

# The Middelgrunden wind farm

by PhD Hans Chr. Sørensen, SPOK ApS



# Disposition

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- Introduction
- Why wind turbines Copenhagen?
- Planning process
- Conflicts of interest
- Environment Impact Assessment
- Construction
- Basic information and references

# SPOK ApS - Hans Chr. Sorensen



Sustainable Projects - Offshore Know-how

## Project management RTD projects

- Ocean wave energy (Wave Dragon)
- Offshore wind (Middelgrunden 40 MW and Samsø 23 MW)
- Evaluation
- EU and DEA projects, Biomass RTD
- Building process optimization

## • Committees

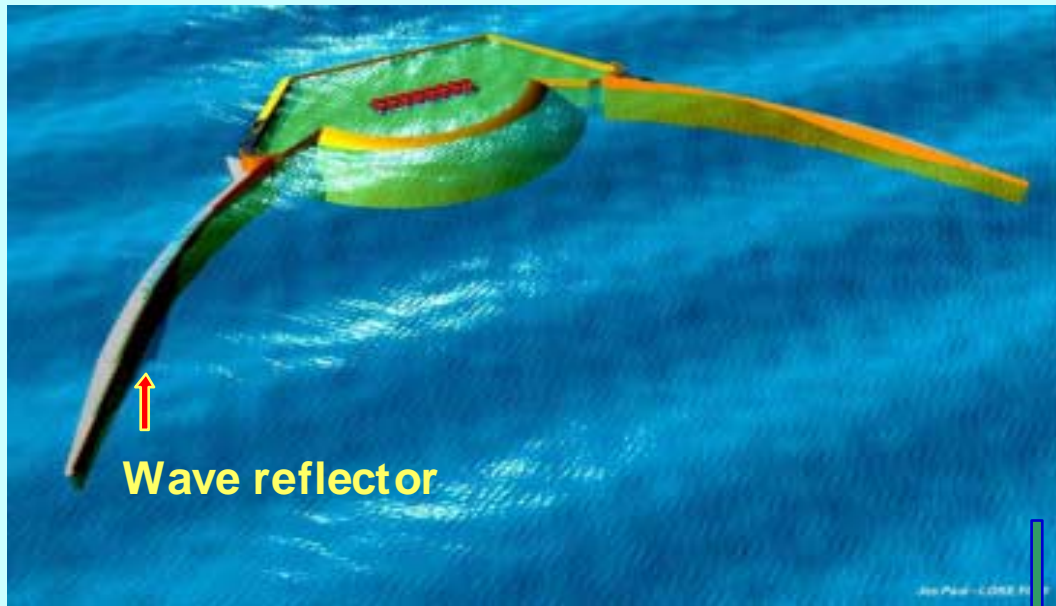
- Danish Wind Turbine Owners Association, board
- Danish Energy Agency; Grid integration of RES
- EU Offshore Wind Concerted Action; Work Package leader
- EU Wave Energy Network; Work Package leader

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consult@spok.dk*

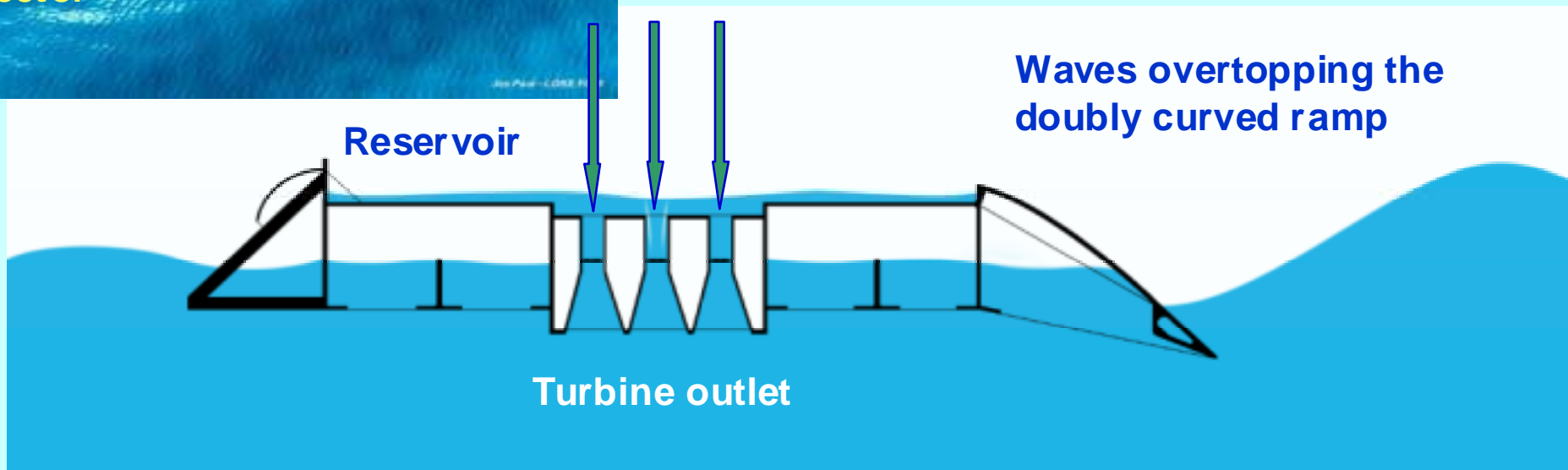
# Wave Dragon principle



The *Wave Dragon* is a slack-moored wave energy converter that can be deployed alone or in parks wherever a sufficient wave climate and a water depth of more than 25 m is found.



Climate	Power production
24 kW/m	12 GWh/y/unit
36 kW/m	20 GWh/y/unit
48 kW/m	35 GWh/y/unit



# Why wind turbines Copenhagen?



- Agenda 21
- Take responsibility for power production
- Power to 32.000 households, 3% of the electricity consumption in Copenhagen
- Wind not too bad offshore

