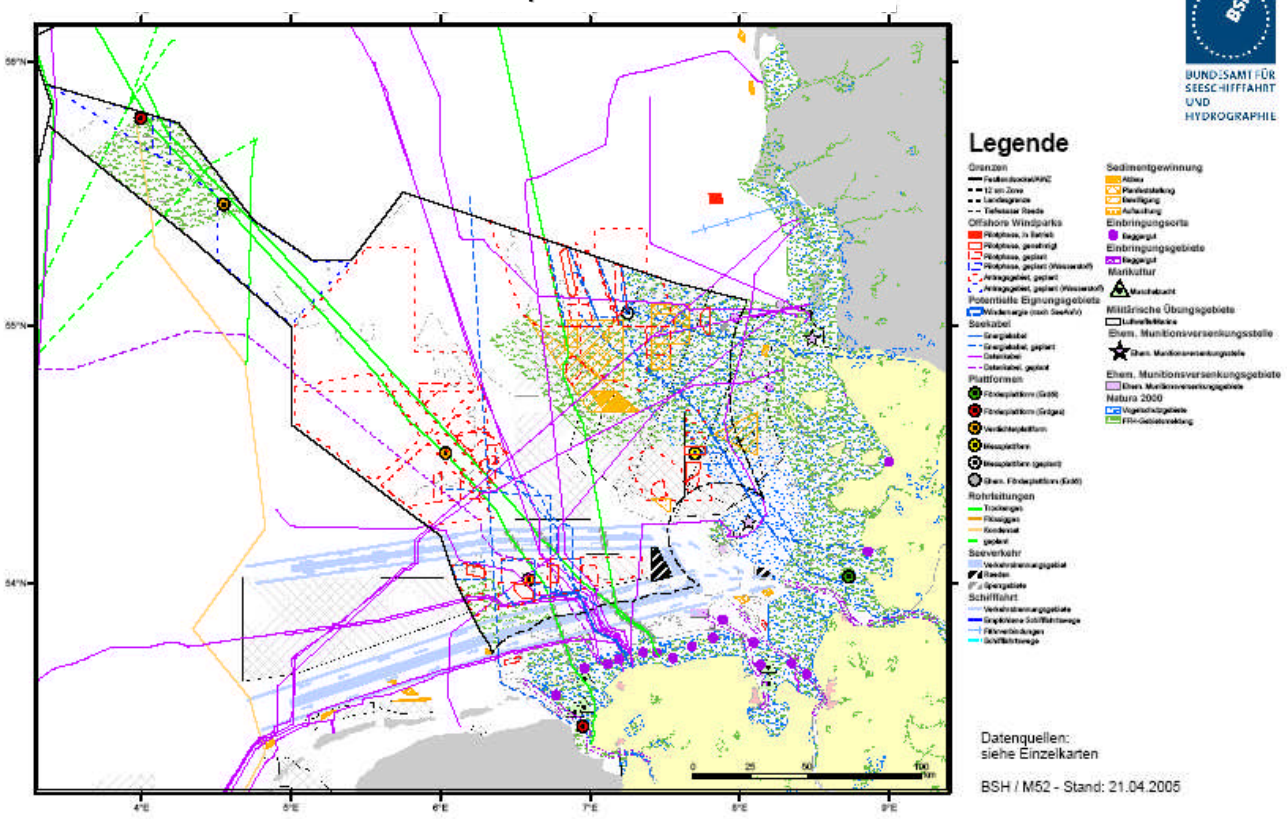

after ENGELHARD 2003

# Conflict: environmental protection vs. offshore windenergy (3)

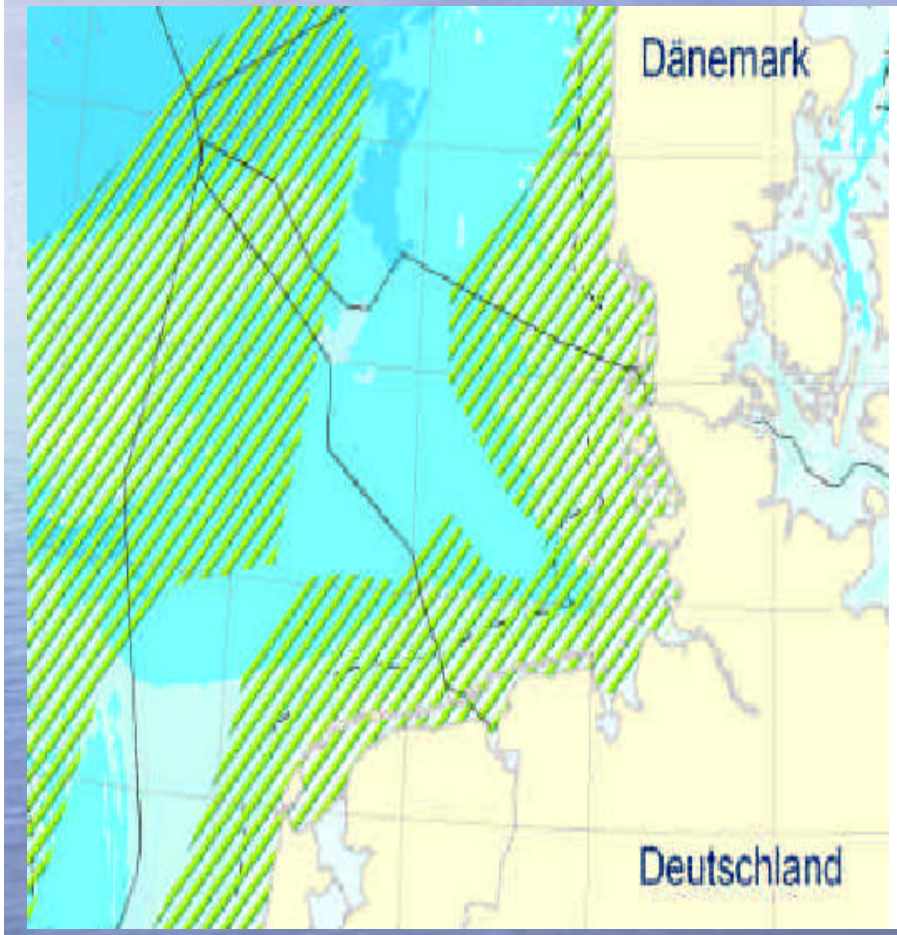
- Areas for windfarms are overlapping with fish sperming grounds (haddock, plaice, sole) and with proposals for protected areas
- fishing prohibition within the windfarms
- Expulsion of birds, fish & marine mammals or vice versa
- Trials for a multiway using of offshore windfarms (energy, mariculture, fishgrounds)

