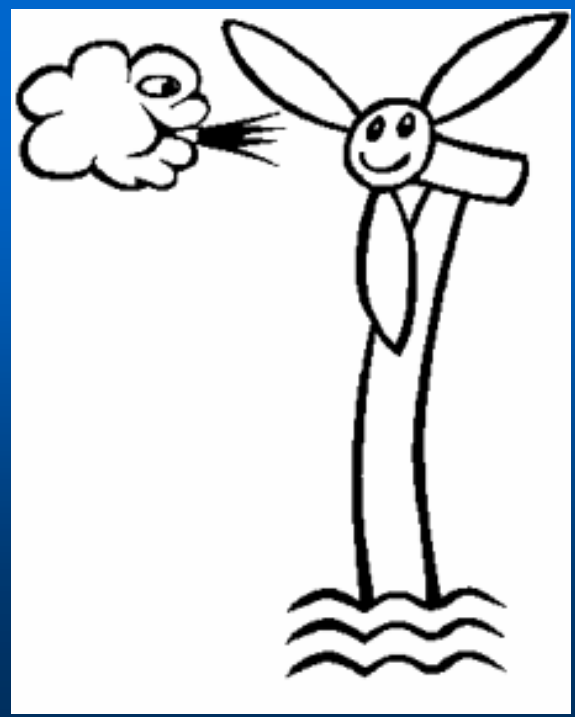
Danish energy policy and Middelgrunden Off-shore Wind Farm

Jens H. M. Larsen, M.Sc.

Copenhagen Environment and Energy Office



Energysavings

Local information and implementation

Danish Network of Energycenters

Energyservice

Offices: 13

People: 50

Danish Energy Policy

- **Danish olie in 1972 and oliecrisis in 1973**
- **Energyplans in year 76, 81, 90,**
- **Year 1996 (Energy 21)**
- **Green majority in parliment 1980-2000**
- **New libral goverment in 2001**

Danish Energy Policy - update

- **Liberal Energy Market**
- **Electricity Saving Fund, labelling ect.**
- **Energy savings in buildings, new regulation**
- **2 % energy saving pr. year**
- **2 new offshore windfarms**
- **Retrofit of 350 MW new wind on land**

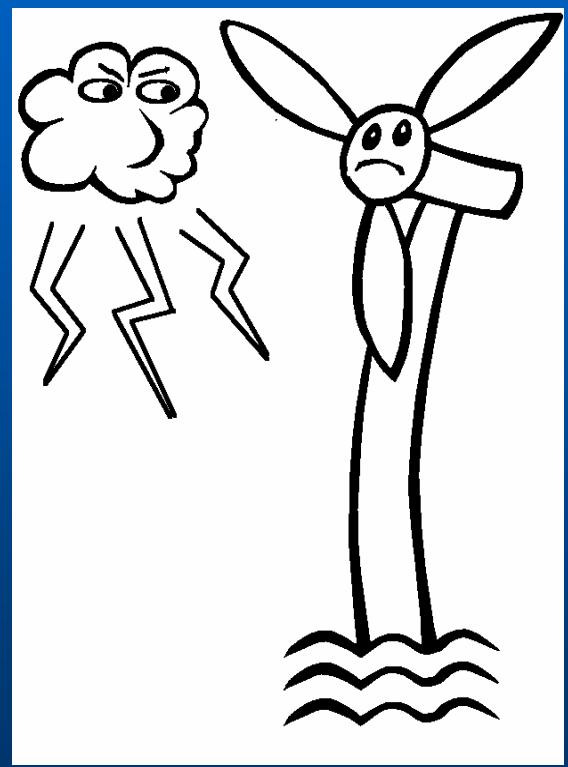
New Danish Wind Policy

No new capacity 2003-2006

Low expectations for new capacity after 2007

Market + Added price

(Max 0.049 euro/ kWh)