## Result:

- 8.553 shareholders – mostly single families

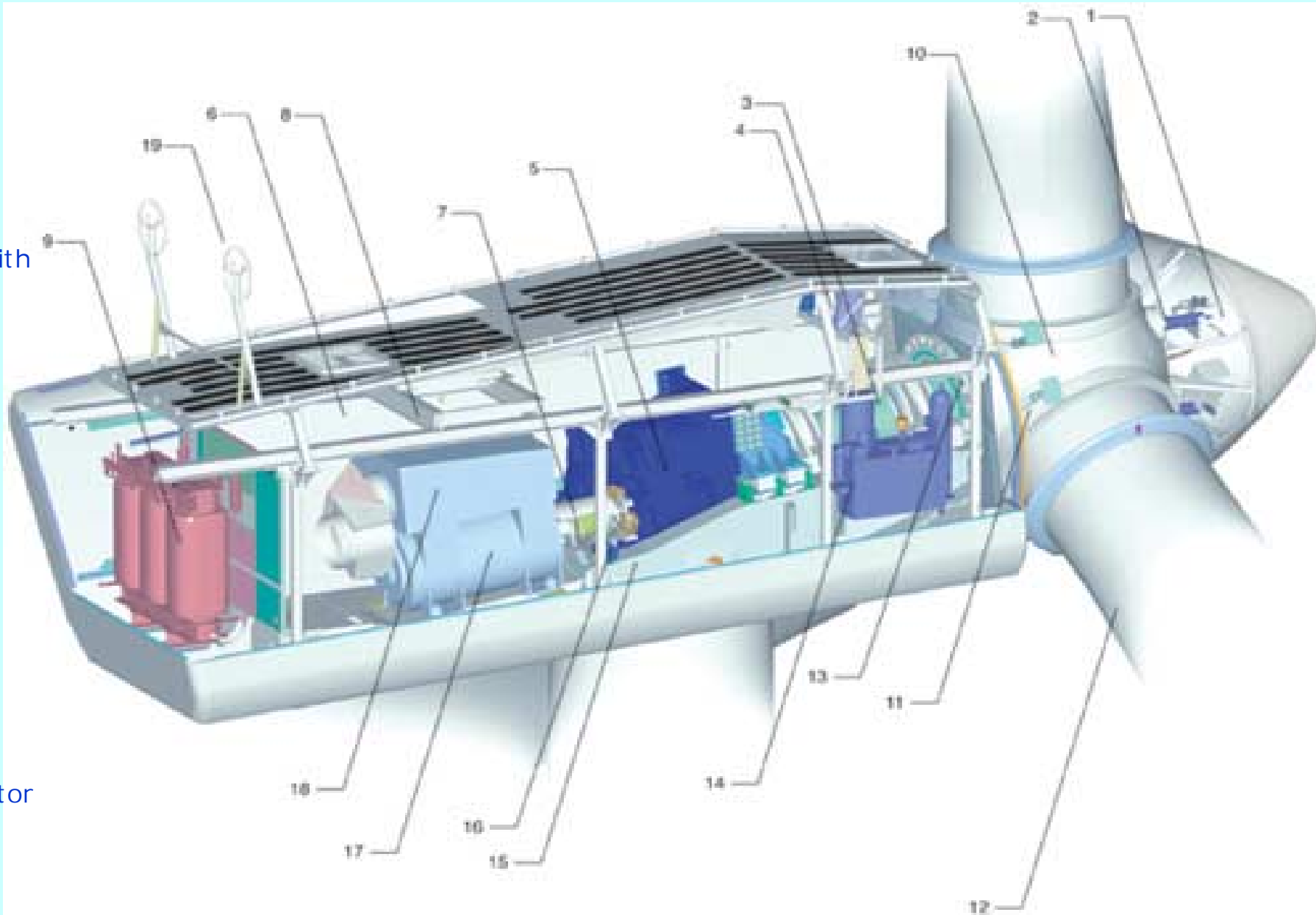
# Lynetten wind farm 7 x 600 kW



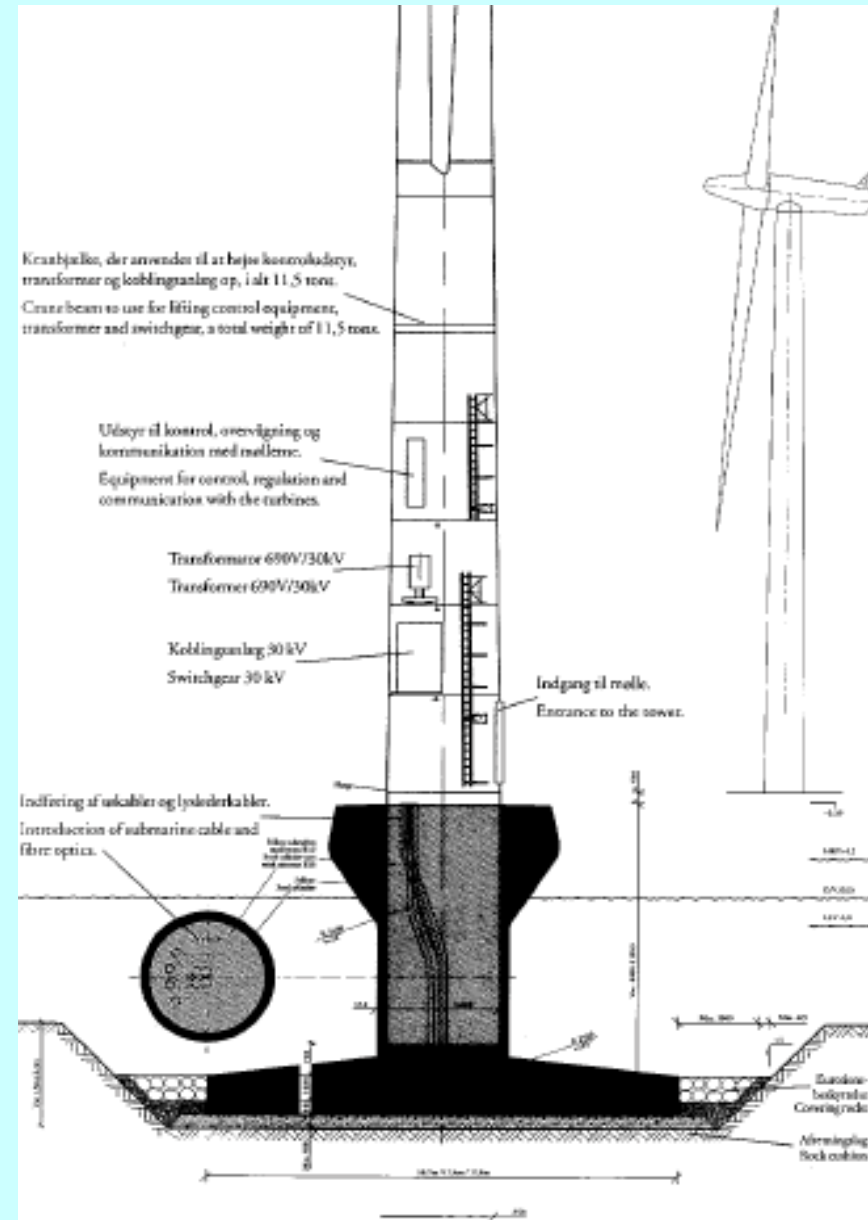
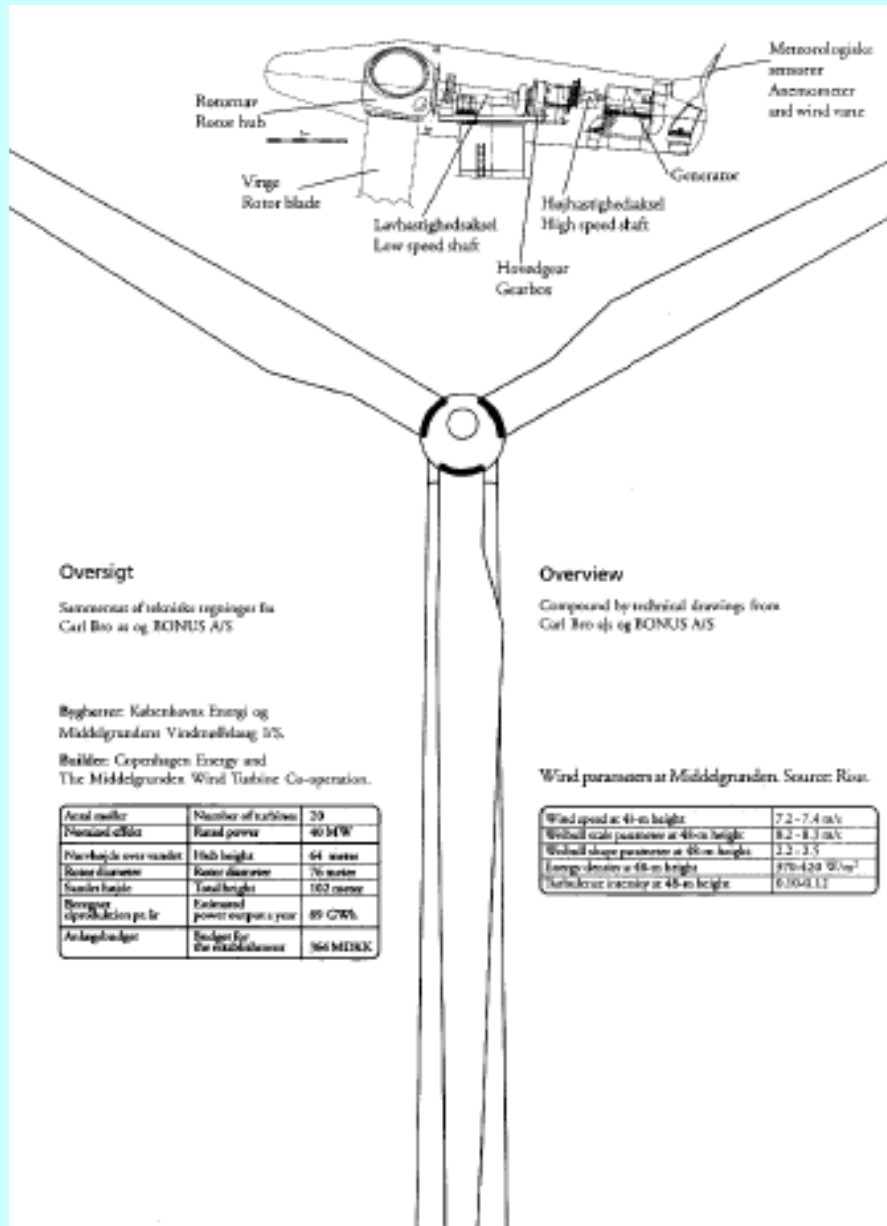


# Layout for a wind turbine

1. Hub controller
2. Pitch cylinder
3. Main shaft
4. Oil cooler
5. Gearbox
6. VMP-Top controller with converter
7. Parking break
8. Service crane
9. Transformer
10. Blade hub
11. Blade bearing
12. Blade
13. Rotor lock system
14. Hydraulic unit
15. Machine foundation
16. Yaw gears
17. OptiSpeed™ generator
18. Ultra-sonic sensors

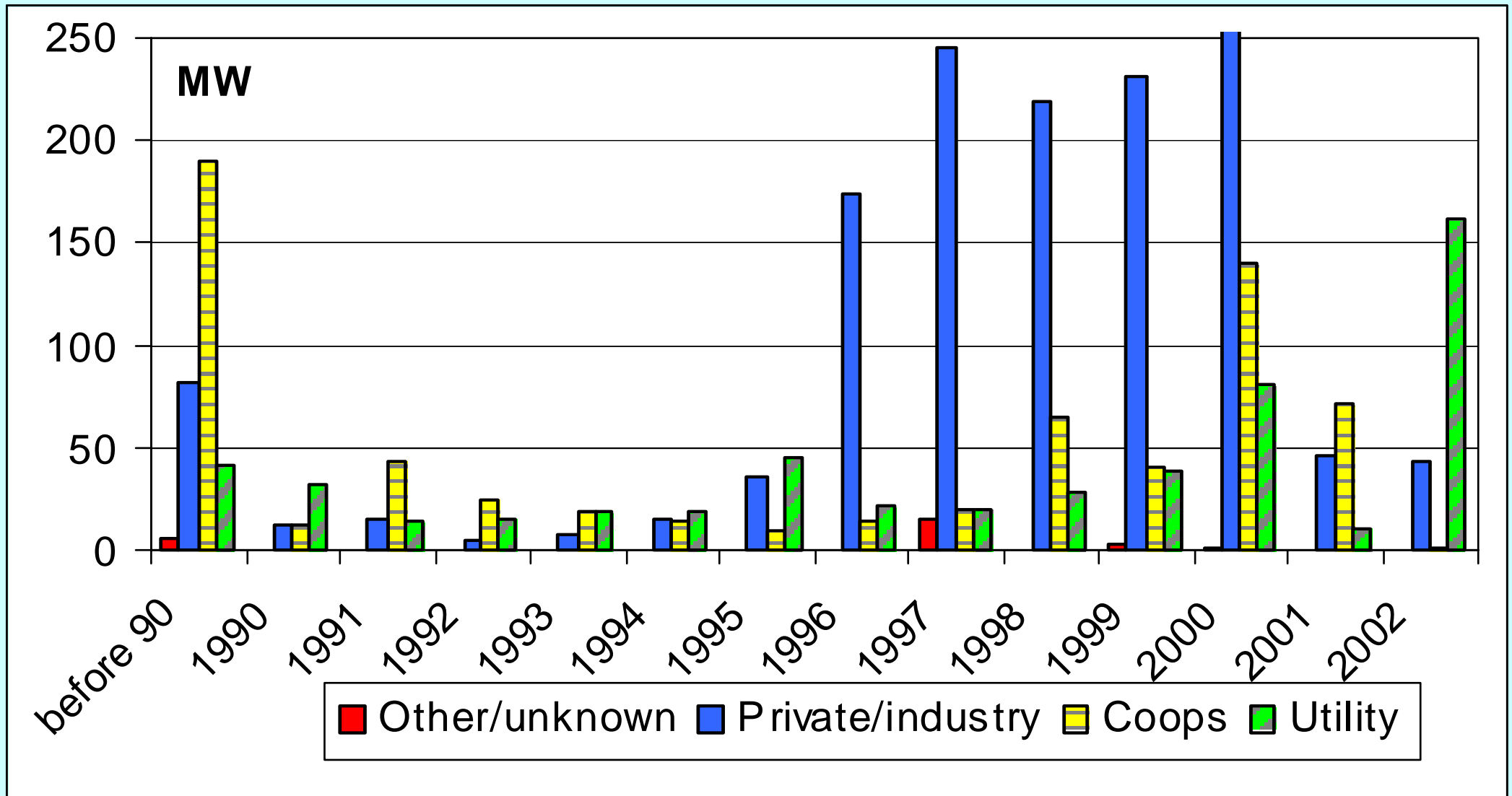


# The Middelgrunden wind turbines





# Invite all kinds of people to participate

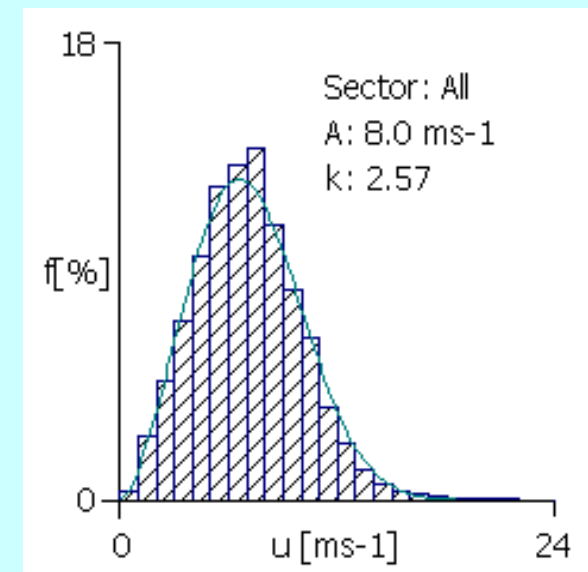
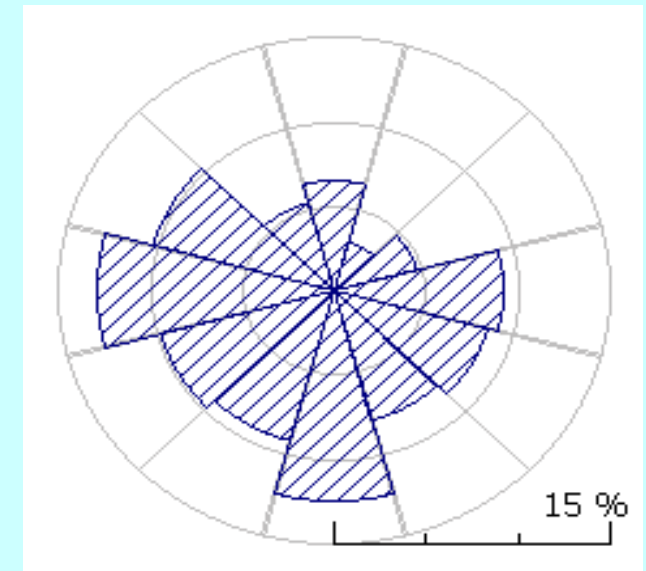


# Planning process



## Killer assumptions:

- Wind resource
- Spatial planning
- Visual impact
- Vast deposit



# The arc from south



# Planning Issues - Principle in DK

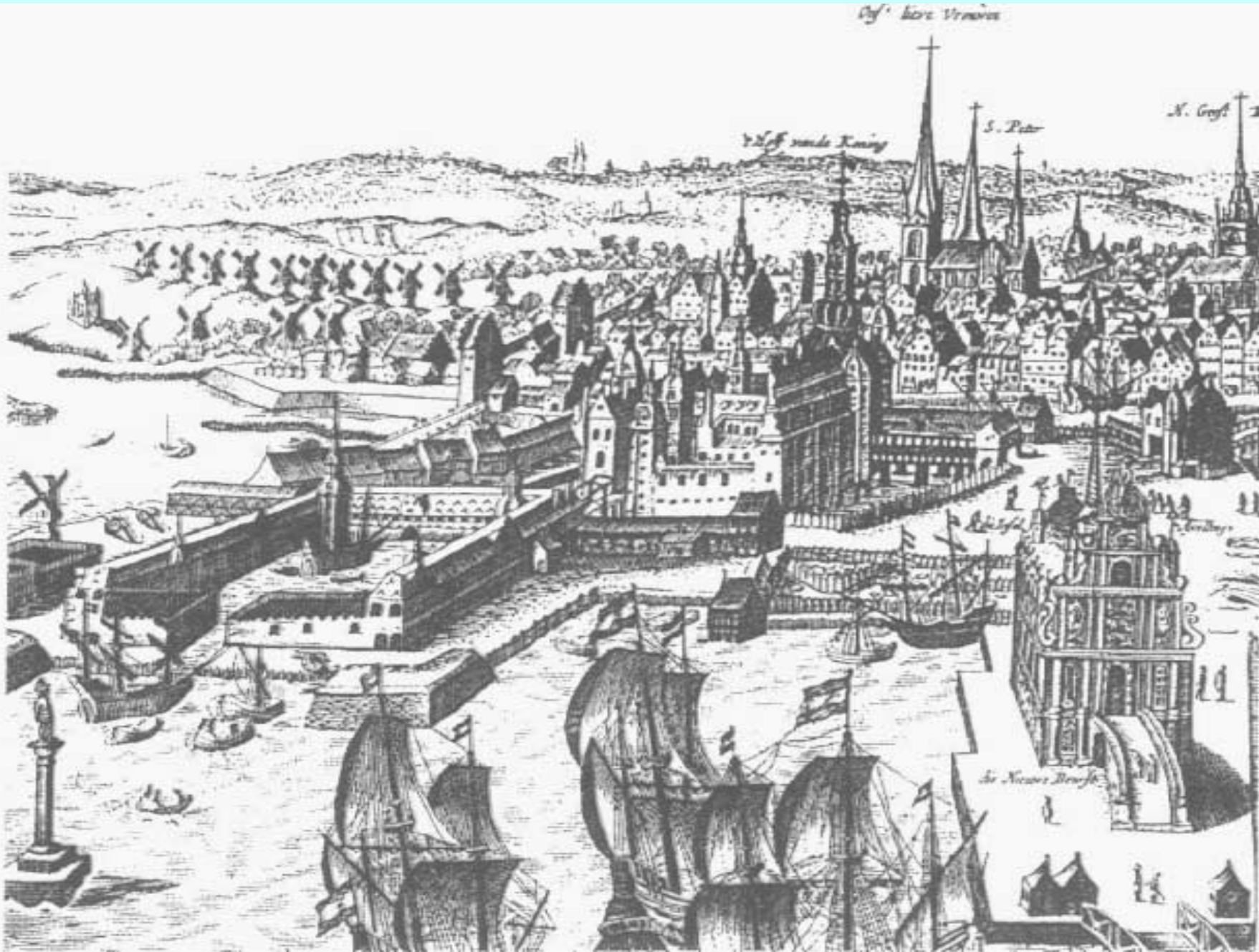


- Country- and site-specific regulations and restrictions
  - in DK: first overall sites for 150 MW test farms, then detailed