# Conflict: environmental protection vs. offshore windenergy (4)

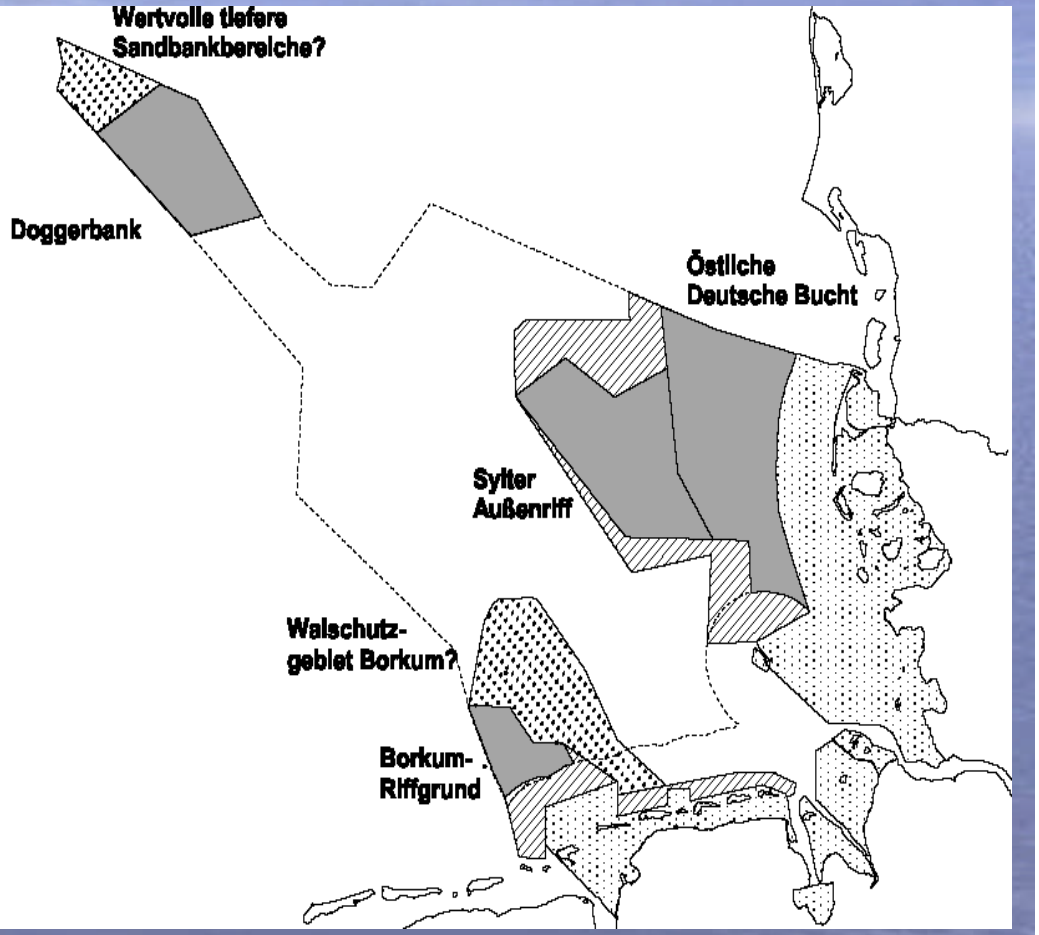
Northsea: all utilisations and protected areas