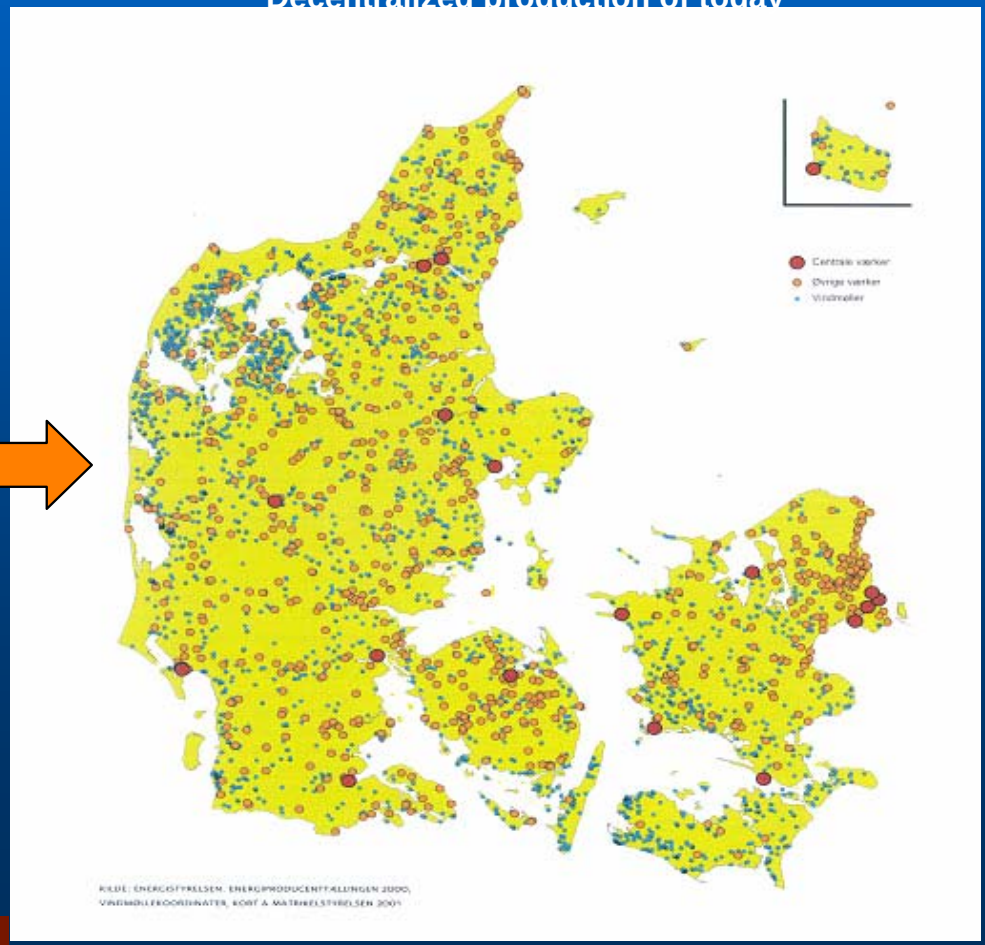


From Centralized to Decentralized CHP

DK annual consumption 32 TWh

Centralized production in the mid 80's

Decentralized production of today

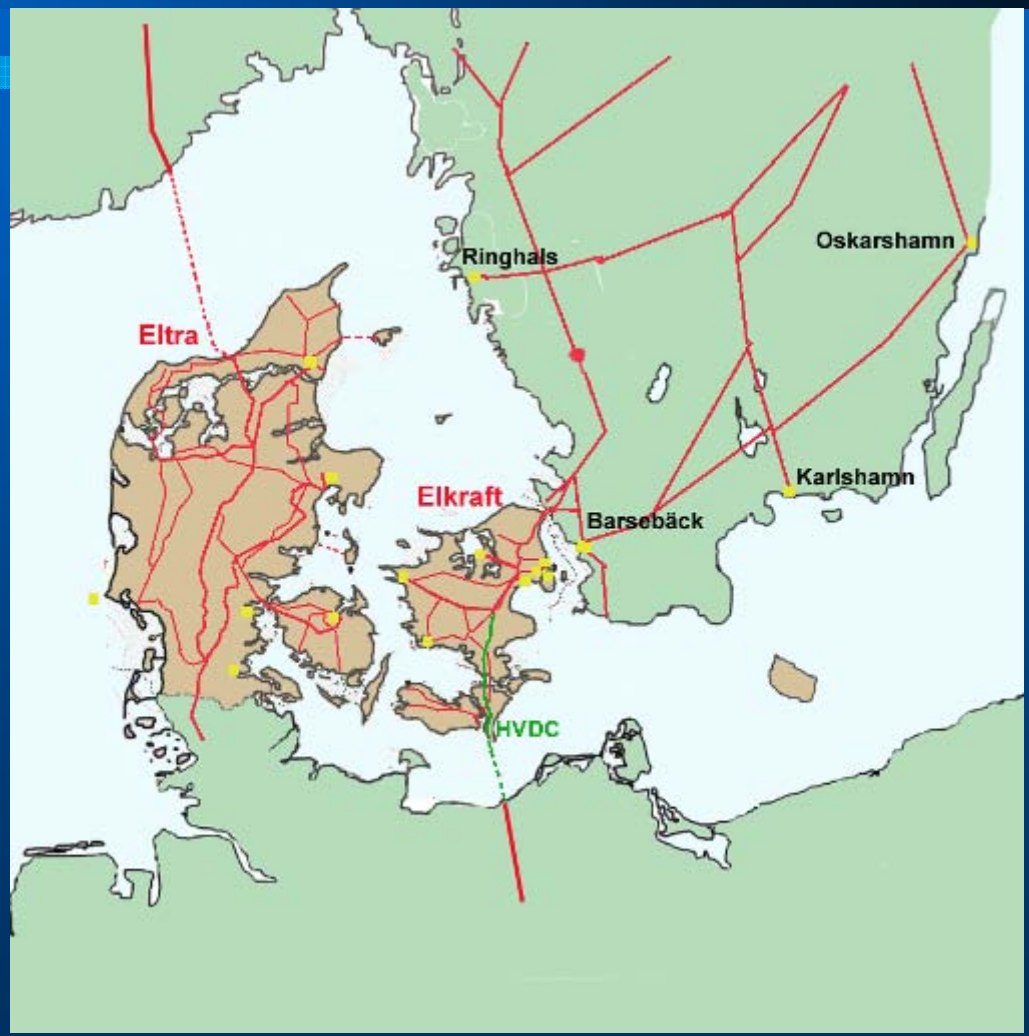


Transmission system in Denmark

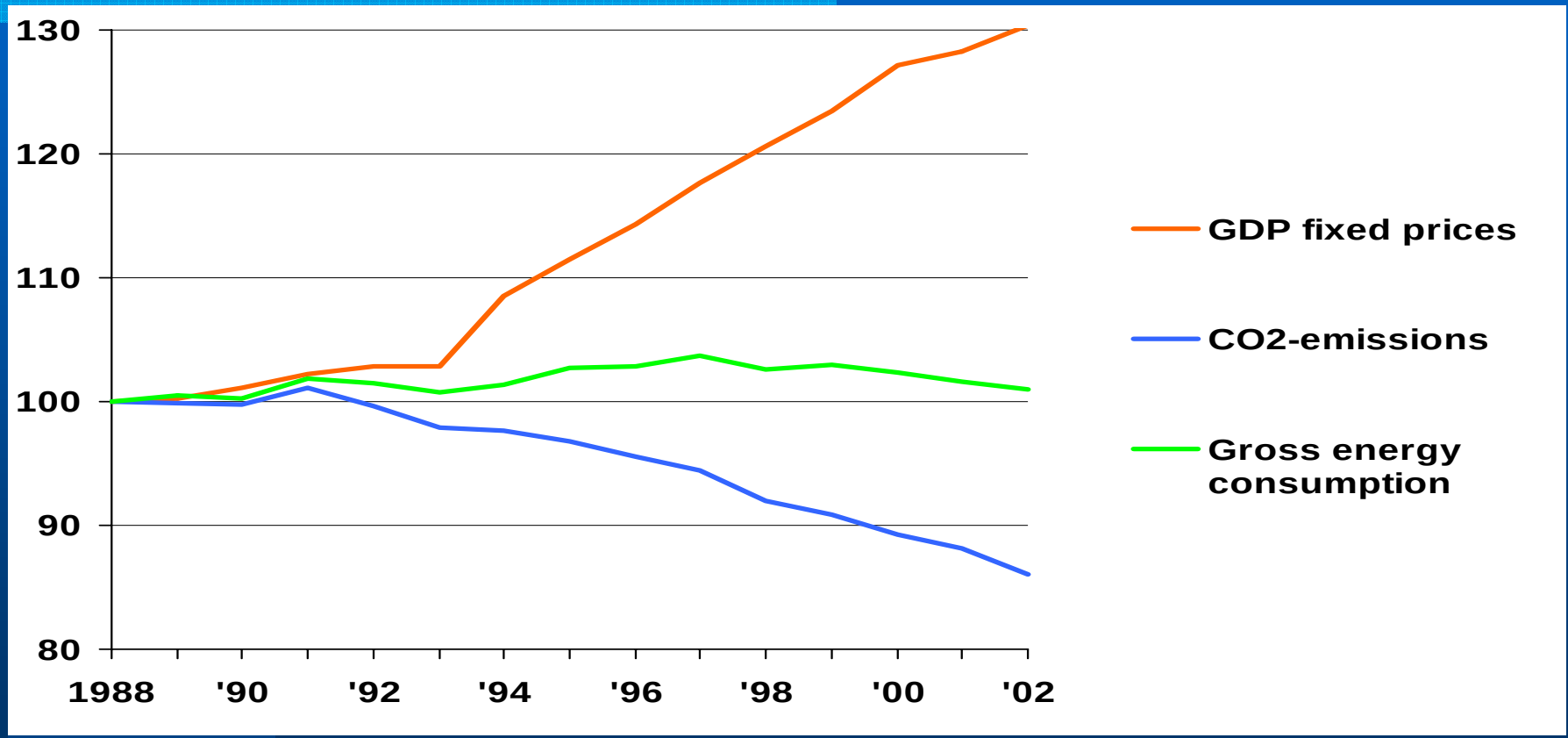
Two autonomy systems.