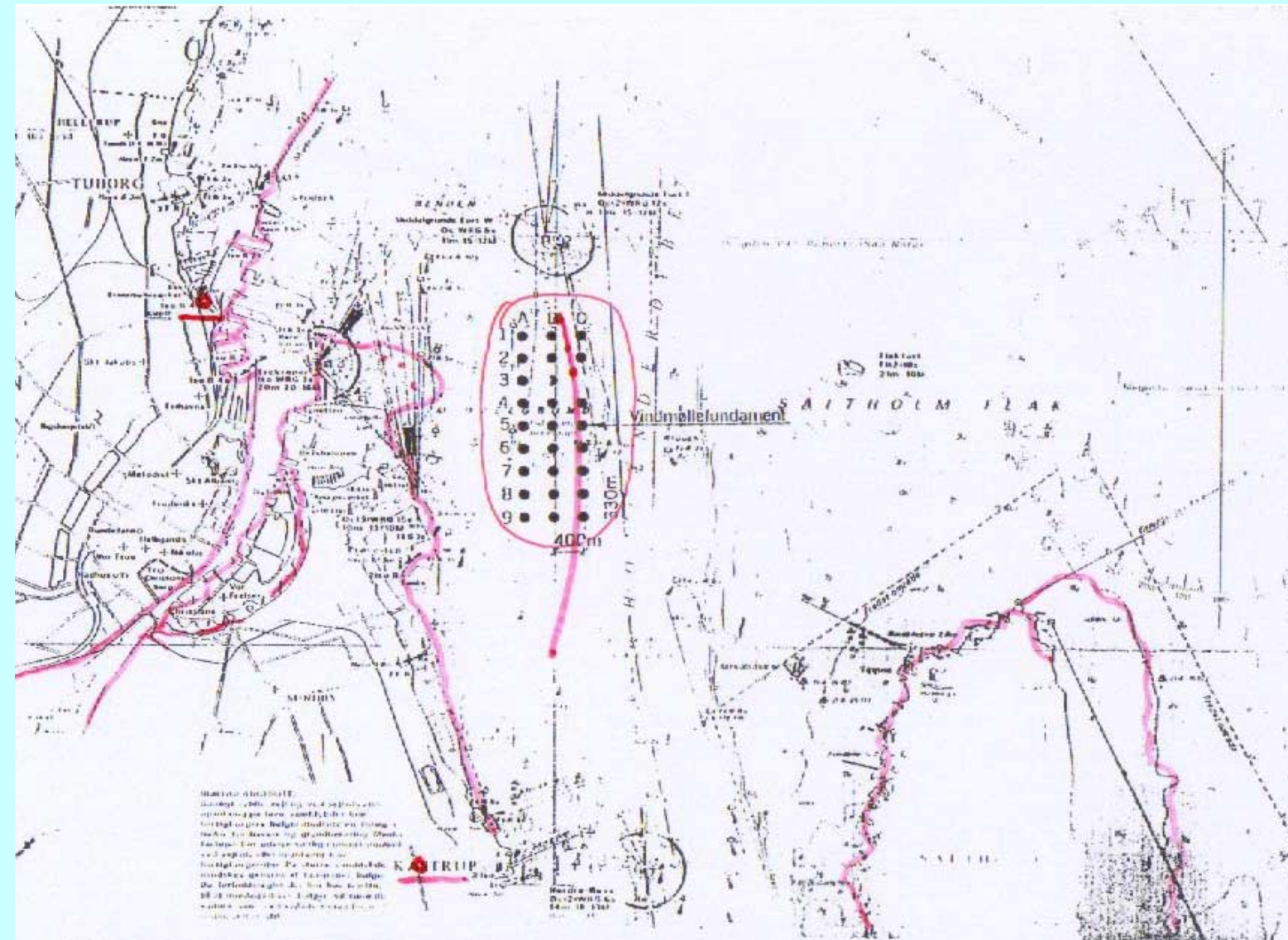


# - Visual Impact : Copenhagen 400 years ago

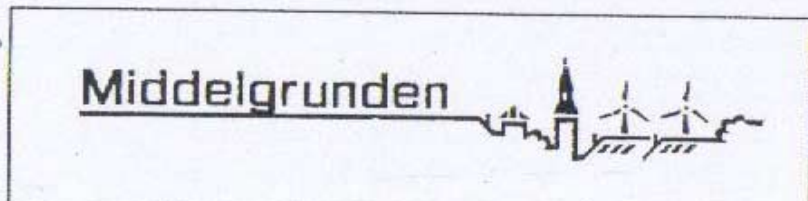


Wind energy is not a new energy source in a city

# Technical optimisation – visual impact



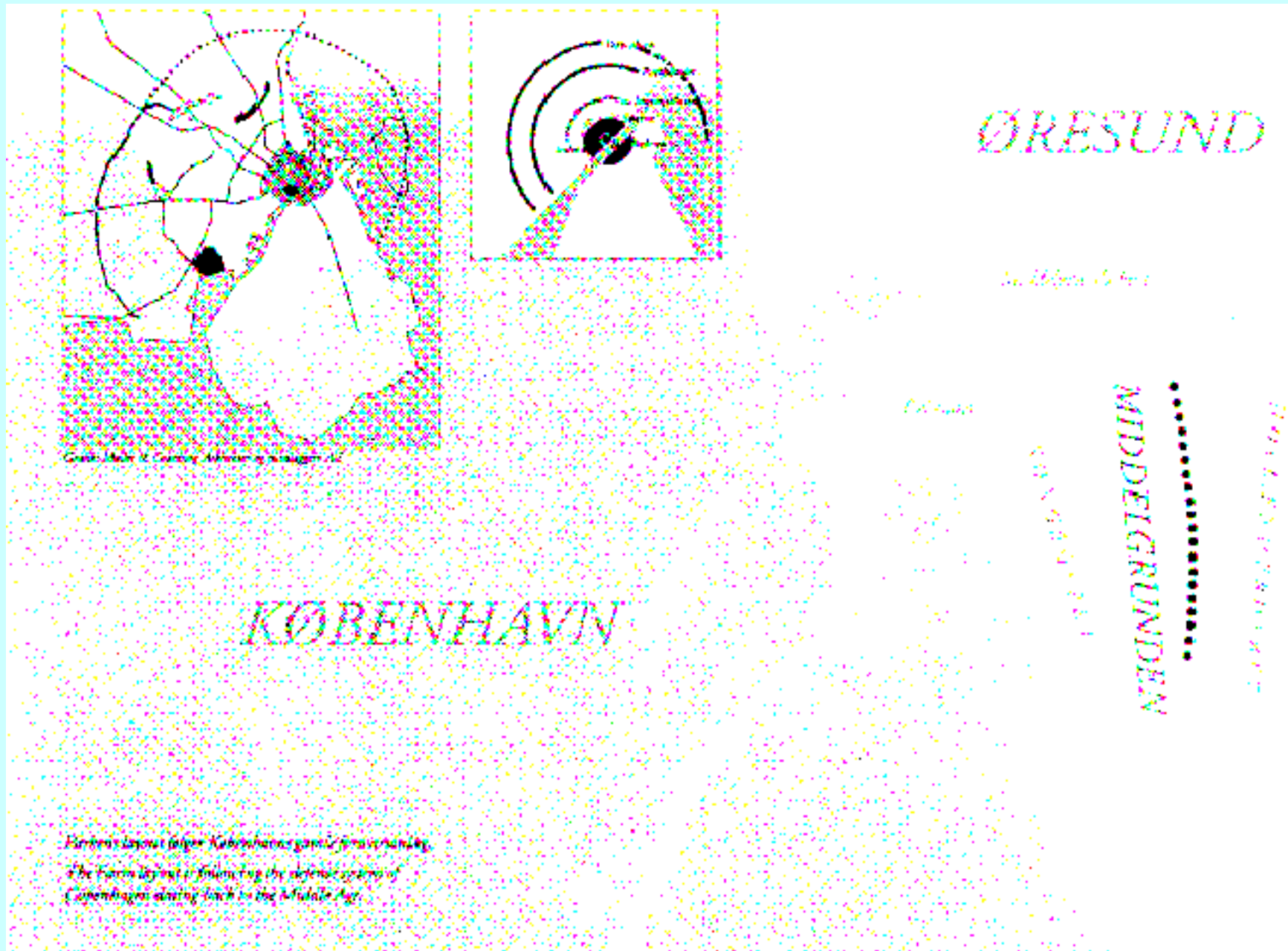
3 rows in the north part – or one line over the whole length



## NOTE

Alle mål er i mm.  
Køler er i størrelse i forhold til DRØI  
Bådstøtning er ikke vist.  
Baggerundersøkt til situationsplan er bilag nr. A01, j.nr. 2 til EGI sags nr. 160 14043  
Baggerundersøkt til oversigtsplan er Sundet, midtstele del, 133 2. udgave marts 1997  
udgivet af Rønt & Madsen/Sjølsheden, Danmark

# Visual impact – the defence circles



Copenhagen & Coasting, Wikimedia Commons

Historical layout of Copenhagen's defense circles. The concentric circles represent the defense system of Copenhagen during the 17th century.