# Demands for marine proteced areas

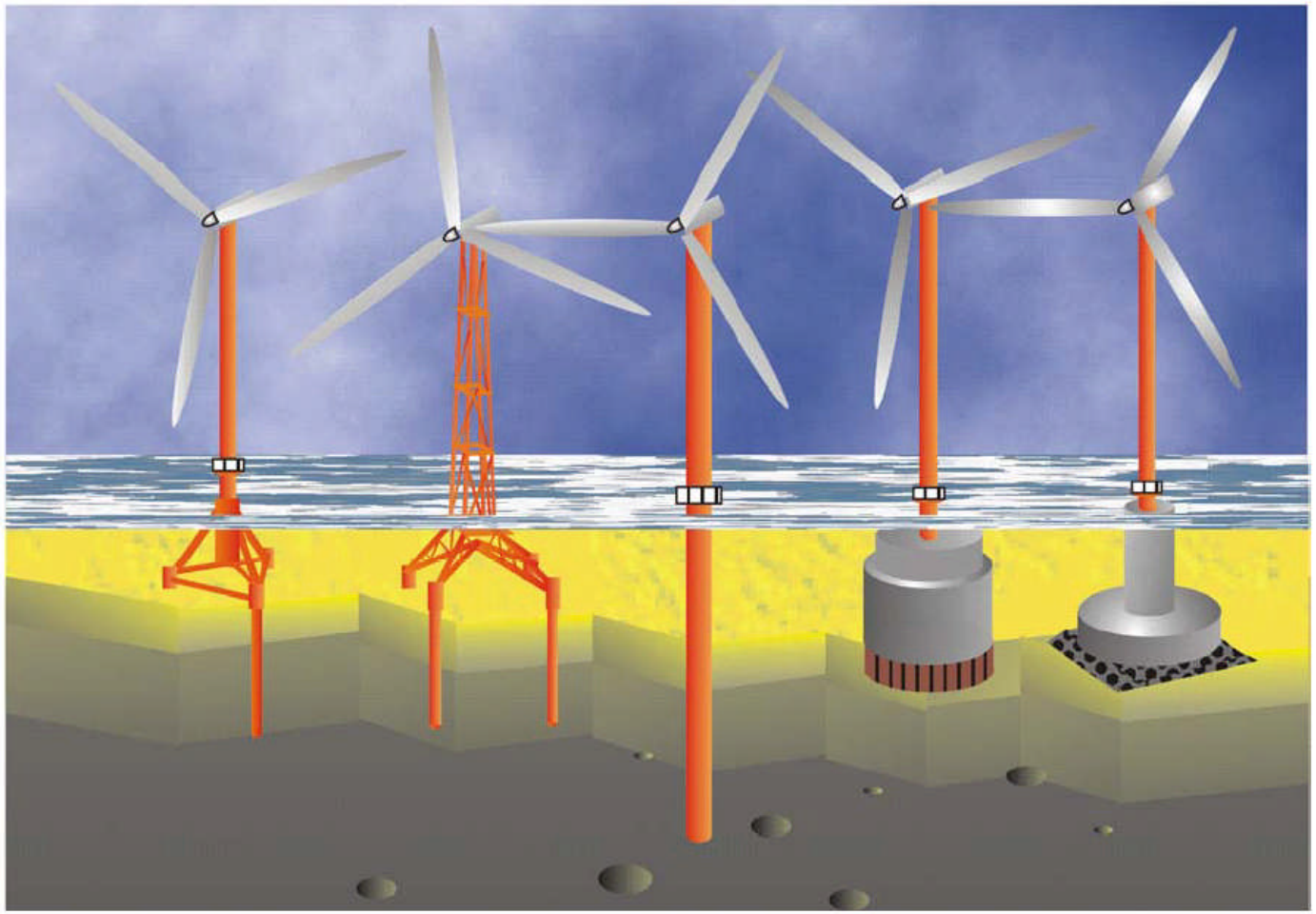



Demands of Greenpeace



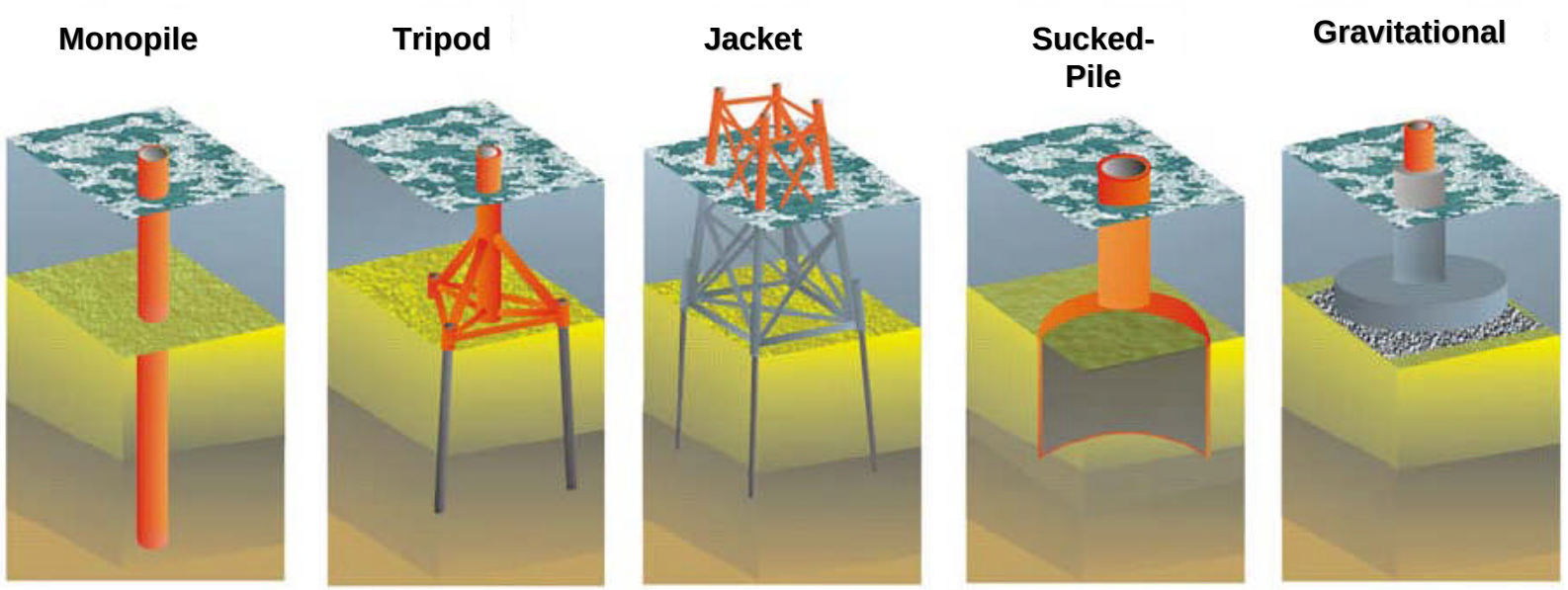

Demands of WWF

# Technical aspects (1)



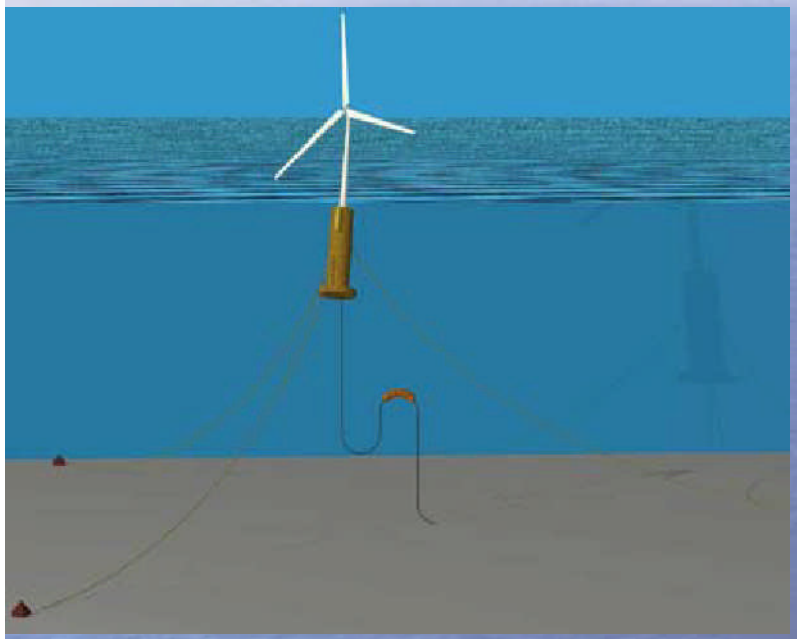
Examples of construction (after LESNY, K.; RICHWEIN, W. & J. WIEMANN (2002)