Connection to Norway, Germany and Sweden

Annual consumption
32 TWh

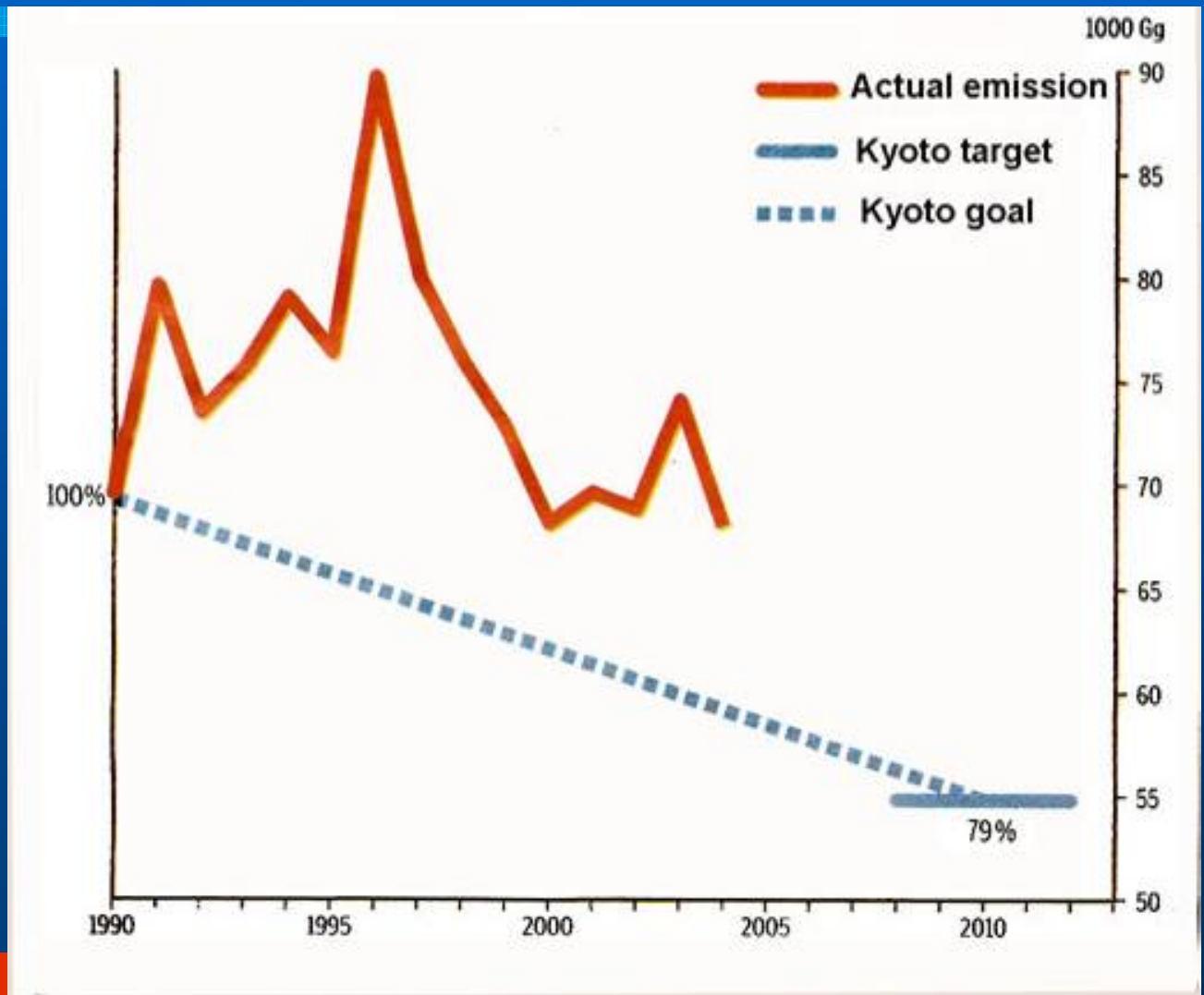


CO_2-Emission and Economic Growth

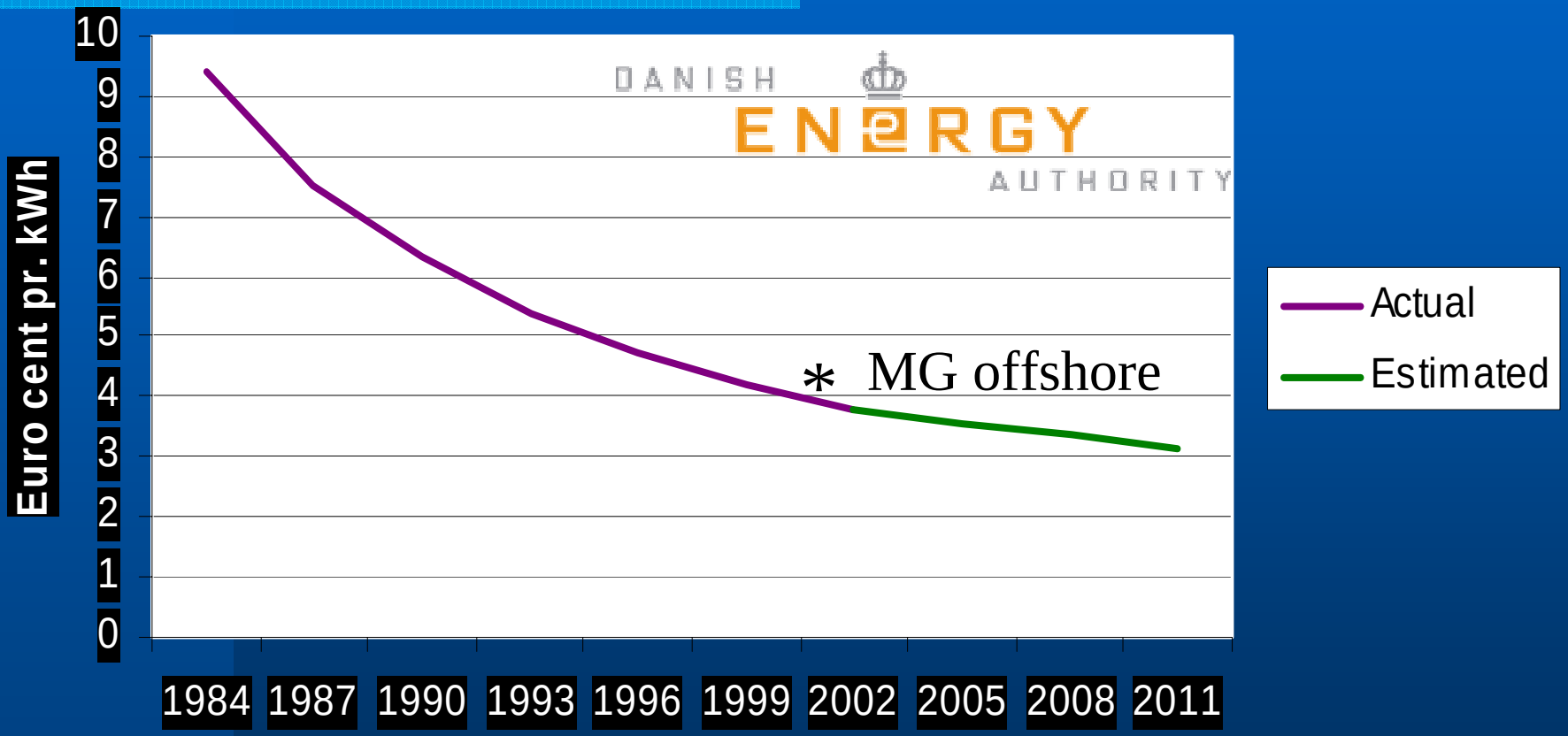


Explanatory factors: 1) Renewable energy, 2) Energy savings, 3) Combined Heat Power

Emission of danish greenhouse gas



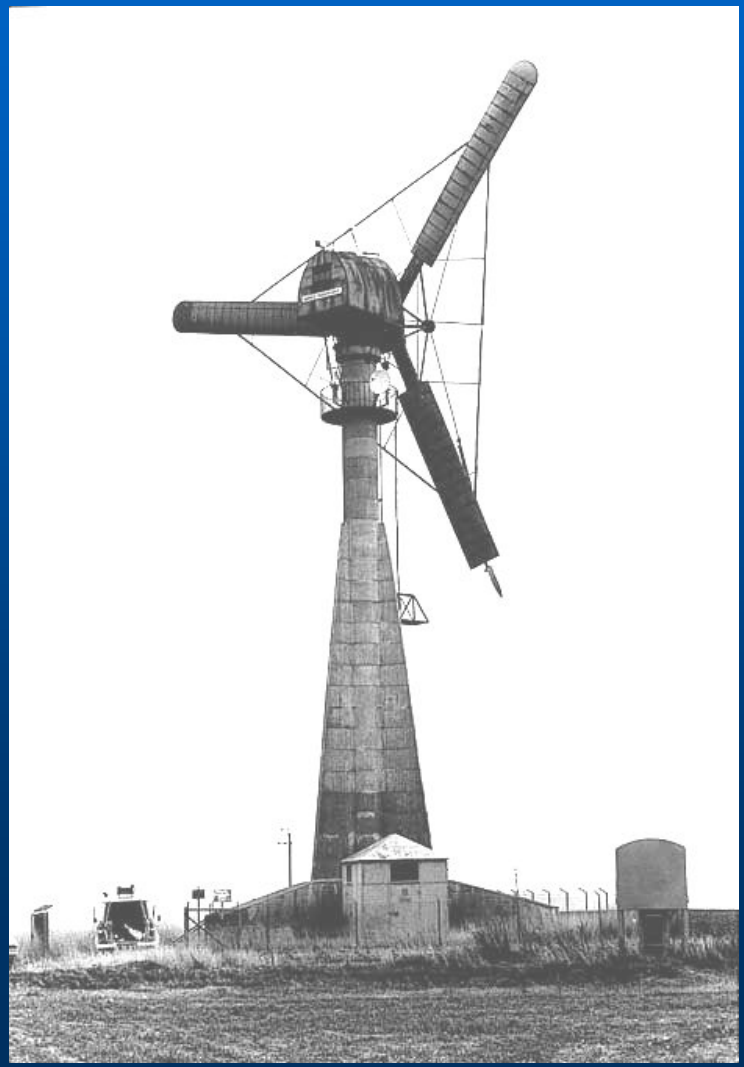
Production Cost at Danish on-shore Wind Power Plants



History of Danish Windpower

History of Danish Windpower

- **Gedser møllen, 200 kW**
- **Installed 1957**
- **shut down, 1967**
- **Testrun in 1977 was financed by US government**



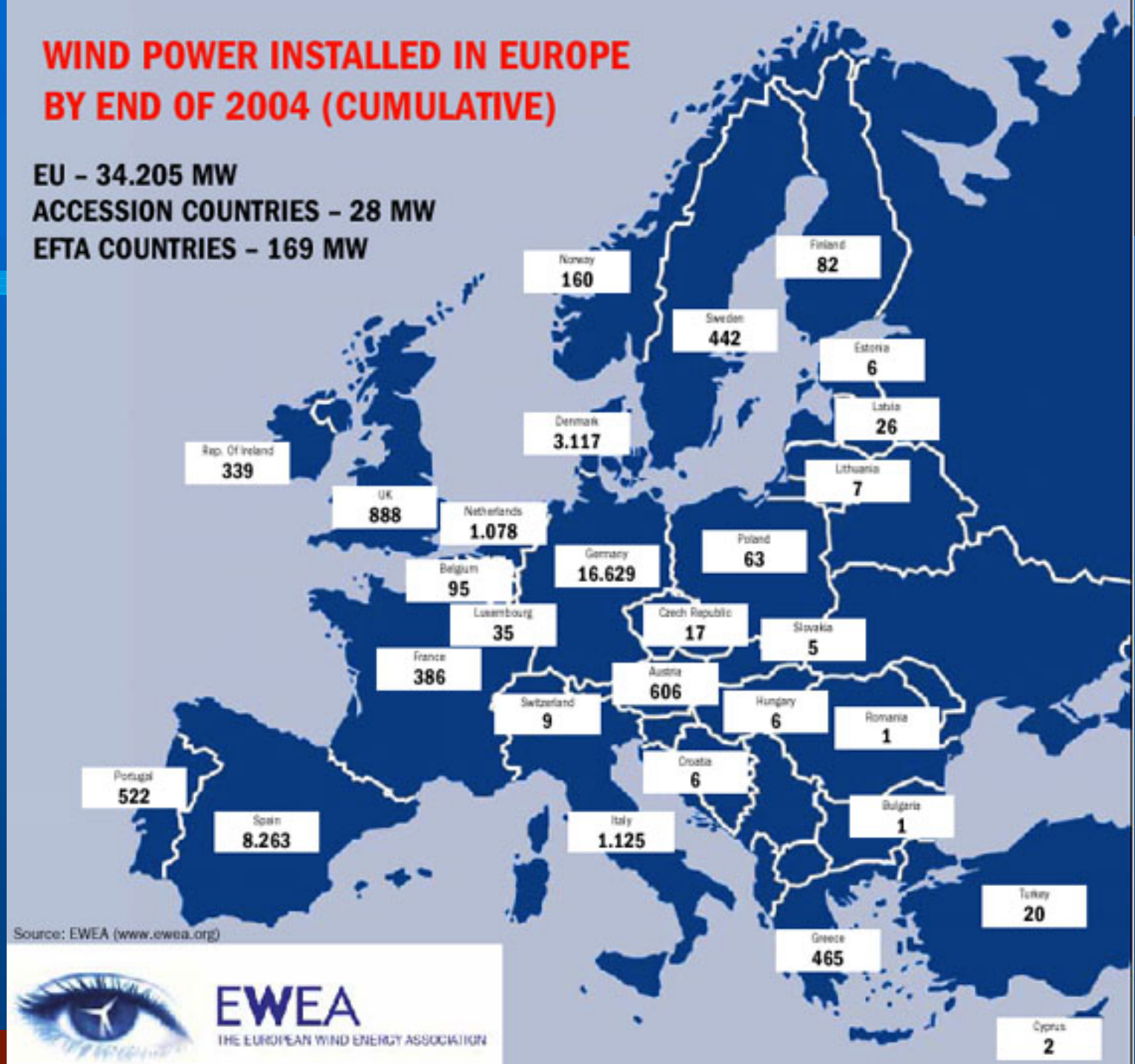
History of Danish Windpower

- **Oil crisis 1979**
- **First modern turbine from 1982**
- **15 - 45 kW for private household**
- **Privately build**
- **Friend – to - friend**