# Visual Impact – two alternatives



27 turbines in 3 rows



20 turbines in a curved line



# Visual Impact



- Distance to shore (<45km)
- Farm and turbine layout
- Marking lights



*Copenhagen today, Middelgrunden 40 MW 5 km away*



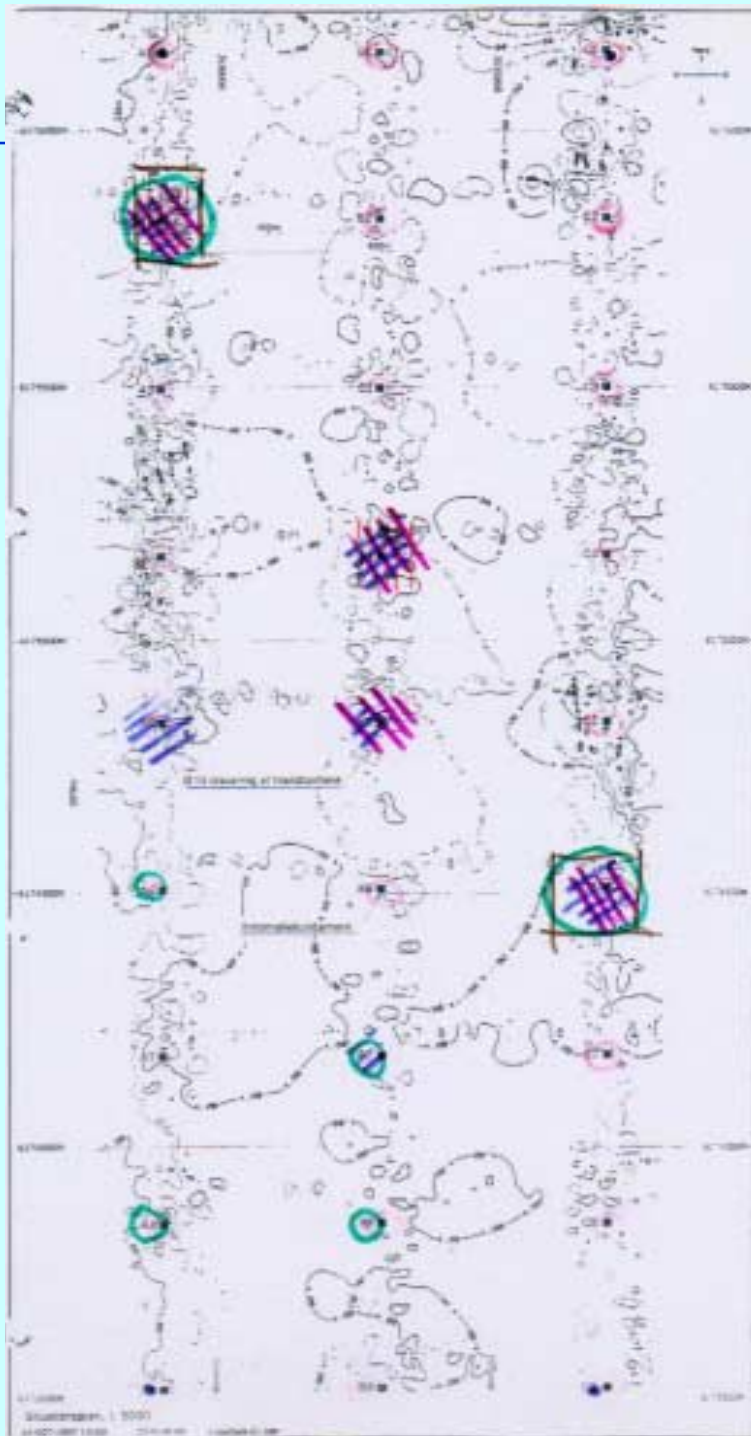
# Waste deposit

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- Deposit for waste for more than 100 years
- In 1900-ies harbour sludge (Hg from mirrors and industry)
- In 1985 the discover of the sludge disappears
- General conclusion: don't move more than necessary



# Waste deposit



Position	Pøvedybde	Lagtykkelse	Glødetab	Bly	Krom	Kobber	Zink	Kviksølv
Nr.	cm	cm	% af TS	mg/kg TS				
1.1Mx1	30+80	0-88	25,8			140	89	3,7
2.1M5	210	178-245	1,2					0,58
3								
4.2M1	20	0-33	2,3		46	42		
4.2Mx2	70+120	54-135	1,6	30				0,43
4.3Mx1	30+80	20-118	1,7	32	45			
5.2Mx2	70+120	56-152	3,2	26				0,43
6.1M1	20	0-30	0,9	31				
6.3M1	10	0-29	1,3			23		
7								
8.1M2	70	48-88	2,6	44				0,58
8.2Mx2	60+110	35-130	1,8			20		0,49
9 - 12								
13.0Mx1	13.2: 10 / 13.3: 20	0-22 / 0-41	1,5	150		1000	140	48
14.0Mx1	14.1: 10 / 14.2: 10	0-27 / 0-19	1,0				220	
15+16	Der er ikke foretaget analyser af bundrøber, idet GI's sedimentbeskrivelse viser at profilen er naturligt aflejet og den vurderes at være upåvirket.							
17.3M1	10	0-15	0,93	33				
18 - 20								
2.1 Mx1	10+50	0-54	2,02			34		
2.2 M1	25	0-35	6,0	52		35	140	1,0
Ikke forurenet <sup>1</sup>				< 20	<20	<20	<75	<0,25
Forurenet <sup>1</sup>				20-50	20-50	20-40	75-100	0,25-0,5
Kraftigt forurenet <sup>1</sup>				> 50	>50	>40	>100	>0,5

<sup>1</sup> Miljøstyrelsens vejledning 1983

# Public project presentation & communication strategies



- Information (passive, although consultation requested)
- Planning participation (involvement in decision making process)
- Financial participation (e.g. share owners)



# The public hearings



- Contact to all relevant bodies including NGOs
- June-August 1998 new visualization 20 turbines
- Feasibility acceptable as the turbines increases from 1.5 MW to 2 MW
- July-September 1999 EIA DK & SE
  - Comprehensive analyzes off pollution, sound, water flow, suspension of sediments etc.
  - Geological survey each site for foundation
  - New analyzes of flora, fauna and archaeology

# Involvement of local people in the project



# Conflicts of interest

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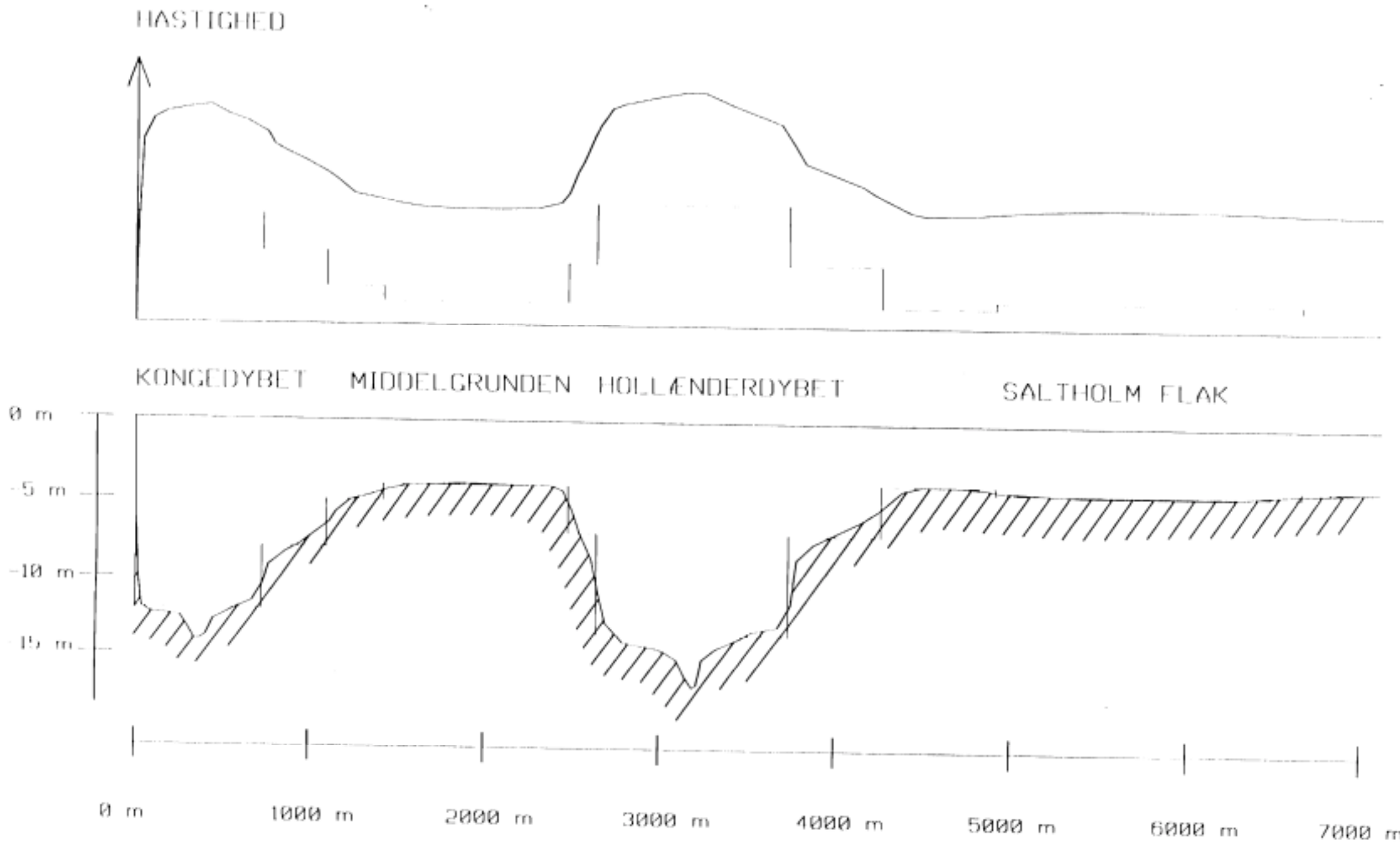


- Flow to the Baltic
- Birds
- Sea mammals
- Sedimentation
- Collision risk
- Navigation risk, radar

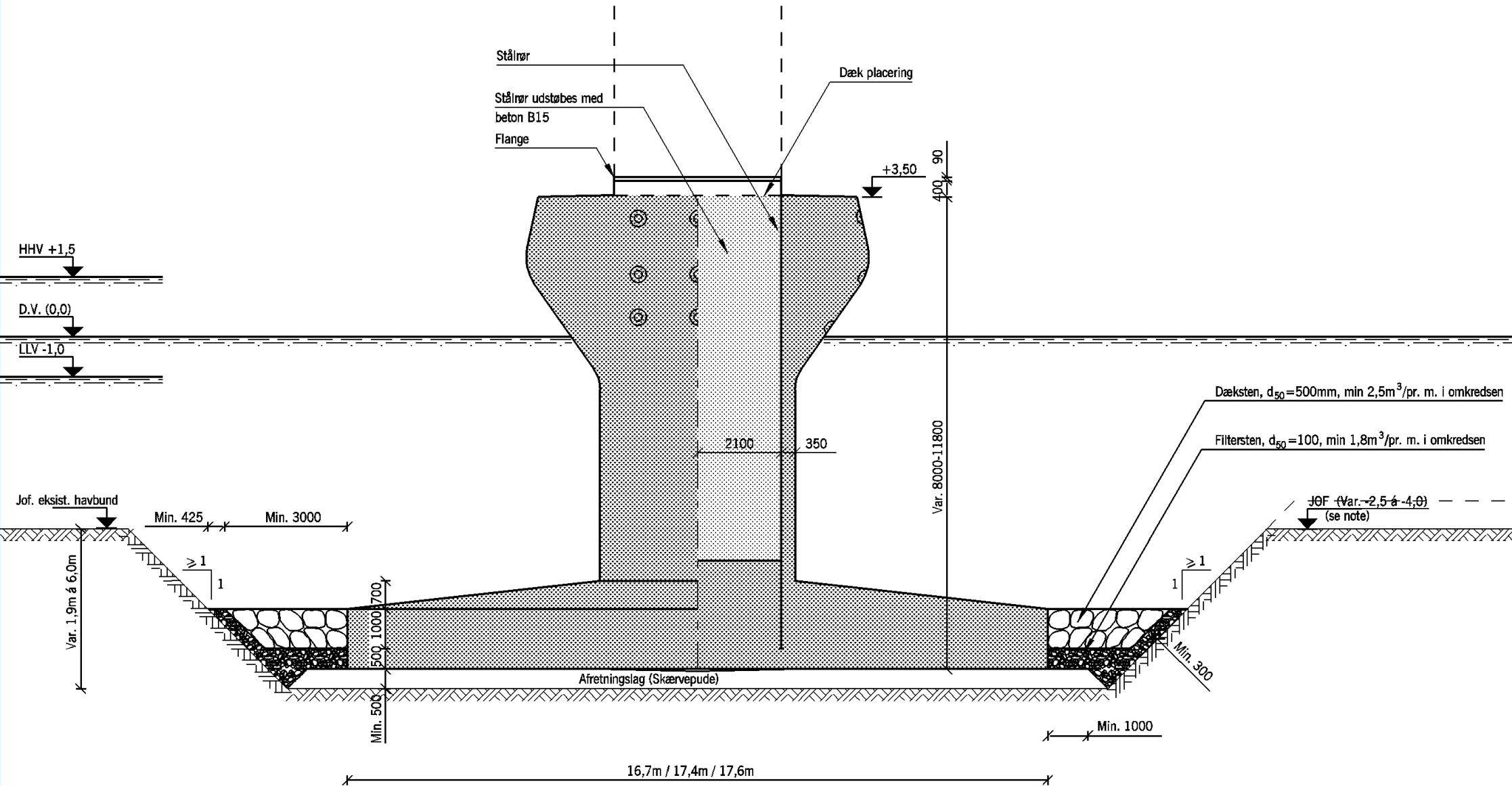




# Cross section Øresund



# Cross section foundation



Bortskrabning / afgravning og afretningslag

# Environmental Impact -Birds



- Limited experience offshore
  - Dutch near-shore
  - Utgrunden / Yttre Stengrund, SE
  - Tunoe Knob, DK
- \* Feeding possibilities more important, but results only valid for wintering eiders



# Environmental Impact -Birds



- Potential effects: collision, ousting, barrier
- Parameters:
  - species
  - migratory paths
  - site (distance to shore, water depth, feeding possibilities, natural reef effect, ...)
  - time of day/year
  - weather
  - noise
  - layout (farm/turbines, incl. marking lights)