# Technical aspects (2)

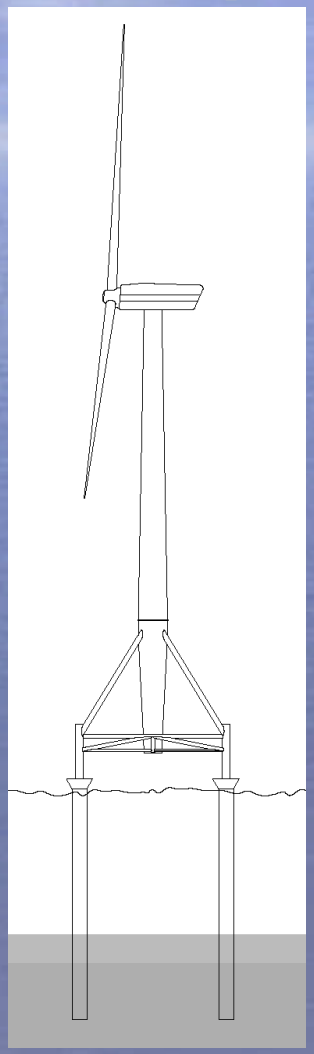



Examples of foundation structures after: Final report GIGAWIND, Univ. Hannover

# Technical aspects (3)



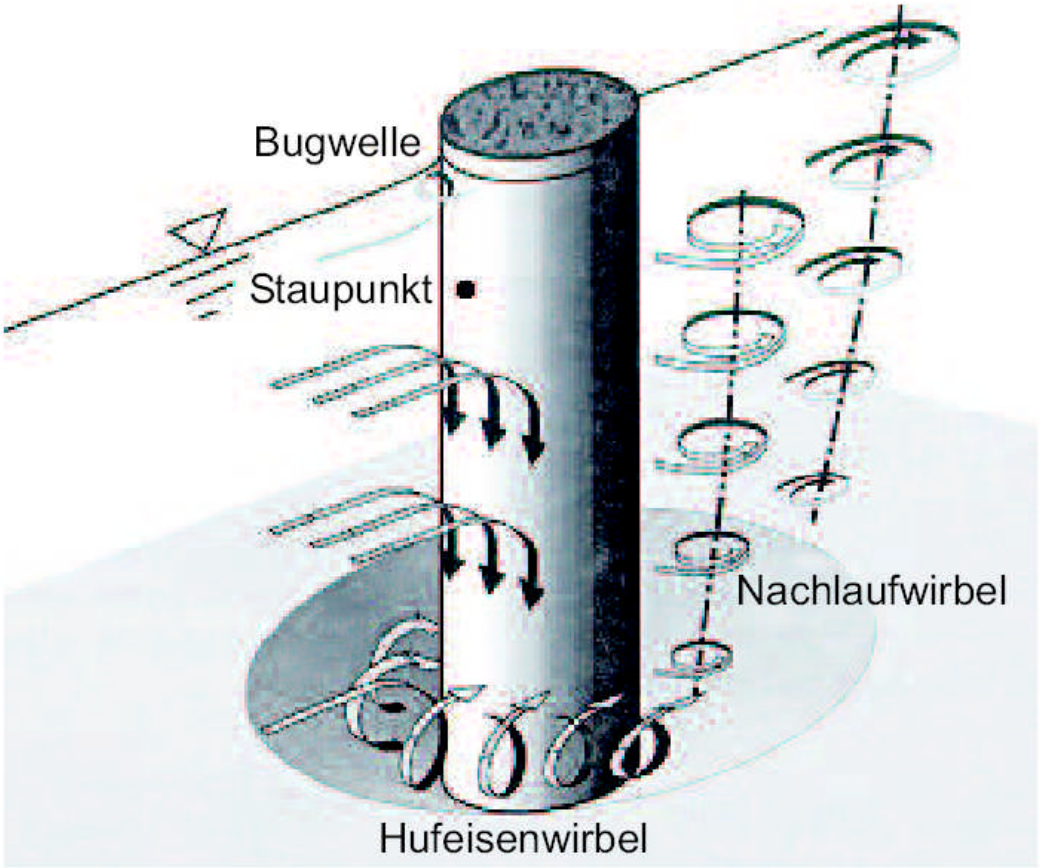
Floating system



„Inclined“ Tripode

Scource: www.offshorewindenergy.org

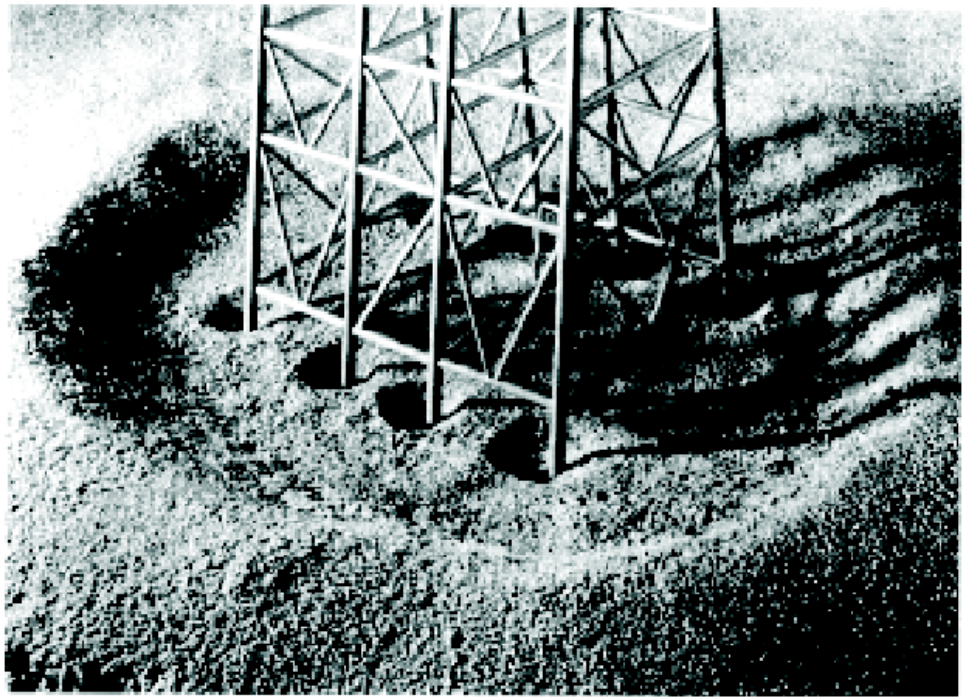
# Technical aspects (4)




Eddies around a pile

(Melville & Coleman, 2000)

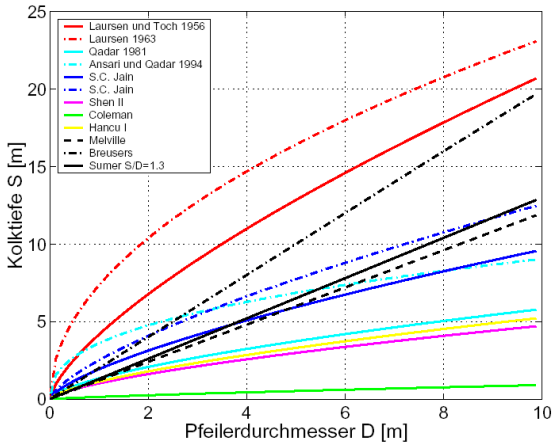
# Technical aspects (5)



Local erosion

(Whitehouse, 1998)

# Technical aspects (6)




bildung 18: Abhängigkeit der Kolktiefe vom Pfeilerdurchmesser (für h = 30.00 m

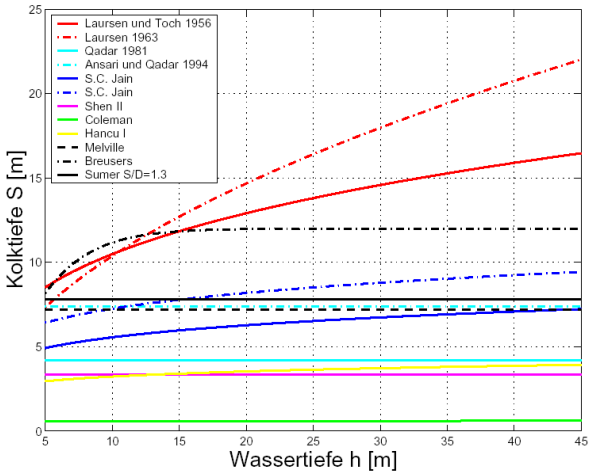
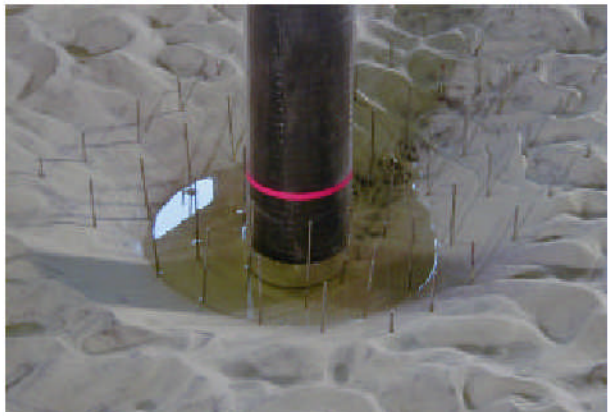