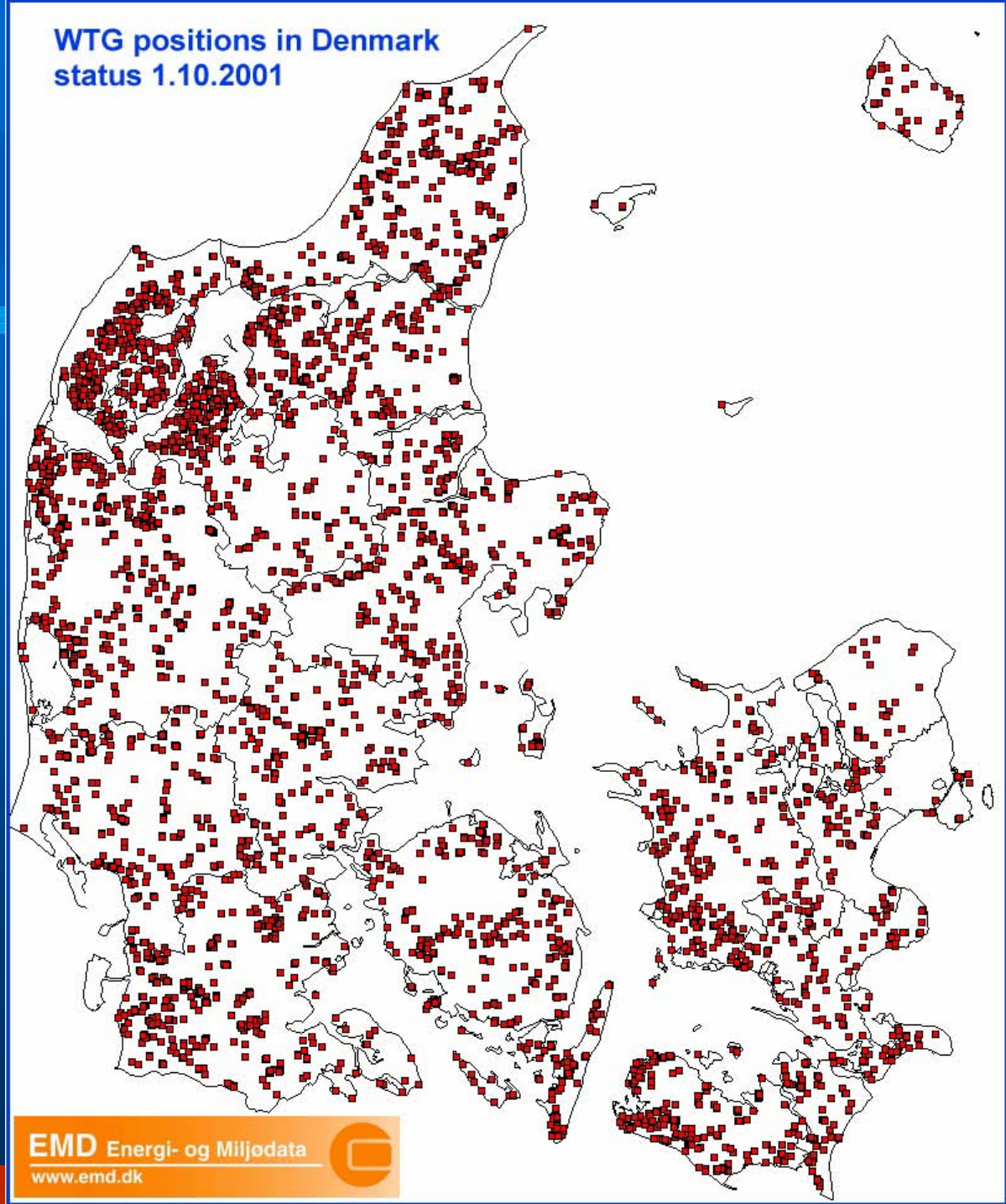
History of Danish Windpower

Ready for the big boom in USA 1985 - 88

Ca. 50 % off all wind turbines in the world is made in DK


WIND POWER INSTALLED IN EUROPE
BY END OF 2004 (CUMULATIVE)
EU – 34.205 MW
ACCESSION COUNTRIES – 28 MW
EFTA COUNTRIES – 169 MW
Norway 160
Finland 82
Sweden 442
Estonia 6
Latvia 26
Denmark 3.117
Rep. Of Ireland 339
Lithuania 7
UK 888
Netherlands 1.078
Poland 63
Germany 16.629
Belgium 95
Luxembourg 35
Czech Republic 17
Slovakia 5
France 386
Austria 606
Switzerland 9
Hungary 6
Romania 1
Croatia 6
Portugal 522
Spain 8.263
Italy 1.125
Bulgaria 1
Turkey 20
Greece 465
Cyprus 2
Source: EWEA (www.ewea.org)
EWEA
THE EUROPEAN WIND ENERGY ASSOCIATION

20.8% of electricity in Denmark comes from Wind in 2004

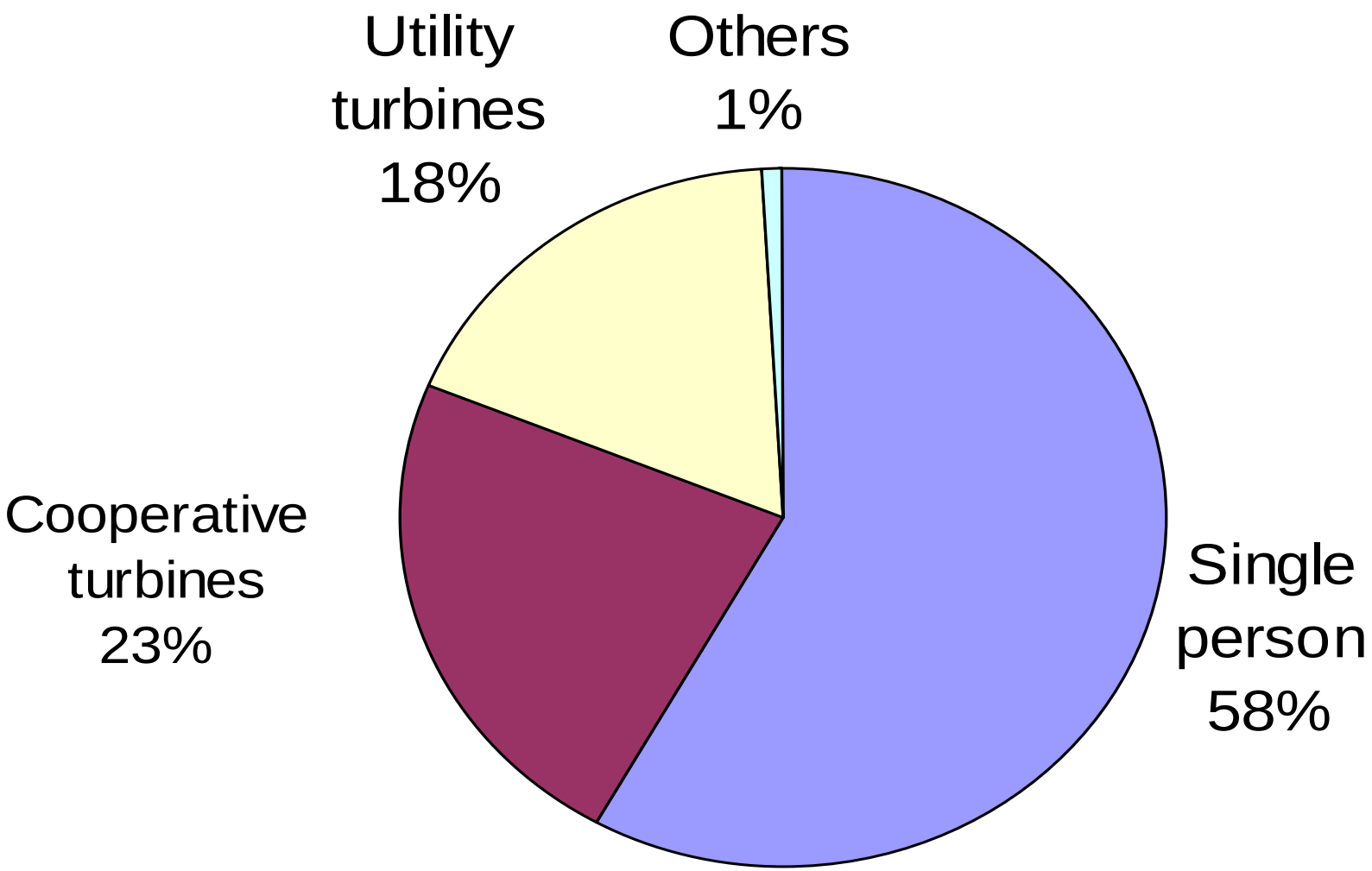


Why did we have this success ?