# Environmental Impact -Birds



## Ytgrunden SE

One million seabirds migrates every season

1) Collision 2) Route 3) Food-searching 4) Darkness/fog

source



# Environmental Impact –Birds



## Ytgrunden SE

### Barrier effect 1

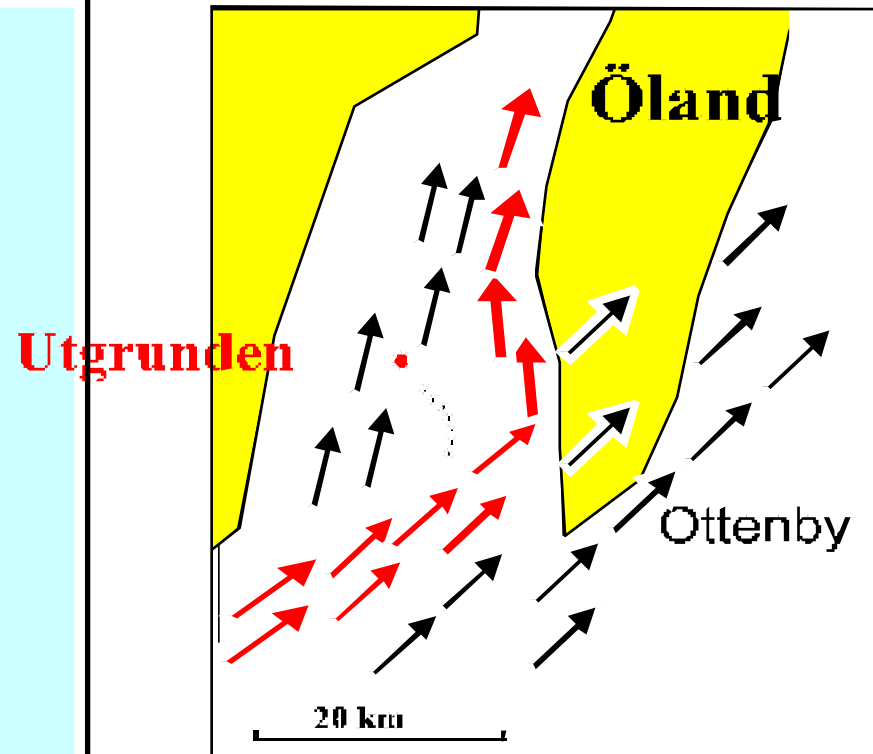
- Eider migration before and after the establishment of the wind farm



Source

## Radarekon av ejdersträcket

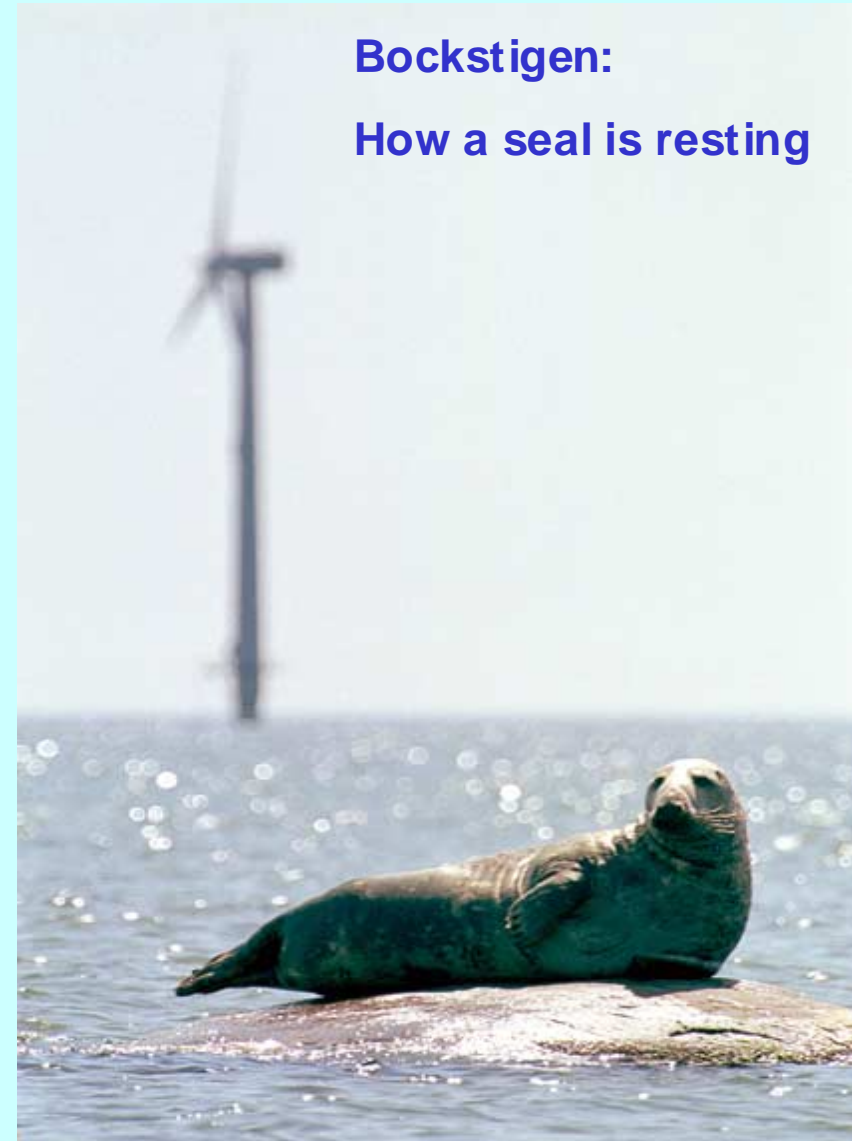
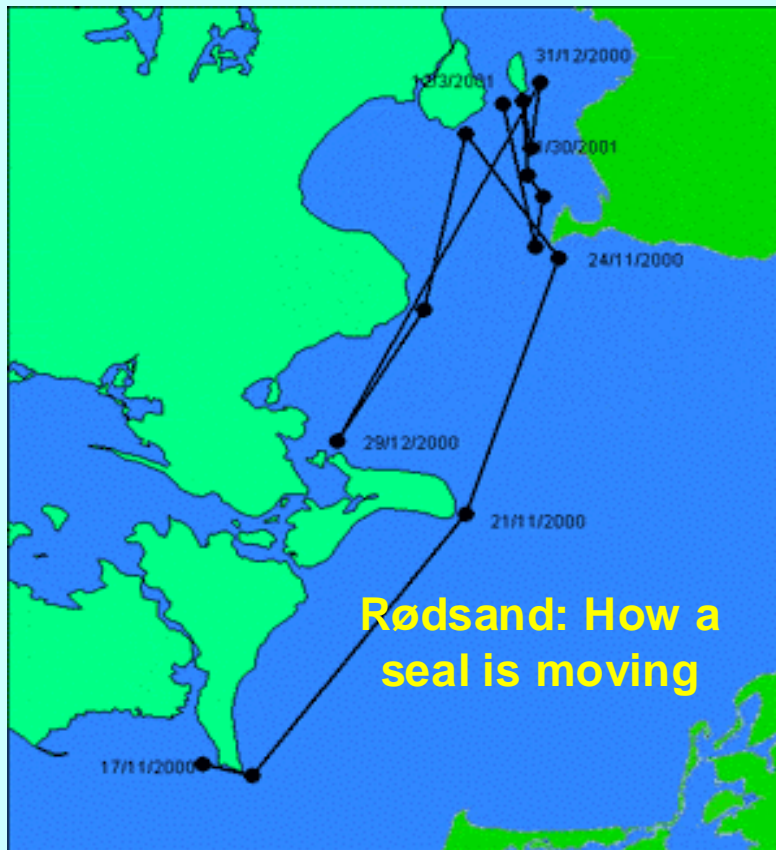
31 mars 2001 kl 13-14 SV 7 m/s



# Environmental Impact - Mammals



- Visual impacts?
- Noise & vibration impacts?
- Change of biotope?



# Sedimentation



Harbor  
sludge



Limestone dissolution



# Conflicts of Interest



## Ships

- Collision risk
- Effects difficult to predict
  - type of ship (cargo)
  - size of ship
- Positive effect?
- \* Mitigation measures
  - marking lights (but...)
  - emergency procedures
  - standardized, “reliable” risk analyses



# Conflicts of Interest



## Radar

- Potential problem (e.g. UK/SE):  
Moving blades causing false signals/disturbance,  
depending on
  - system (age, GPS, satellite)
  - turbine tower
  - number of turbines
- \* No serious problems if exact coordinates of wind turbines are known - unless radar equipment is surrounded by turbines.

# The radar prefers massive towers



Not lattice

# Marking light requirements



- The difference in visual impact



# Environmental Impact Assessment

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- Fauna and flora
- Noise
- Sedimentation
- Oil spill
- Special attention during construction