Abbildung 19: Abhängigkeit der Kolktiefe vom Wasserstand (für D = 6.00 m)

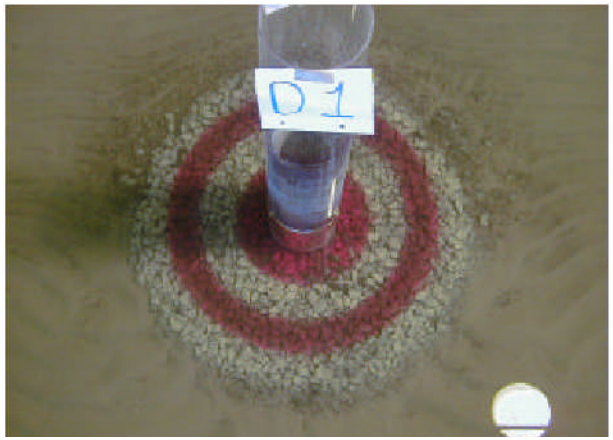
| Autor | Jahr | Ermittelte Kolktiefe [m] | |
|---|---|---|---|
| Laursen & Toch | 1956 | 14,59 | |
| Laursen | 1963 | 17,98 | MAX. |
| Qadar | 1981 | 4,19 | |
| Ansari & Qadar | 1994 | 7,37 | |
| Jain | 1981 | 6,74 | |
| Jain | 1981 | 8,79 | |
| Shen II | 1969 | 3,36 | |
| Coleman | 1971 | 0,60 | MIN. |
| Hancu I | 1971 | 3,73 | |
| Melville & Coleman | 2000 | 7,20 | |
| Breusers et al. | 1977 | 12,00 | |
| Sumer | 1992 | 7,80 | |

After UNGRUH, G. & W. ZIELKE (2004)

# Technical aspects (7)



Physical experiment: erosion around an unprotected pile (Horns Rev)




Physical experiment: d50 = 0,016m (0,4m original)

Hs = 0,108 m (2,7 m original)

- Protection measures:
- Riprap (stones, gravel etc.)
- Soil consolidation
- Geotextile
- Bonded systems
- Concrete etc.

After PRECHT, E.; LARSEN, O. & E. A. HANSEN (2004)

# Technical aspects (8)

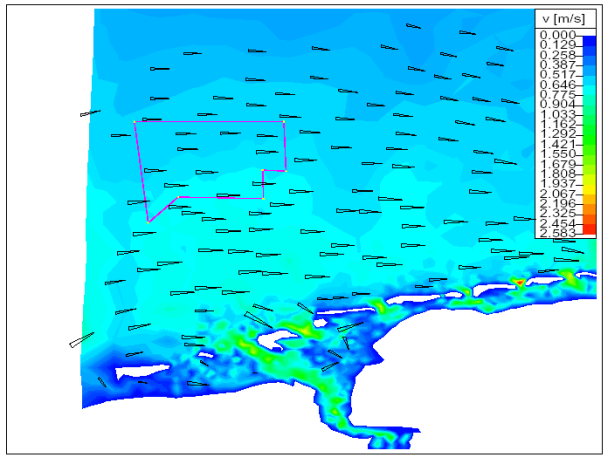
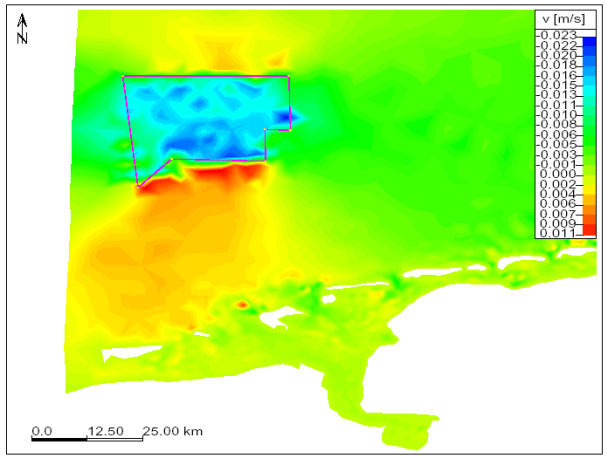



Abbildung 20: Maximaler Flutstrom bei t=383.0h ohne Bebauung




Influence to velocity of a windpark, flood current

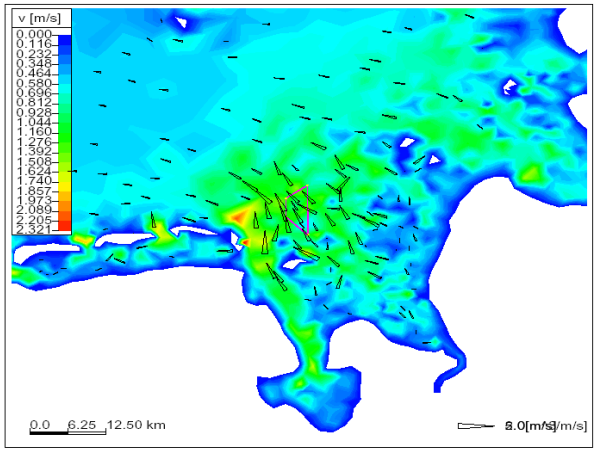
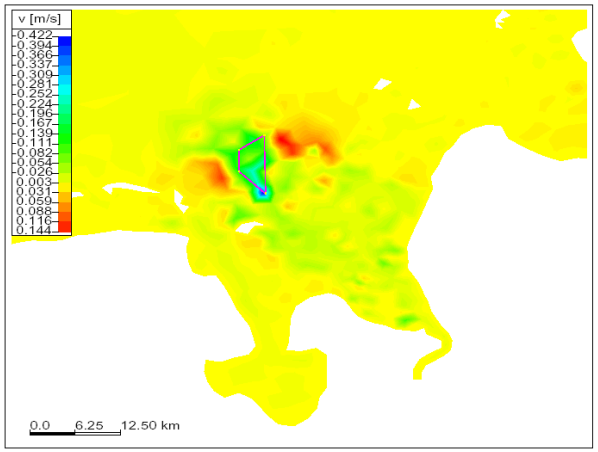