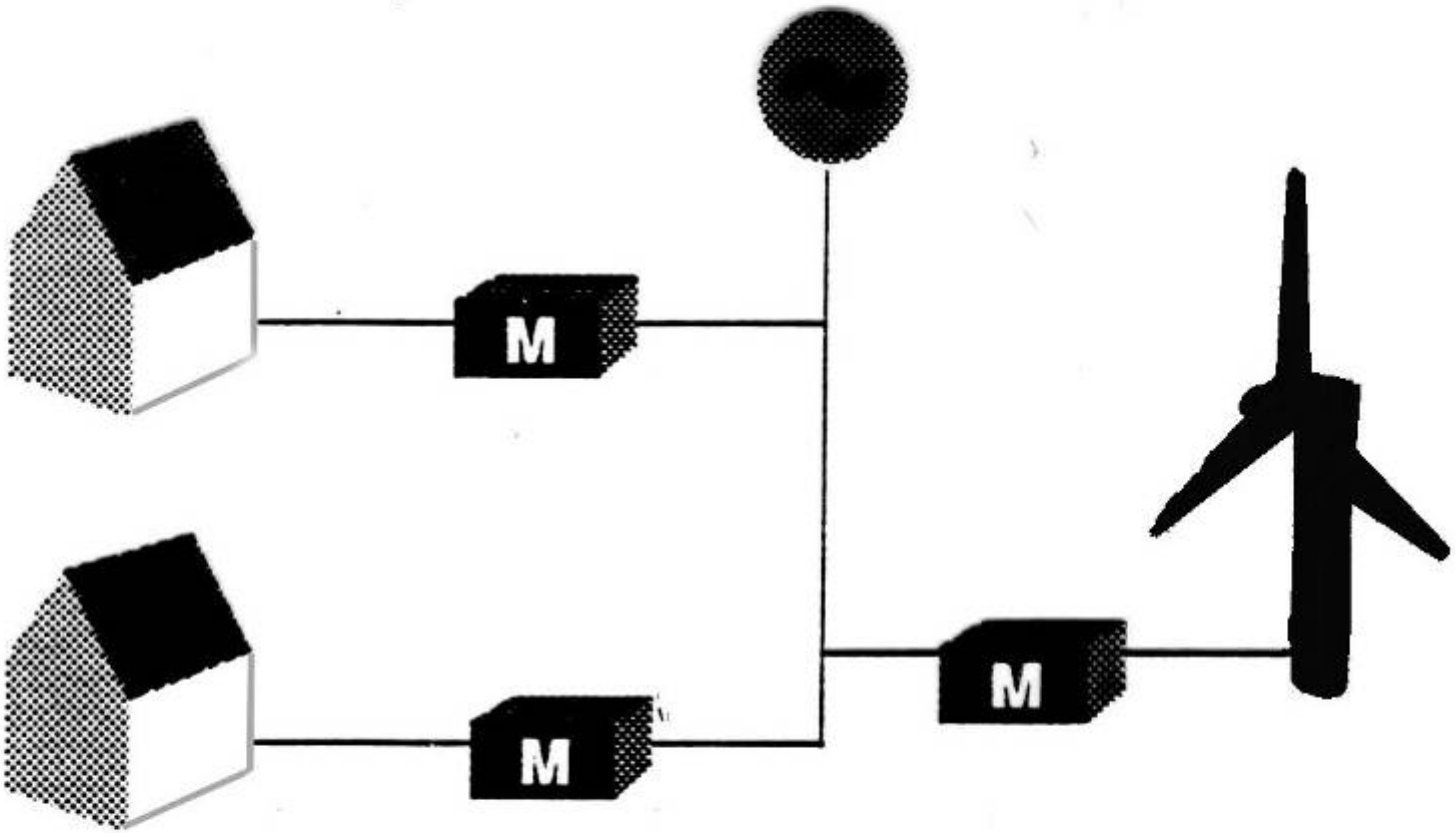
- **81% of Danish wind energy projects are local and community-based**
- **We had a policy which supported this development**
- **Feed-in tarif system**
- **Grid connection law**