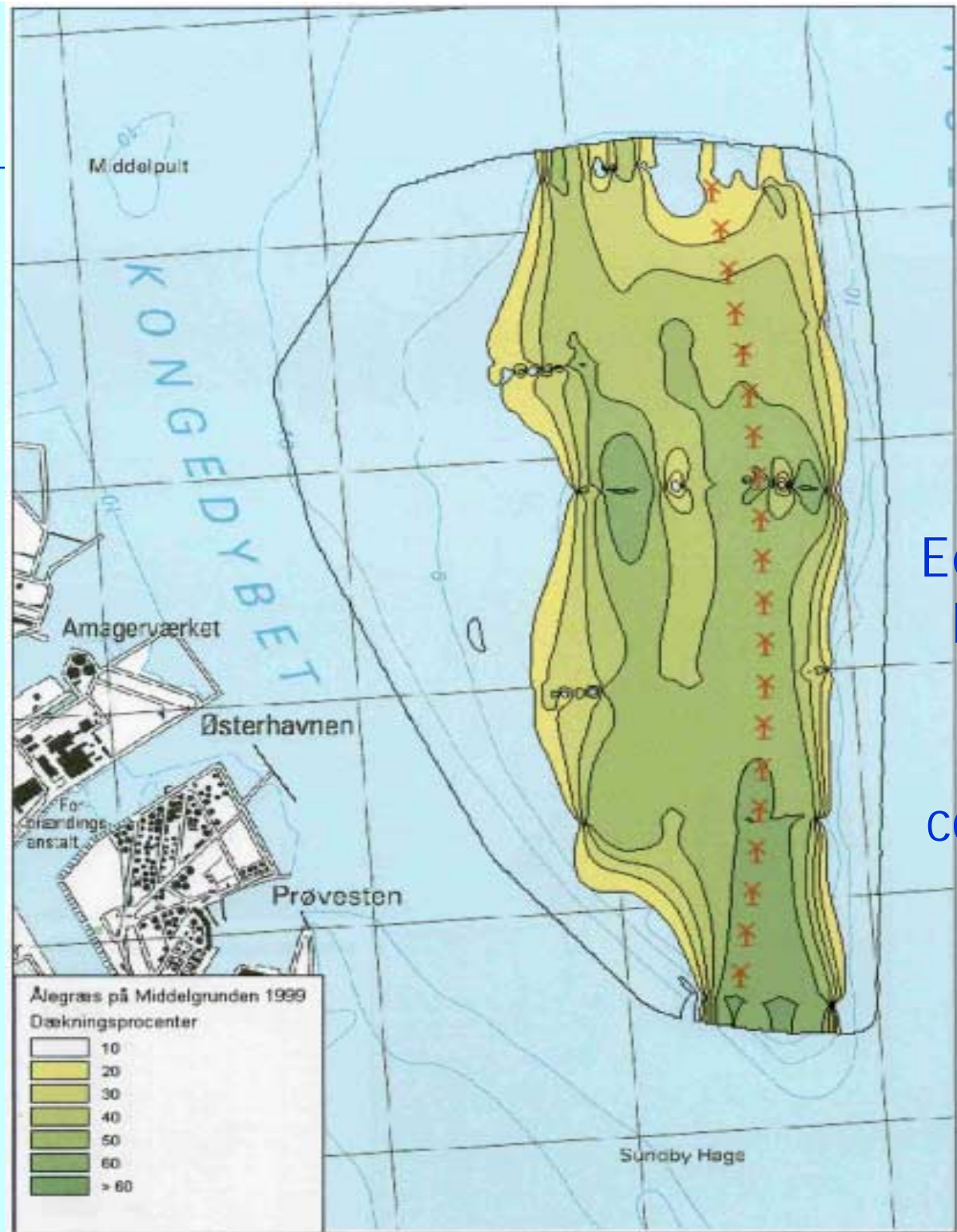
# 3 phases



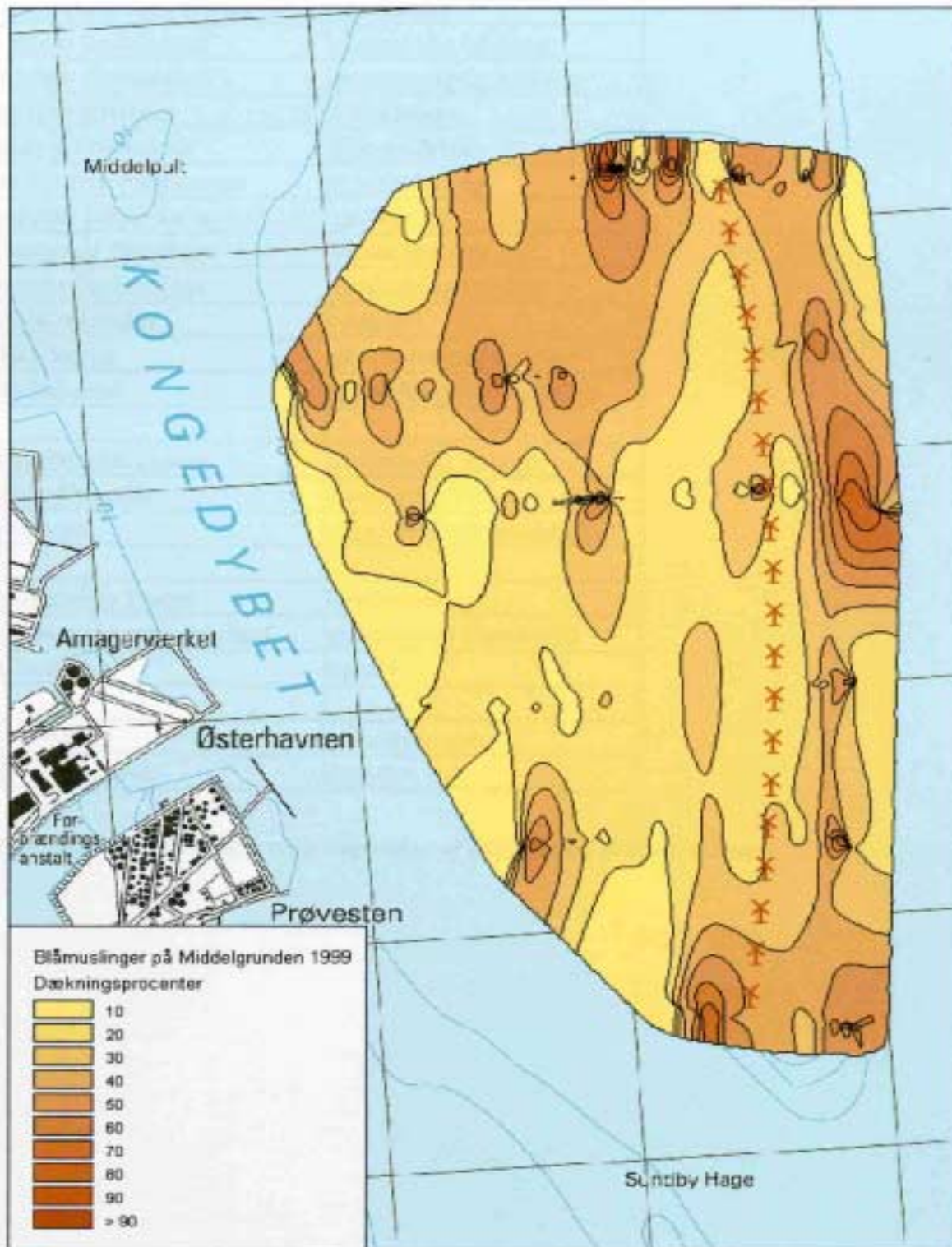
1. Construction\*
2. Operational
3. Dismantling\*

- \* temporary effects,
  - sedimentation (flora, fauna)
  - noise/vibrations (birds, mammals, fish)
- avoid sensitive periods





Eel grass  
before  
and  
after  
construc  
tion



# Shellfish



# Noise and Vibrations



- Airborne Noise
- Underwater noise and vibrations

Examples:

## Porpoises

Produce pulsed sounds: 2 kHz (perhaps communication)

Echo localization sounds: 13-130 kHz

Fair hearing: 1-150 kHz

Good hearing: 8-30 kHz

## Speckled Seals:

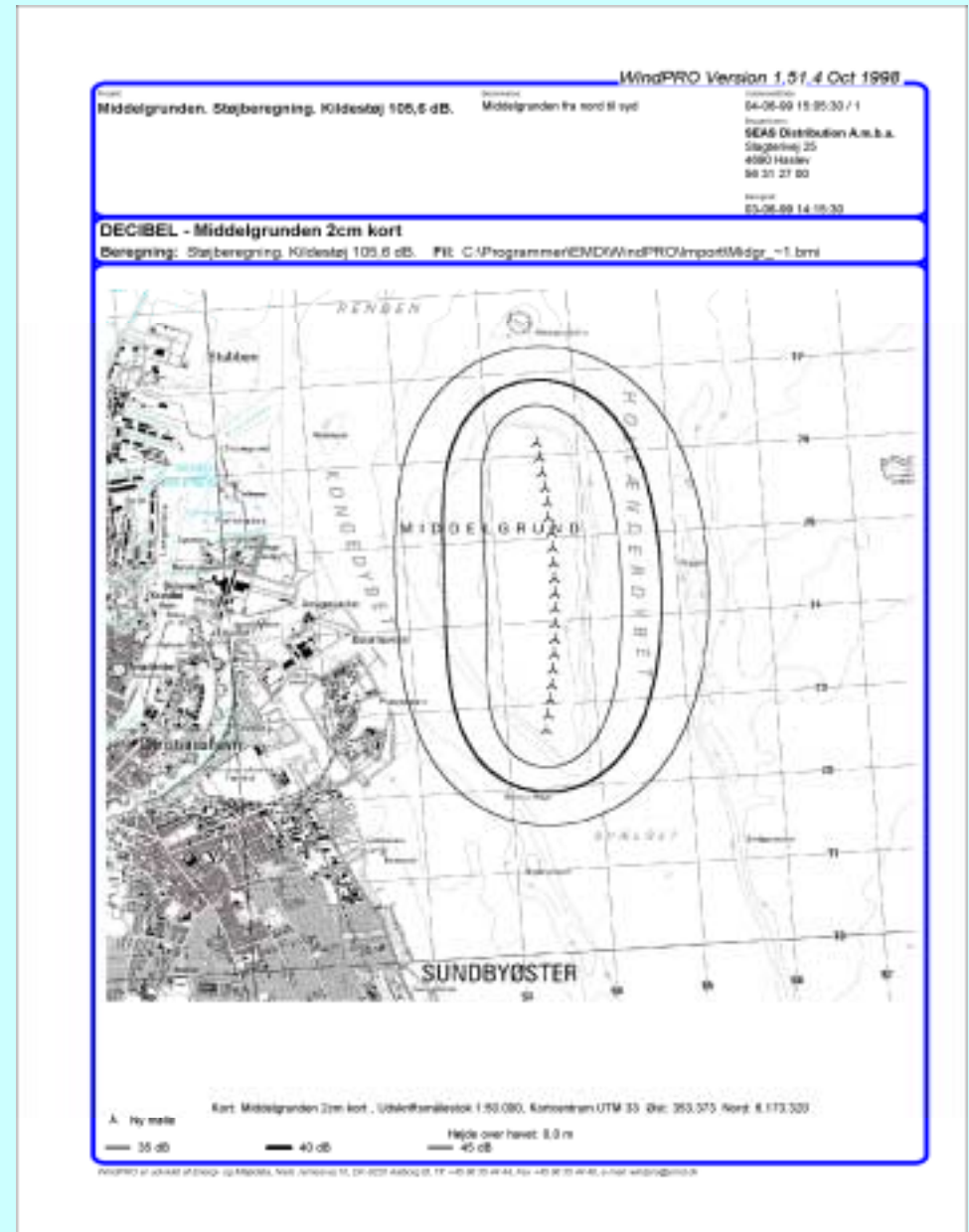
Produce sound: 0,1-40 kHz

Fair hearing: 0,1-60 kHz

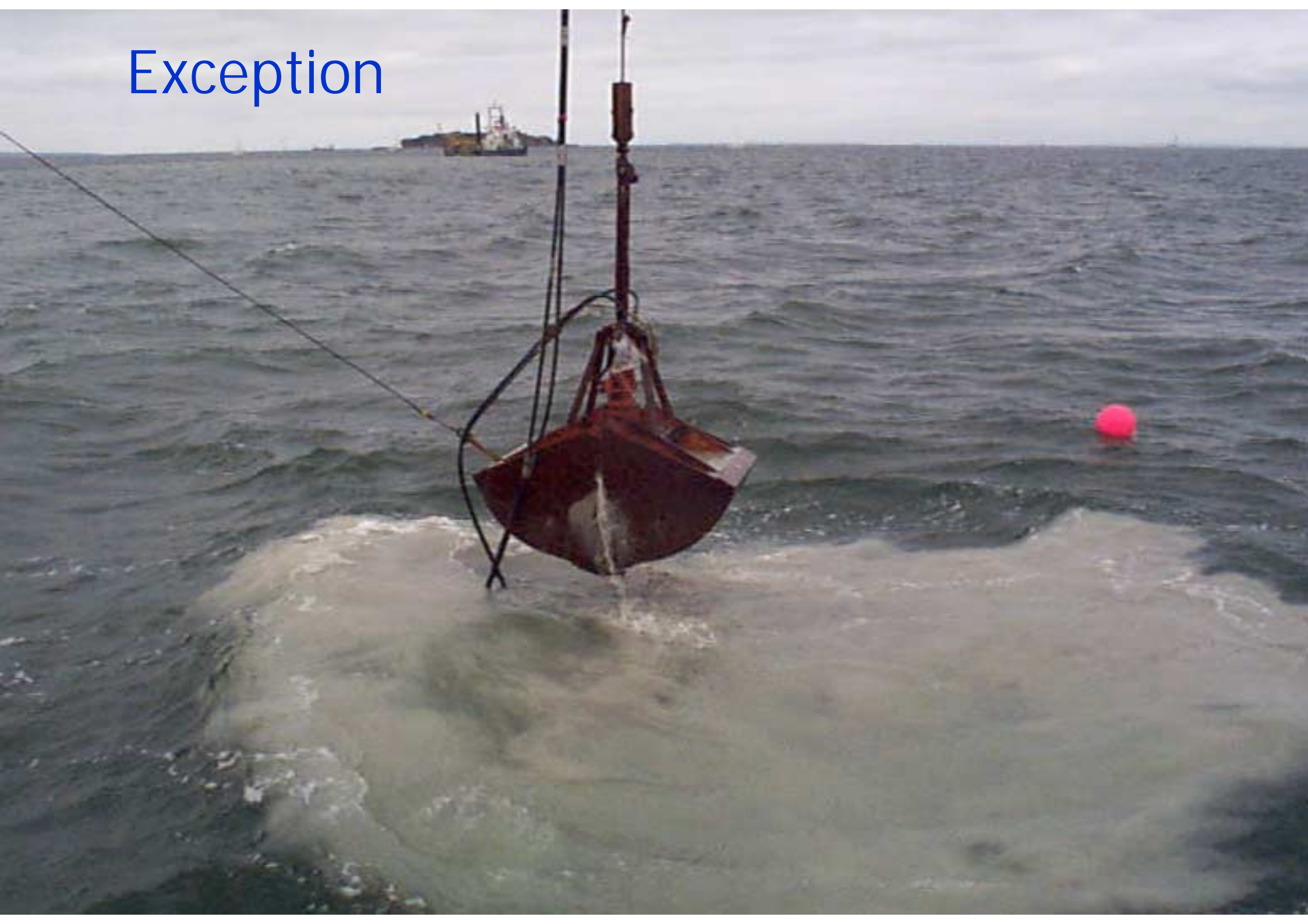
Good hearing: 1-50 kHz

**Fish:** 0-130 kHz

\* **More studies needed!**



Exception





Moving sludge is not possible to hide



By two foundations - special attention



# Consideration for failure, oil spill



The submarine cables was of the PEX type (without oil)



The 690V/30kV transformer of the dry type (without oil)