Abbildung 22: Maximaler Ebbstrom bei t=318h




Influence to velocity of a windpark, ebb current

After MITTENDORF, K.; HOYME, H. & W. ZIELKE (2001)

# Constructing phase

| Cause | Change | Afflicted organisms | Effect |
|---|---|---|---|
| Construction fundament, lay of cable | Movement of sediment, Resuspension, sedimentation of tiny particles, brightness Turbidity | Benthic organisms, demersal fish, mammals | Changing community, Changing structure of the habitat by stabilization of the fundament, Changing of trophic sphere |
| Ram of the Piles | Noise Trembling Trubidity | Fish Marine mammals Benthic organisms | expulsion desorientation disturbance of communication Injury of hearing organs |
| Transport of Material and Persons | More Traffic (ship, helicopter) | Fish Marine mammals Birds | Loss of resting place, moulting place and feeding grounds Desorientation |

# Working phase (1)

| Cause | Change | Afflicted organisms | Effect |
|---|---|---|---|
| Piles | Sealing of the sediment surface,<br>placement of new hard substrate,<br>changing of the hydrography & sediment structure,<br>noise | Benthic organisms,<br>Demersal fish,<br>Marine mammals | Changes within the community due to changes of the structure of the habitat,<br>Changes within the settling process due to changed hydrography,<br>Desorientation |
| Transport of energy through cables | Formation of electric and magnetic fields | Evertebrates<br>Fish<br>Marine mammals | Desorientation<br>Disturbance of migration |

# Working phase (2)

| Cause | Change | Afflicted organisms | Effect |
|---|---|---|---|
| Rotation of the rotor blades | emission of sound into the water and ground and into the air | Fish<br>Marine mammals | Desorientation, expulsion, disturbance of communication |
| Windmill as a „tower“ with rotating rotor blades | Barrier for flying birds | Birds | Barrier for migration of birds, Barrier on the way to feeding grounds,<br>loss of feeding grounds, restingplace & moulting place, collision with windmill |
| Marker of the windfarms | Lightning the windfarms | Birds | Desorientation, recognition as a possible resting place |
| Traffic for maintenance | Acustic and visual disturbance | Birds<br>Marine mammals | Expulsion |

# Windfarms as artificial reefs (1)

- fish are found near rocks, wracks,…
- placement of new hard substrate (fundaments) => settling place for sessile benthic organisms (mussel, barnacle) & hiding place for young and small fish ► artificial reef

- structures in water allure fish => the more complex the sturctures are the more fish are allured
- big fish are found at Horns Rev => consideration for fishing permission (big fish instead of too small ones: stop „Fishing down marine food web“ (Pauly, 1998))

# Windfarms as artificial reefs (2)

- haddock (100 cm length) are found at oil & gas platforms in the North Sea
- plaice, sole and haddock migrate between the parts of the reefs (distance about 1000m between the windmills)
- area where young fish can grow and reproduce => stabilization of the commercial used fish stocks
- trial: mariculture (cultivation of mussel & algae) at the fundament of windmills (*demand for research)*

# Summary (1)

- ✓Benthic organisms will be killed, fish and marine mammals may be banished through the constructing phase
- ✓Resettling of benthic organisms within 1-5 years => changes in the composition of the benthic community
- ✓placement of new hard substrate => change of the habitat (hydrography, sedimentation)
- ✓Working phase: barrier for migrating birds => collision with windmills; noise: disturbance for communication of marine mammals & expulsion for mammals, birds (& maybe fish) => loss of resting places and feeding grounds

# Summary (2)

- ✓electric and magnetic fields along the cable trace
- ✓placement of hard substrate => allure fish area where young fish can grow and reproduce => stabilization of the commercial used fish stocks
- ✓trial: mariculture (cultivation of mussel & algae) at the fundament of windmills (*demand for research)*
- ✓demand for more research
- ✓demand for a European directive to get better comparability

# What is maricultur?

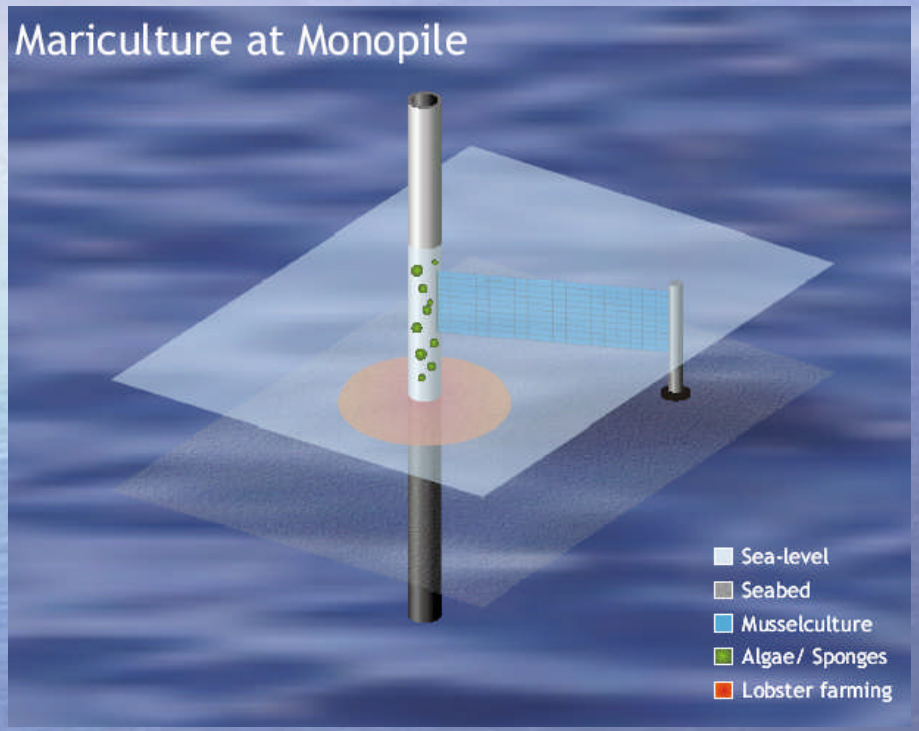
- Mariculture is the offshore cultivation of marine organismens
- An assumption is the natural settlement or the output of spawn to anthropogen structures like oil-stations or windenergy bracket structures
- No additional feeding and no hygiene measures will take place because a windpark is open to all sides
- Ingestion and excrementation underlying natural conditions