Ownership in Denmark

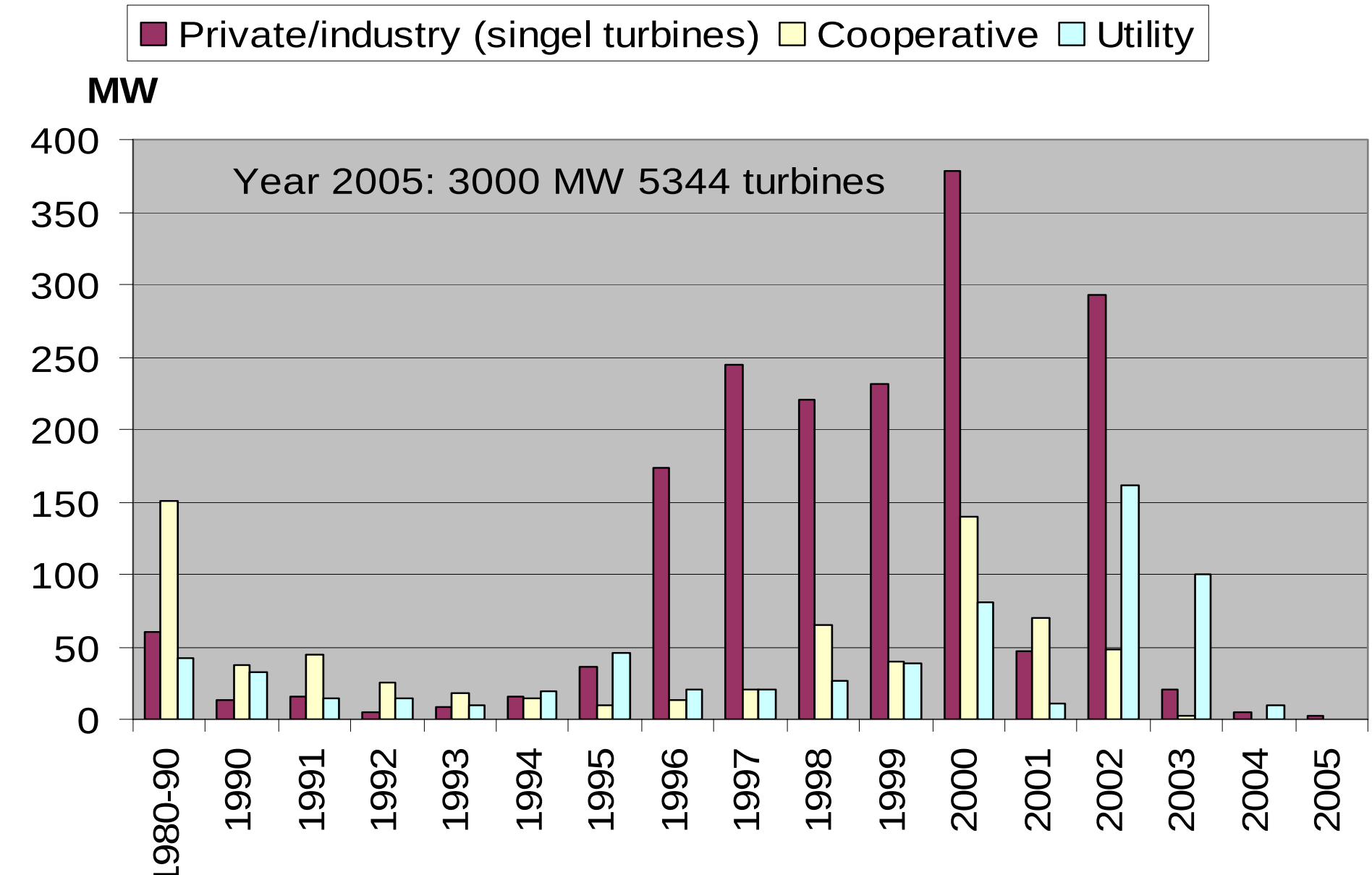
Year 2002: 3000 MW, 5000 turbines



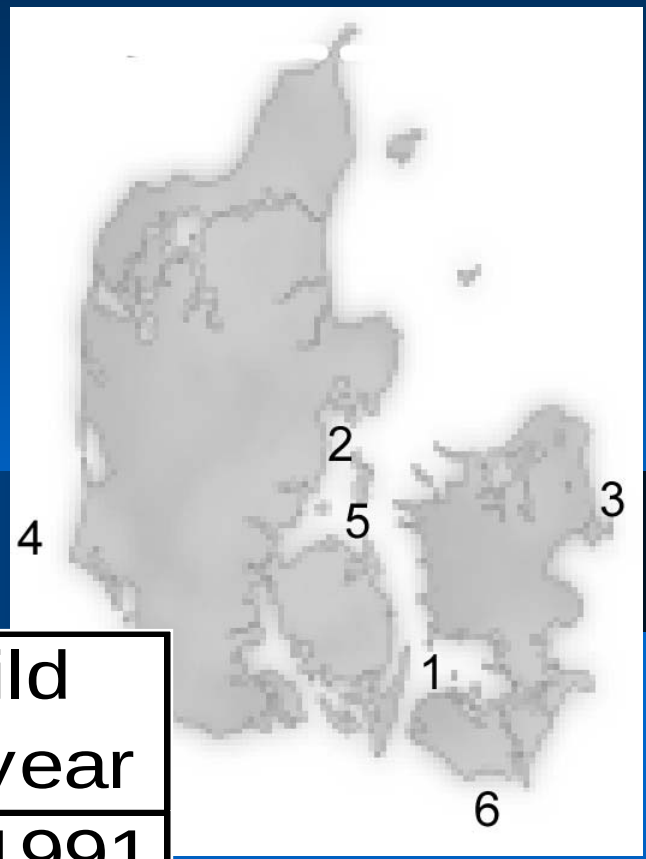
Joint ownership installation



Ownership for windturbines in Denmark



Offshore windfarms in Denmark 2005



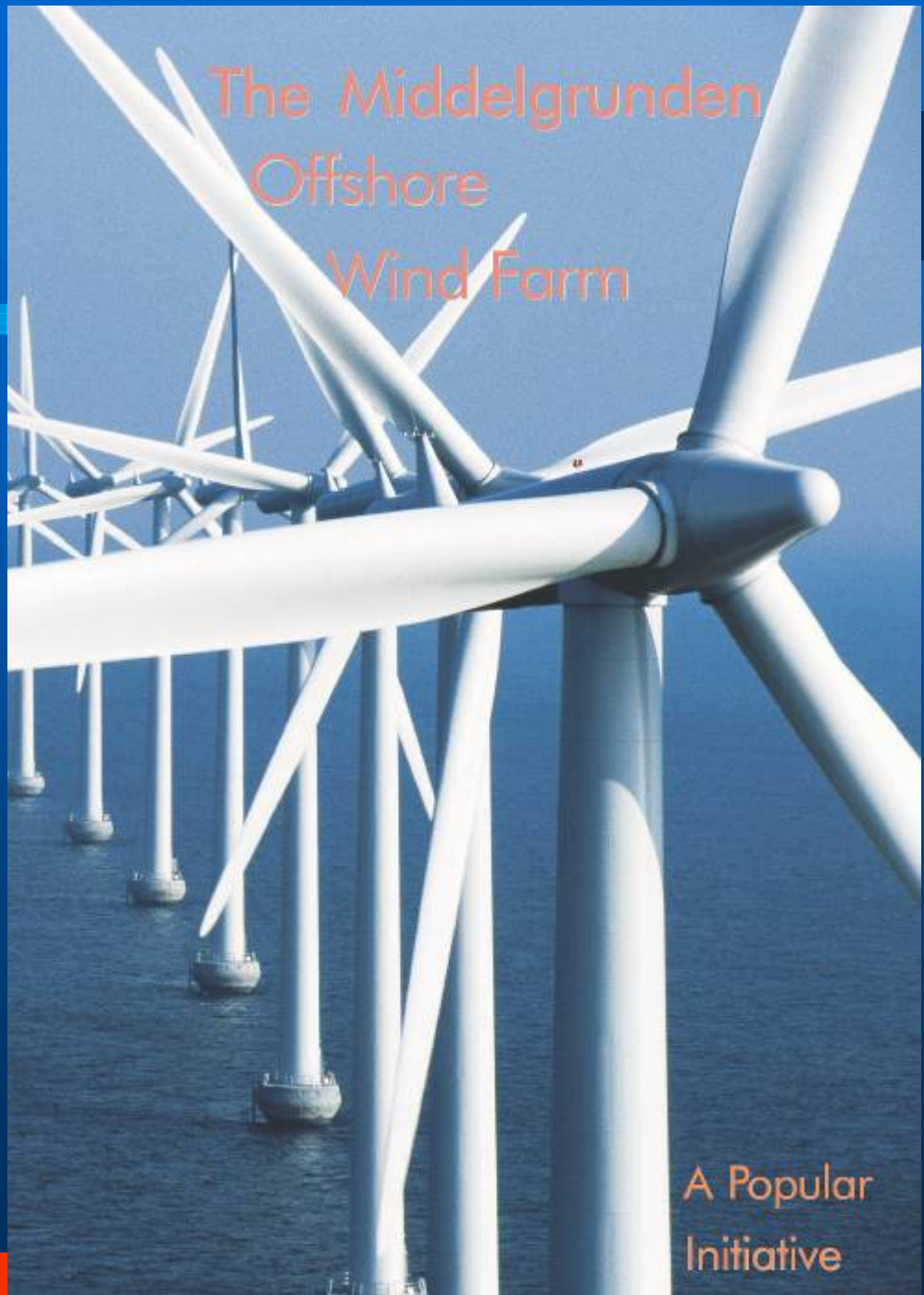
Location	Power	Build in year
1. Vindeby	5 MW	1991
2. Tunø Knob	5 MW	1995
3. Middelgrund	40 MW	2001
4. Horns Rev	160 MW	2002
5. Samsø	22 MW	2002
6. Rødsand	160 MW	2003

Middelgrunden Offshore Wind Farm

Number of turbines	20 x 2 MW
Installed Power	40 MW
Hub height	64 metres
Rotor diameter	76 metres
Total height	102 metres
Foundation depth	4 to 8 metres
Foundation weight (dry)	1,800 tonnes
Wind speed at 50-m height	7.2 m/s
Expected production	100 GWh/y
Production 2002 (wind 97% of normal)	100 GWh
Park efficiency	93%
Construction year	2000
Investment	48 mill. EUR

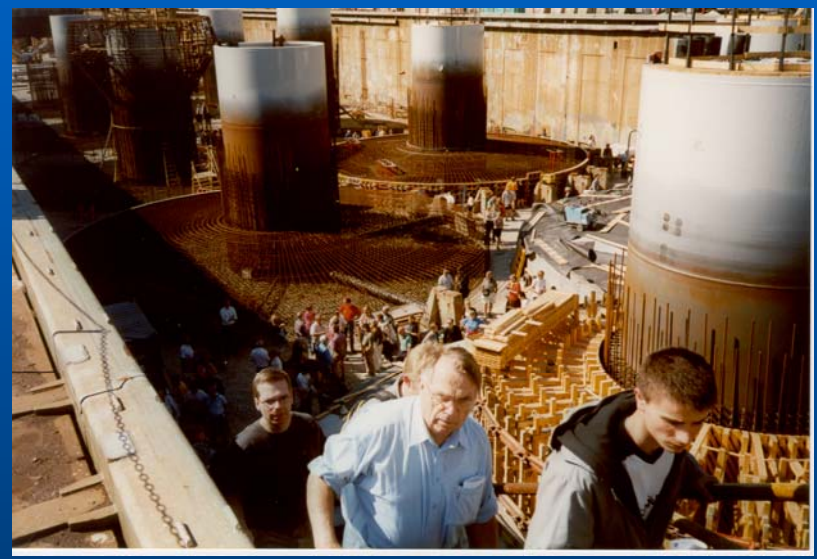
Kastrup Airport

A beautiful view


The Middelgrunden
Offshore
Wind Farm
A Popular
Initiative

Wind turbine Co-operative

- **Big scale wind energy for the city**
- **Local placement**
- **Local dialog**
- **Local ownership**
- **Involve of people in process**
- **Example of Agenda 21 and cityecology**

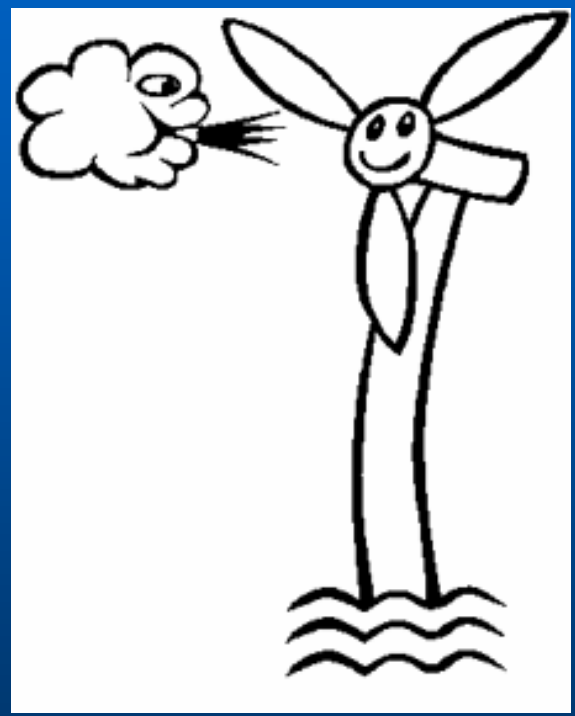


History of cooperatives

- N.F.S. Grundtvig, 1783
- Theologian, author and poet
- Everyone can and must make a difference
- Change his conditions of life
- Country high schools
- Farmers education
- DK agriculture and industry organzed by coops

Wind turbine Co-operative

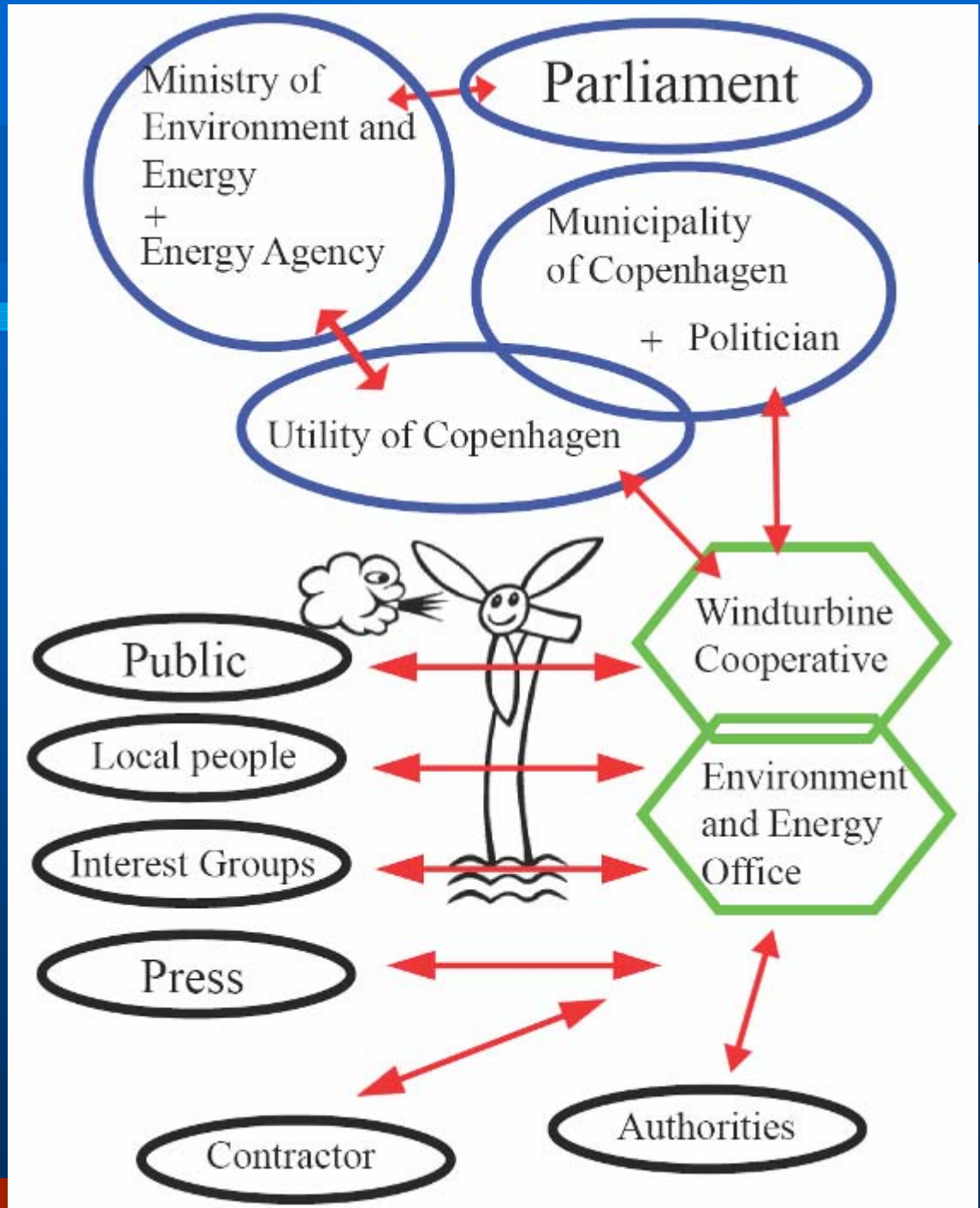
- **8527 members private, organizations, companies**
- **40,500 shares**