# Construction phase



15 6 2000 12:37

# Placing reinforcement



Casting concrete

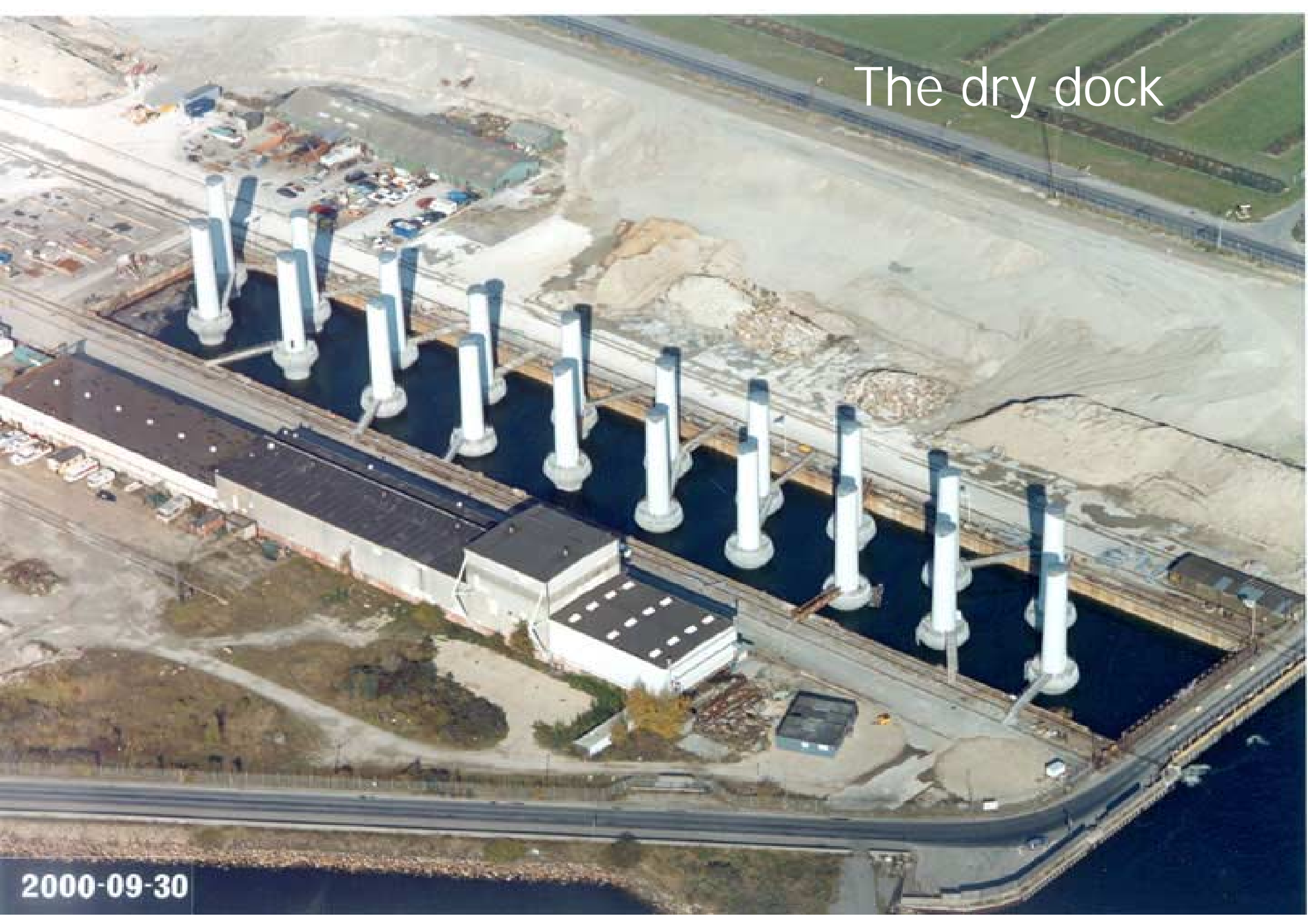






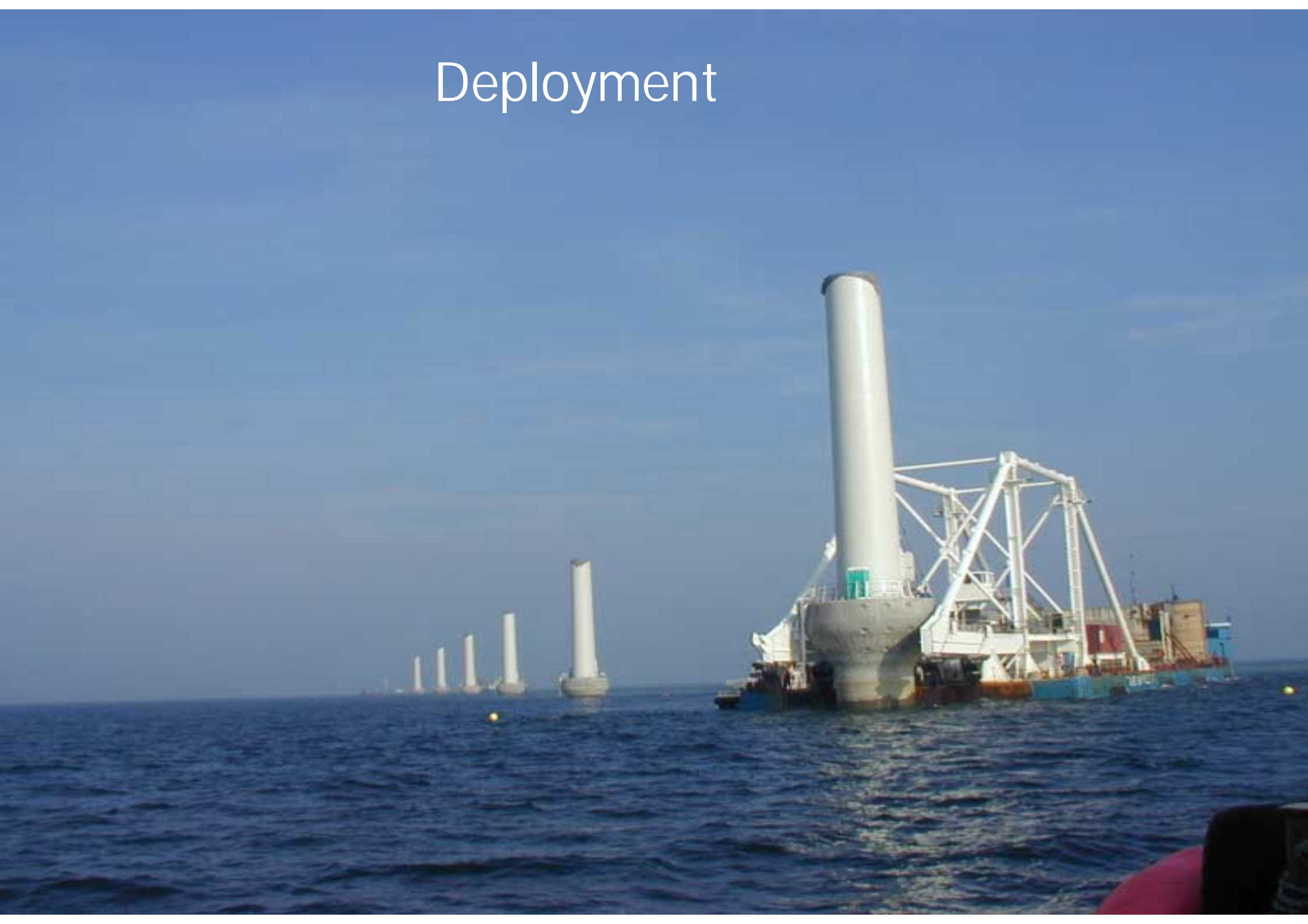
Lower part of  
towers in place in  
the dry dock