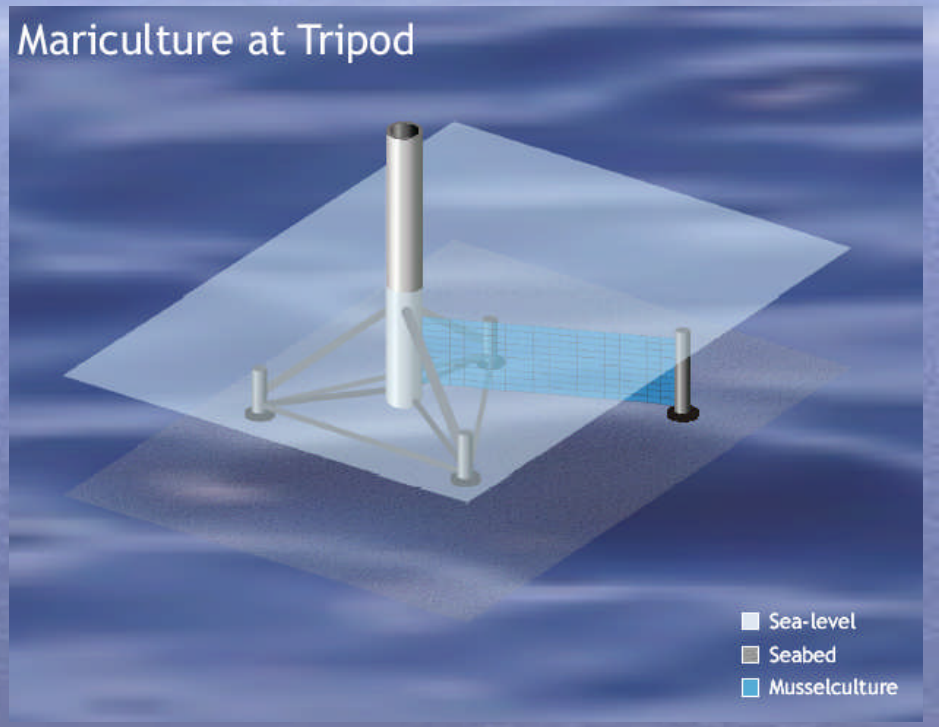
# Who can be cultivated?

- The following species are from economic and ecological interest in the southern North Sea:
- Macro-algae: Laminaria and Palmaria useable in aliment, textil and color industry also in cosmetic and pharmacological industry
- Blue Mussel/Mytilus edule: as aliment
- Oyster/Ostrea gigas: as aliment organismens
- Spongae: useable in pharmacological industry
- Lobster/Homarus vulgaris: resettlemt of strongly reduced population
- In other regions of the world other species can be cultivated.

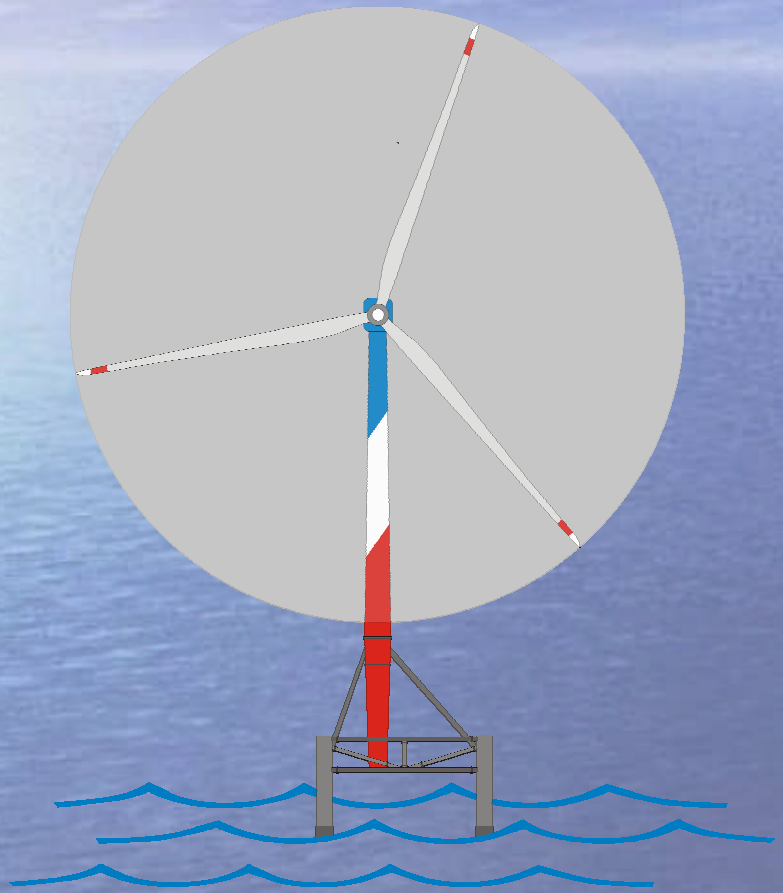
# How can the system work?

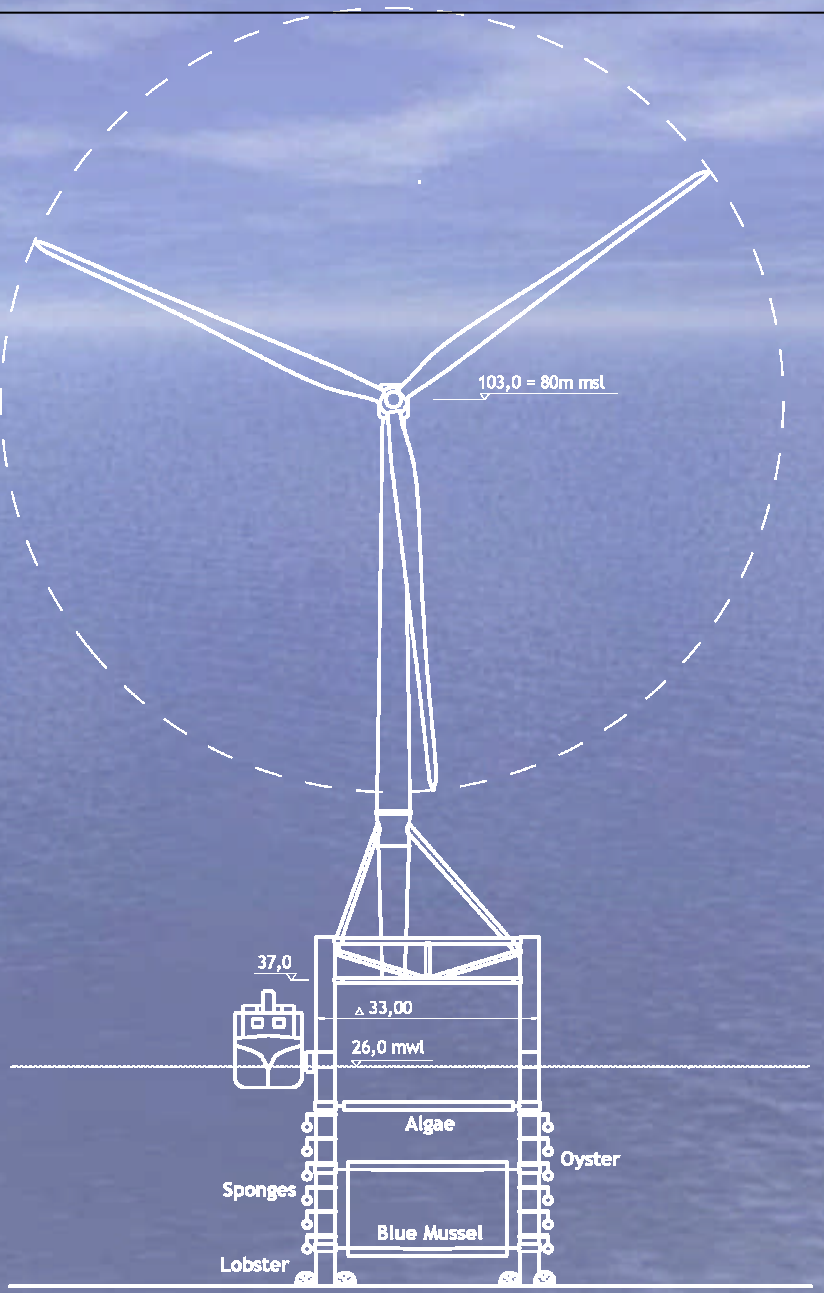
- The foundations of the offshore wind turbines should accomplish the circumstances for a co-using for mariculture without confinement as a bracket for the turbines