Involvement of 8500 people

500 members visited their turbine on open-house day in June 2005

Proces


Ministry of Environment and Energy + Energy Agency
Parliament
Municipality of Copenhagen + Politician
Utility of Copenhagen
Windturbine Cooperative
Environment and Energy Office
Public
Local people
Interest Groups
Press
Contractor
Authorities

Debate

SPRINGFORBI-PLANEN

Medaljens bagside

Aase D. Madsen (DF), MF
mdl. af miljøudvalget

I over et år har jeg gennem utallige skriftlige spørgsmål til miljø-og energiminister Svend Auken forsøgt at få ham til at standse "Springforbi-planens" nedrivning af strandvejspalæerne. Det er derfor med stor tilfredshed, jeg kan konstatere, at ministeren nu finder det uklogt at rive husene ned nu.

Han priser nu landskabsværdierne : "Med Springforbi-planen har Københavnerne fået et stort sammenhængende landskab med skov og vand placeret i den smukkest tænkelige sammenhæng med Øresund på den ene side og Dyrehaven på den anden side".

Hvorfor nævner han ikke samtidig, at han har givet tilladelse til at opsætte det flere kilometer lange vindmøllestakit på Middelgrunden, som totalt ødelægger de kystnære landskabelige værdier ved Springforbi-planen?

Jeg kan da godt forstå, at han har et stærkt behov for at være populær for tiden, men jeg tror, at det er gået op for befolkningen, at den socialdemokratiske medalje altid har en bagside.

JP 28/1 - 2000
Vi kan jo svare?!
Hvem gider
HES

VINDMØLLEPARK

Miljøet set fra Springforbi

Verdens største havvindmøllepark. Fra Springforbi er der cirka 11 km til Middelgrundens Vindmøllepark, og kun når man befinder sig tæt på kysten, vil det være muligt at se møllerne. Kan De få øje på dem? *Fotovisualisering: Møller & Grønborg*

Projektleder for Middelgrundens Vindmøllelaug
Jens H. Larsen

Politikere i Lyngby-Tårbæk kritiserede også møllernes placering. Det ændrede dog ikke den samlede miljøvurdering, som viser, at møllernes miljøfordele er langt større end deres konsekvenser for landskabet. Vindmøllerne ligger godt 11 km fra Springforbi, og arkitekterne Møller & Grønborg har

horisonten vil således være ugeneret.

Hos kritikerne savner jeg en erkendelse af, at dagens energiforbrug forurener, og vindmøller er et af de få realistiske alternativer, der kan afhjælpe problemet.

Derfor er det skuffende, når politikerne går efter den laveste fællesnævner og kun tænker på egen

I stedet kunne politikerne se perspektiverne i, at verdens største havmøllepark bygges lige uden for København, og at der faktisk er gjort en stor indsats for at indpasse mølleparken i landskabet. Det har Svend Auken noteret sig, da han forleden udtalte: »Middelgrunden bliver et flot udstillings-

Debate – before

Fax 3326 5301
ktion@ing.dk
Fredag den 19.11.99
Nr. 46

Vindmøller

Vindmøller på Middelgrunden er økonomisk vanvid

Af Peter Schoubye
Civilingeniør, Hørsholm

overskud af strøm som bipro- Strømmen fra de kommu- merudgifterne ved at placere

Jeg har ikke hørt en en
fornuftig begrundelse f
skamfere Københavns

Vindmøller

God økonomi på Middelgrunden

Af Jens H. Larsen
Projektleder for Middelgrundens Vindmøllelaug

Produktionsprisen for Middelgrundens Vindmøllepark er beregnet til 37 øre/kWh (20 års levetid og 5 pct. i realkalkulationsrente). Til sammenligning har elværkerne estimeret omkostninger på 35-38 øre/kWh for de kommende års

absolut billigste ende – også når man sammenligner med hidtidige danske vindmølleprojekter. Hertil kommer det teknologiske udviklingsperspektiv og nødvendigheden af, at møllefabrikanterne overhovedet kan få lov til at opstille de store møller i Danmark.

Danmark er blevet en førende vindkraftnation, fordi vi har gjort erfaringerne for de andre lande. De

den traditionelle forurenende elproduktion. P. Schoubye kender i hvert fald merprisen på røgrensningsanlæg. ■

Before

Nov. 1999

DEBAT

VINDMØLLER

Vindvanvid

Lene Kaspersen,
formand for byplanudvalget
i Lyngby-Taarbæk Kommune,
medlem af Københavns Amtsråd

Lene Kaspersen kalde
planlagte havvindmø
på Middelgrunden fo
skæmmende forsøg.
Arkivfoto.

VINDMØLLEPARK

Park uønsket

Suzi Kjær
Strandvejen 178
2920 Charlottenlund

til den tid fjerne vind-
møllerne igen. Så vidt jeg
ved, er det måske smartest

KRAFTVÆRKER

JP 3/11-1999

Udskyd overflødige energi-projekter

Aase D. Madsen (DF)
MF - næstformand i energiudvalget

Københavns Belysnings-
væsen er en noget ubeha-
gelig "sidegevinst" i forbin-
delse med elreformens libe-
ralisering af elmarkedet.
Flere politikere udtaler
sig da også bekymret om el-
prisstigningen, og forman-
den for Folketingets Ener-
giudvalg, Martin Glerup
(S), mener, at man skal for-

mål siger ja til det tota
overflødige vindmølle
jekt på Middelgrunden
fordyrer strømmen me
millioner kroner om å
hovedstadsområdet. Sa
dig med at kraftværke
nærmer sig fallittens r
og ikke kan konkurrer
grund af, at de gennem
litiske pålæg skal inve

DEBAT

JP-KBH
12/11-99

UDSIGT

Vindmølle-skandale på vej i Øresund

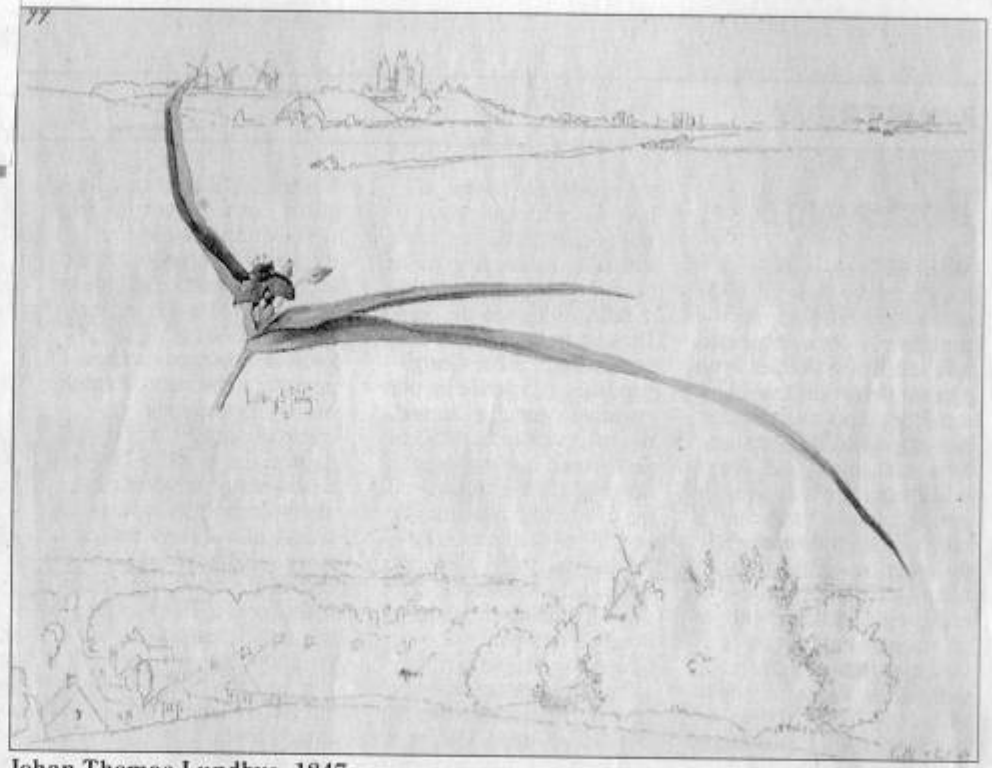
Erik K. Abrahamsen
Refsnæsgade 67, 2. tv
2200 København N

Engang lå Københavns
Red frit direkte ud til Øre-
sund. Frihavnen, Nordhav-
nen og Refshalegen har luk

weekendavisen
13. – 19. november 1998 Kulturredaktør: POUL ERIK TØJNER

Kommentar. Danmarks Naturfredningsforening og Foreningen til Hovedstadens Forskønnelse har sagt nej til vindmøller på Middelgrunden. Er vi virkelig så angste for vor egen tids tekniske anlæg?