The dry dock

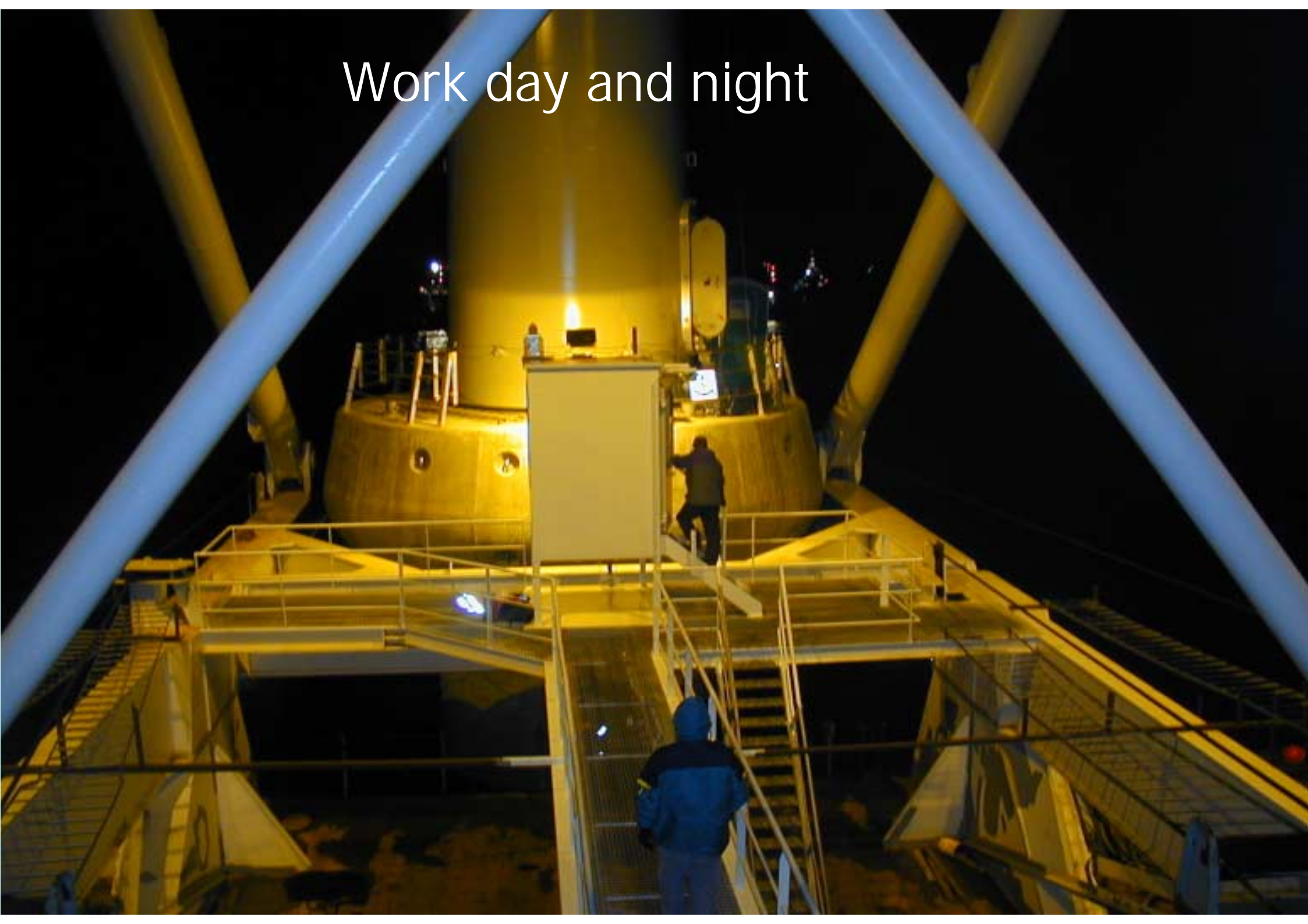


2000-09-30

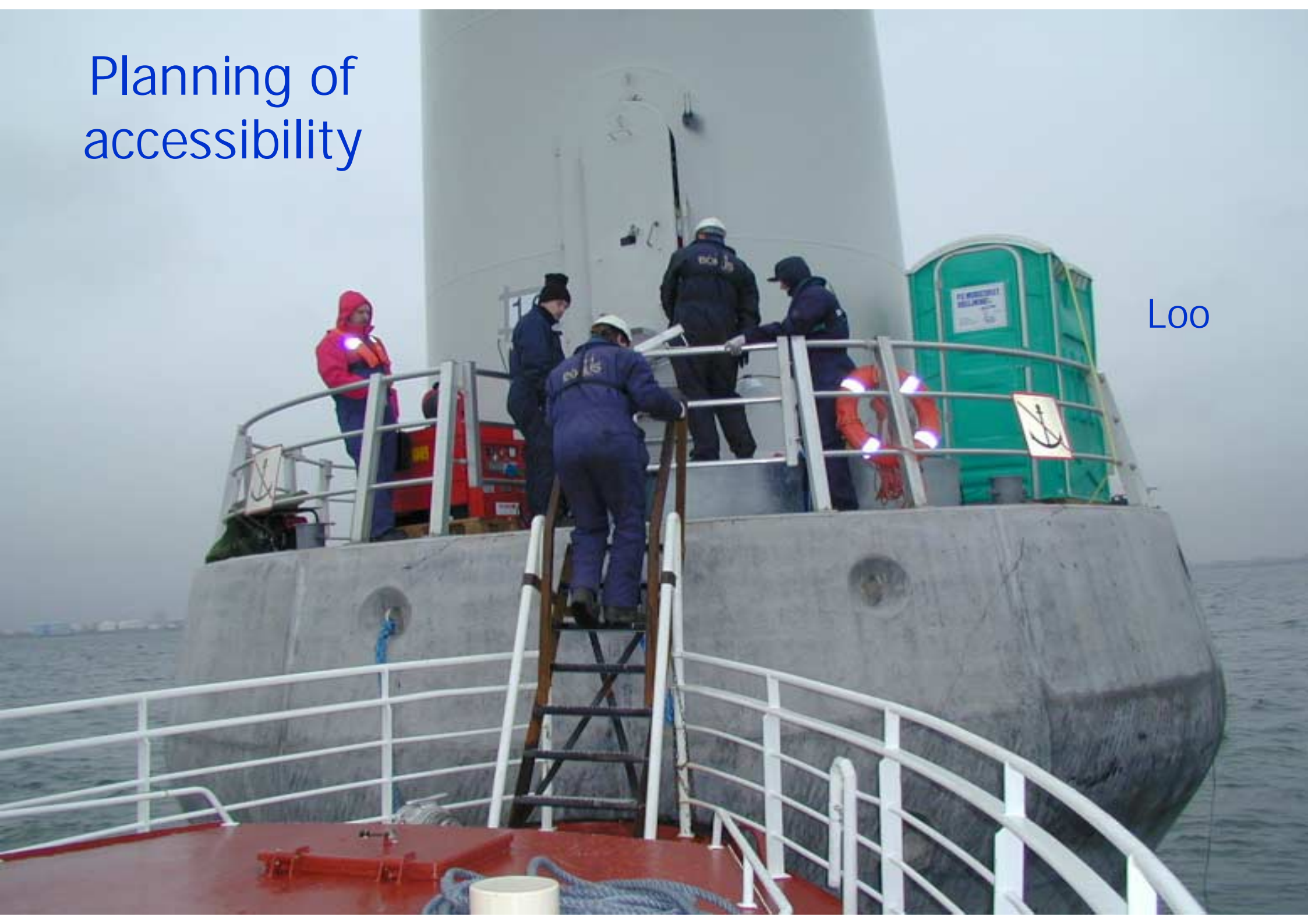
# Deployment



Work day and night



# Planning of accessibility



Loo

A rotor on the barge in the Copenhagen harbour



Ready for lifting in place



On the way up





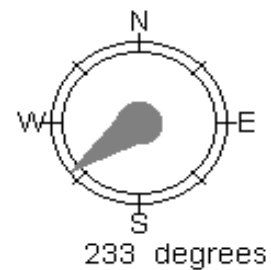
# Cable deployment



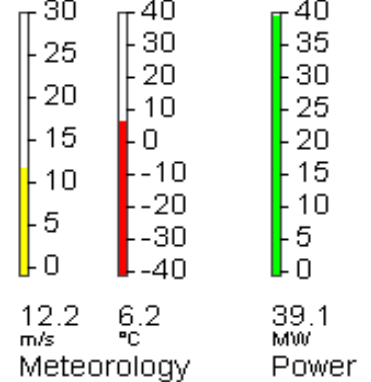
# Production from March 2000



# Park view, Middelgrunden



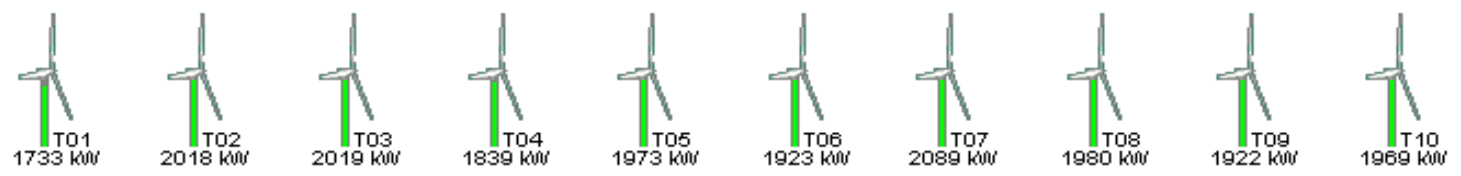
### Summary from All Turbines



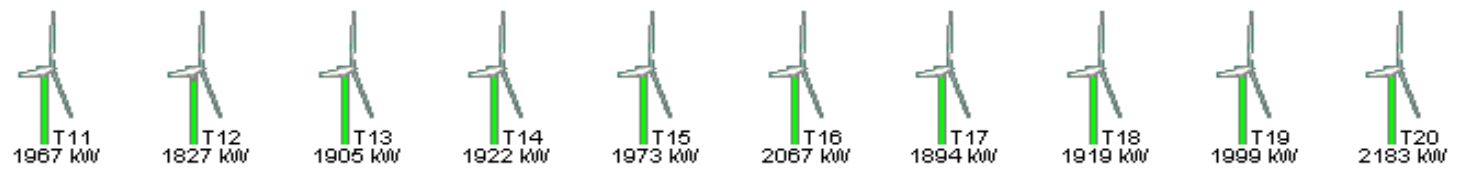
### Legend

- Turbine in Service
- Turbine Event
- No communication

### Københavns Energi



### Middelgrundens Vindmøllelaug



# Conclusions



- EIA must be conducted, careful planning essential
- Environmental concerns:
  - especially birds, but additional studies needed
- Conflicts of interest:
  - radar effects
  - collision risk (ships, low-flying aircraft)
  - fishermen must be compensated
- Social acceptance: Early, active public involvement
- Policies: Varies between different countries and even within specific countries

# Sources & References



## Sources, e.g.

- EIAs (Danish and Swedish projects, so far)
- EU EIA Directive and amendment  
<http://europa.eu.int/comm/environment/eia/full-legal-text/9711.htm>
- NOVEM/Ecofys (Inventory of Policy, Regulations, Administrative Aspects and Current Projects for Offshore Wind Energy in Northern Europe, [www.ecofys.nl](http://www.ecofys.nl))
- Two papers from the EWEA special topic conference Brussels, Dec. 2001, session Environment (Stefen Nielsen, DEA and H. C. Sørensen, Karin Hammerlund et al)
- Offshore Wind Farms (Guidance note for EIA in the UK [www.mecu.gov.uk](http://www.mecu.gov.uk)), “similar” in DK ([www.ens.dk](http://www.ens.dk) in Danish)
- CA-OWEE Report: [www.offshorewindenergy.org](http://www.offshorewindenergy.org)



# Legal Background (1)



- ESPOO convention
- EIA - Environmental Impact Assessment
- ES/EIS - Environmental (Impact) Statement

EU Council Directive 85/337/EEC, June 85

Amended in Council Directive 97/11/EC, March 1997:

## “Article 3

The environmental impact assessment shall identify, describe and assess in an appropriate manner, in the light of each individual case... the direct and indirect effects of a project on the following factors:

- human beings, fauna and flora;
- soil, water, air, climate and the landscape;
- material assets and the cultural heritage;
- the interaction between the factors mentioned...”

# Legal Background (2)



- Regarding installations for the harnessing of wind power for energy production (wind farms) the Member States shall determine whether the project shall be made subject to an assessment through:
  - (a) a case-by-case examination, or
  - (b) thresholds or criteria set by the Member State
- All offshore projects expected to be subjects of EIA
- Alternatives and mitigation measures must be included
- Public:

“Member States shall ensure that any request for development consent and any information gathered... are made available to the public within a reasonable time in order to give the public concerned the opportunity to express an opinion before the development consent is granted.”

# The cooperative



- Options 50 DKK each shear - no refund
  - 4,250 DKK/1,000 kWh/y
  - 600 DKK/y first 6 years
- Full payment of shares starts November 1999
- 30,000 shares reduced to 20,000
- TV spots from February 2000
- Sigurd on the Town Square April 29th 2000
- Visit to building site May 2000 - 1,600 participants
- Article in *Jyllands Posten* September 17th 2000
- All 40,500 shares sold September 18th 2000



# Time table



- EU pre-qualification February - August 1999
- Tender turbines, foundations and grid October 1999
- Signing of contract December 1999
- Casting concrete April - August 2000
- Work on sea bed June - September 2000
- Placing caissons September - November 2000
- Placing turbines October - December 2000
- Placing grid connection November 2000
- Upstart production December - March 2000

## Middelgrunden Wind Farm 40 MW - Facts



Power	40 MW
Hub height	64 meter
Rotor diameter	76 meter
Total height	102 meter
Foundation depth	4 to 8 meter
Foundation weight (dry)	1,800 tons
Wind speed at 50-m height	7.2 m/s
Power output	89/100 GWh/y
Distance to shore	3.5 km

# Final costs = Budget

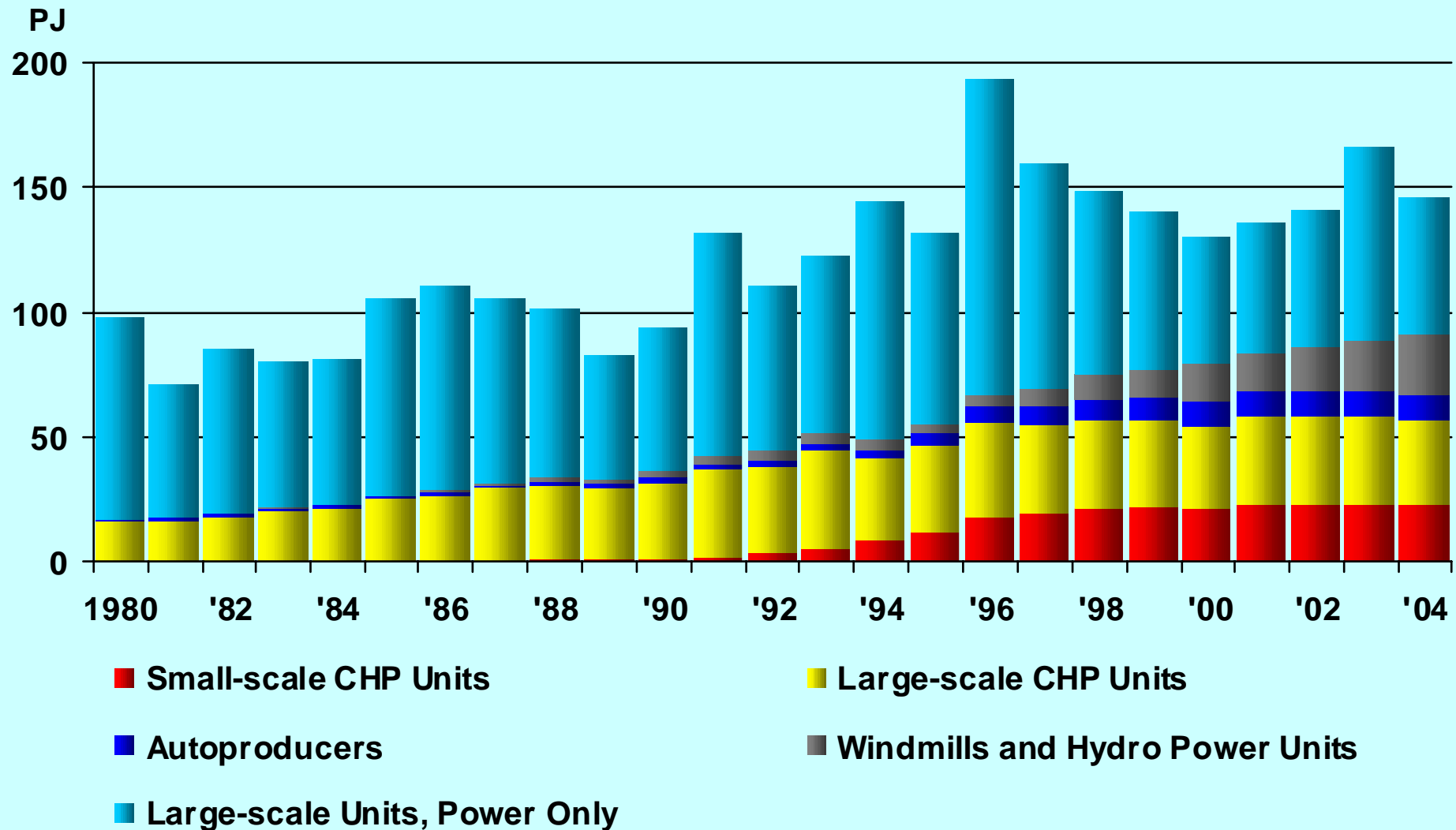


<b>The total investment in the project</b>	<b>M EUR</b>
Wind turbines	26.11
Foundations including changes after the tender to reduce the working period	9.92
Grid connection, offshore	4.56
Design, advice and planning	2.15
Wind turbine cooperative	0.54
Other costs	1.61
<b>Total</b>	<b>44.9</b>

# Danish energy mix



## Electricity Production by Type of Producer



Source: [www.ens.dk](http://www.ens.dk)