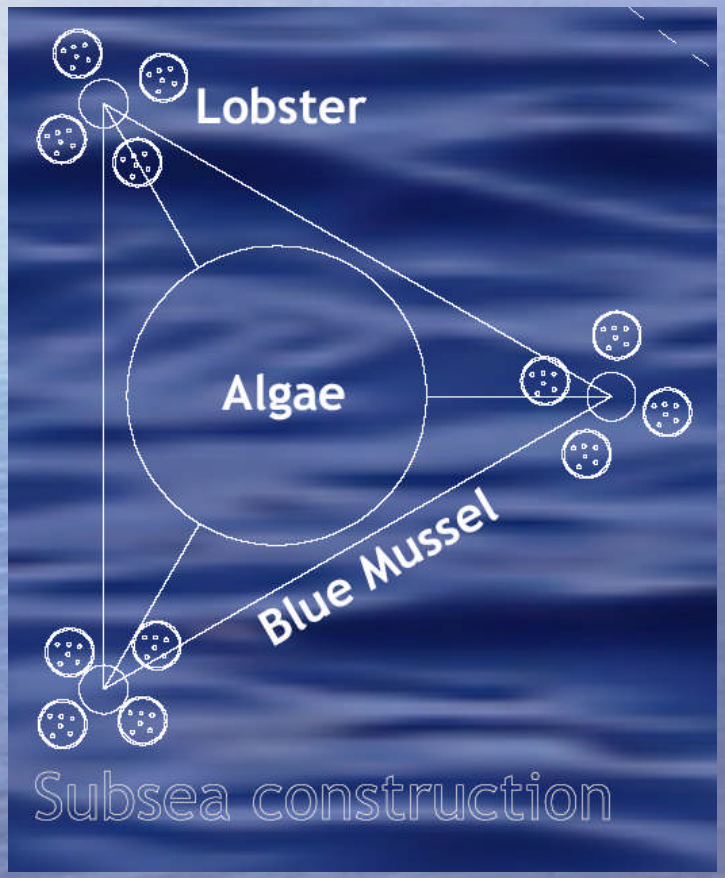

Mariculture at Monopile
Sea-level
Seabed
Musselculture
Algae/ Sponges
Lobster farming

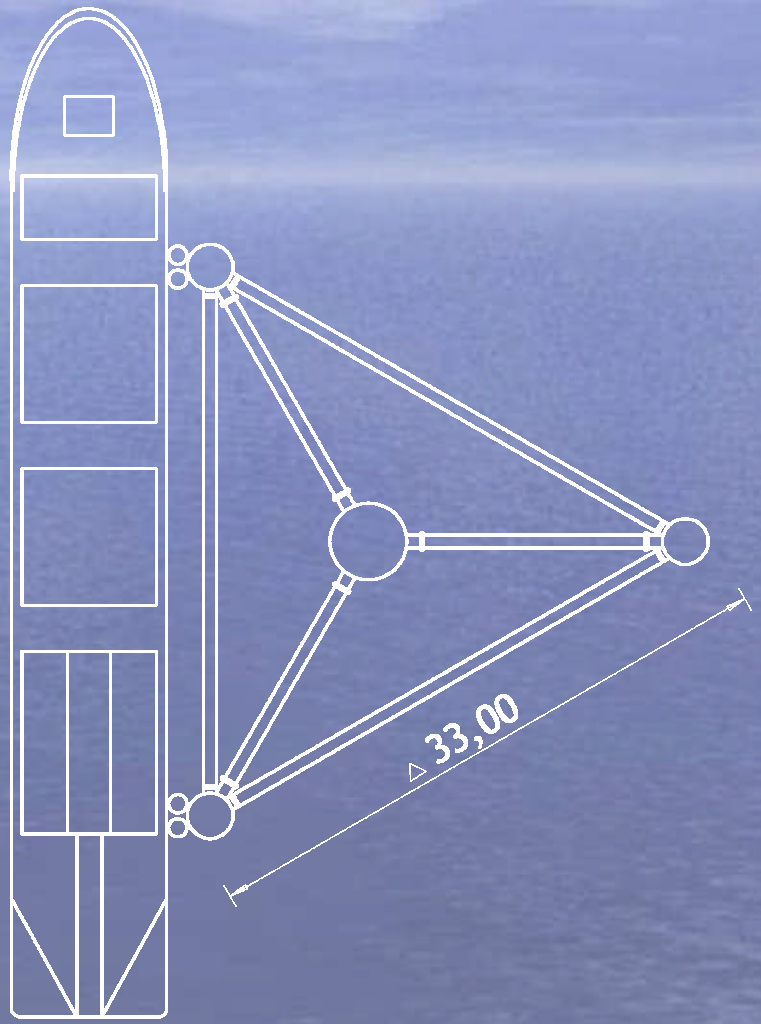

Mariculture at Tripod
Sea-level
Seabed
Musselculture

# Zukunft Küste – Coastal Futures






Lobster
Algae
Blue Mussel
Subsea construction


33,00
docking station for service

# Why offshore maricultur?

- In opposite to the high-technology land based aquacultur, which produces only some few noble fishes in completly aseptic conditions, maricultur can produce a high amount of bio-mass in natural way for different application
- This is especial interesting for transition nations/developing countries
- The cost can be reduced for both, the windpark-owner and the maricultur operater: a classical „Win-Win“ situation

# Which risk can be appear?

- The risk are the same as for other offshore constructions. Extrem wind and wave action can destroy the structur.
- The settlement and the food supply underly the natural conditions and can not be controlled.
- The accessibility is not given at any time, because the weather conditions in the North Sea are incalculable

**Thank you for your attention!!!**