Nutidsangst



Johan Thomas Lundbye, 1847.

Af STEEN ESTVAD PETERSEN

lig som et kristent mindes-

Debate

Debate

Green landmark for Copenhagen

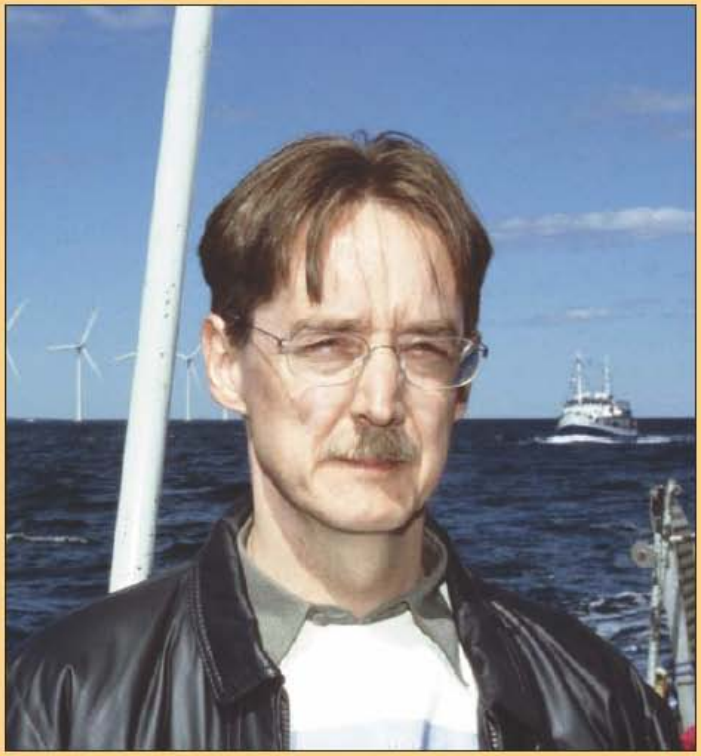
- **Said by the: Danish Minister of Environment, Conni Hedegaard, member of danish Conservatives**

"I bathe all year at Helgoland and enjoy the view of the turbines. It gives positive energy."
Marianne Iversen.

Helgoland is a public bath at Amager Beach. The distance to the nearest turbine at Middelgrunden is 2 km.

"Whenever the wind turbines at Middelgrunden are running, I know the wind outside Skovshoved Marina is perfect for sailing and training with the team."

Jeppe Blak-Nielsen, yachtsman.



With the many involved and committed members the cooperative has fulfilled its most important aim: to show public involvement in environment projects of high calibre. In appreciation of the public involvement, the project has received several prizes, including The European Solar Prize and The Global Energy Award in 2000.

Erik Christiansen, chairman of the Cooperative

"In my opinion the success of this project can be explained especially by the constructive cooperation between the municipality, the municipal energy company and the private partnership. The cooperation ensured the local commitment and engaged local authorities and politicians."

Winnie Berndtson, Mayor of Environment, Copenhagen.

"As a fisherman I am not in favour of offshore wind turbines, but we have had to accept the wind farm on the Middelgrunden Shoal."

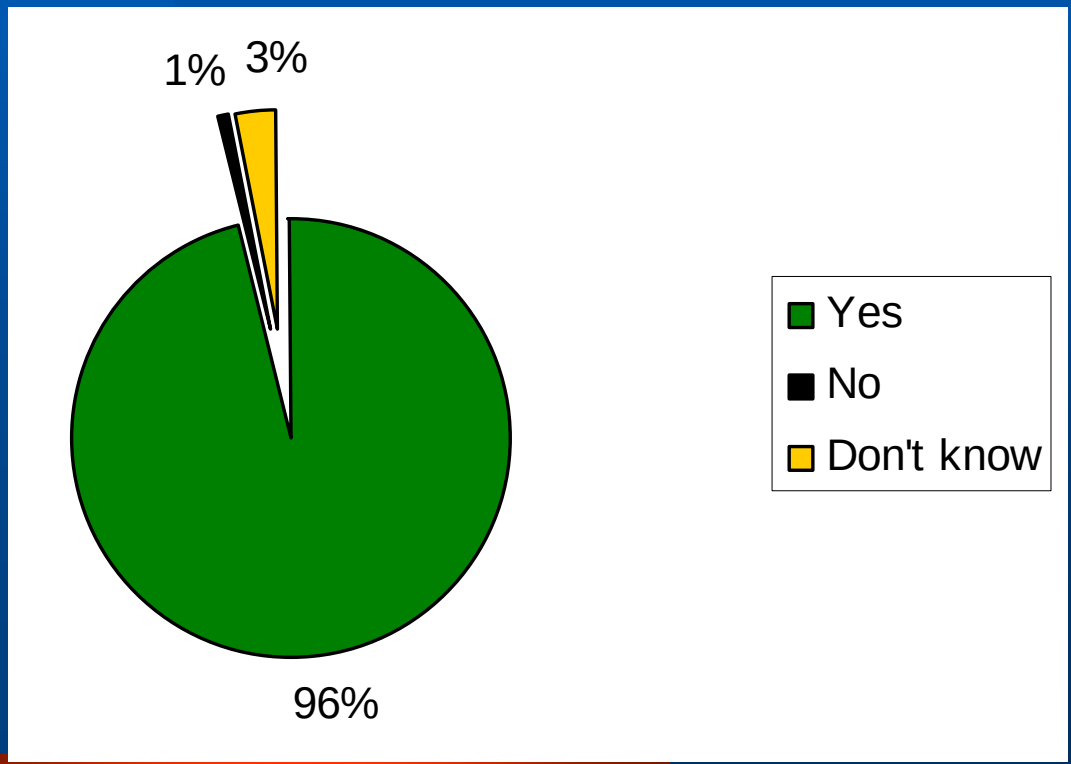
Torben Christensen
Østerbro Fishing Association

Danish opinions about windpower

- **70-85% of people in Denmark support more windpower in Denmark (from 1992-2006)**
- **People are pleased with existing turbines and the positive attitude is highest among those who can see the turbines every day.**
- **Positive attitude is also highest among those who can see the offshore turbines every day.**
- **Complaints from less than 2% of all turbines (mostly old noisy turbines, not allowed today)**

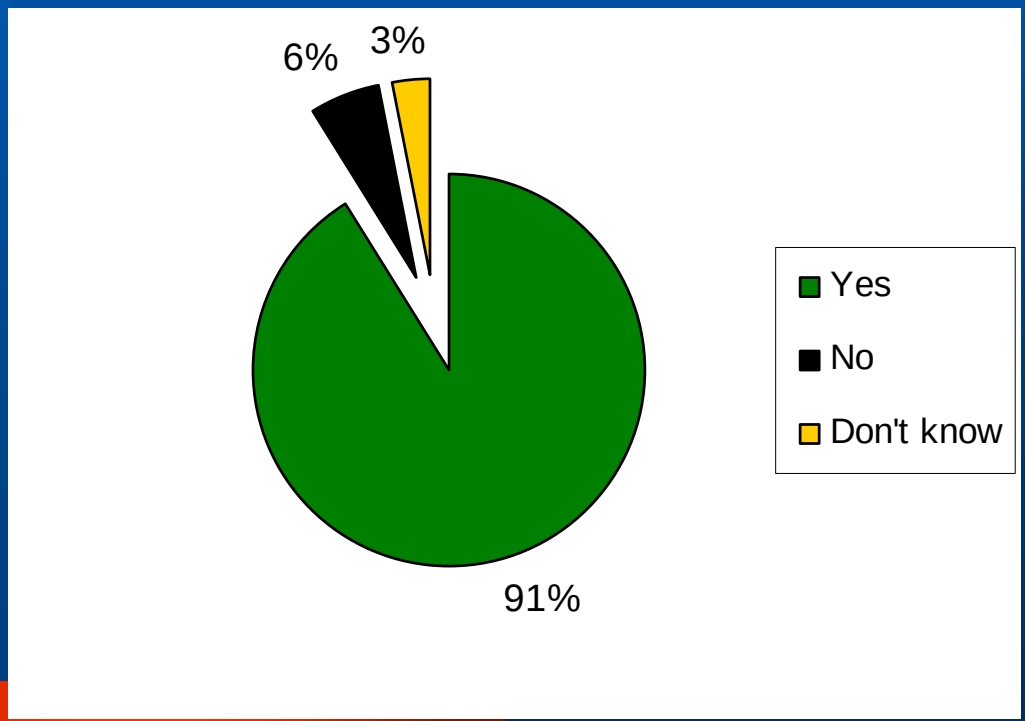
Danish opinion poll, ACN, 2006, Wild about wind

- **Are you favorable to wind power?**



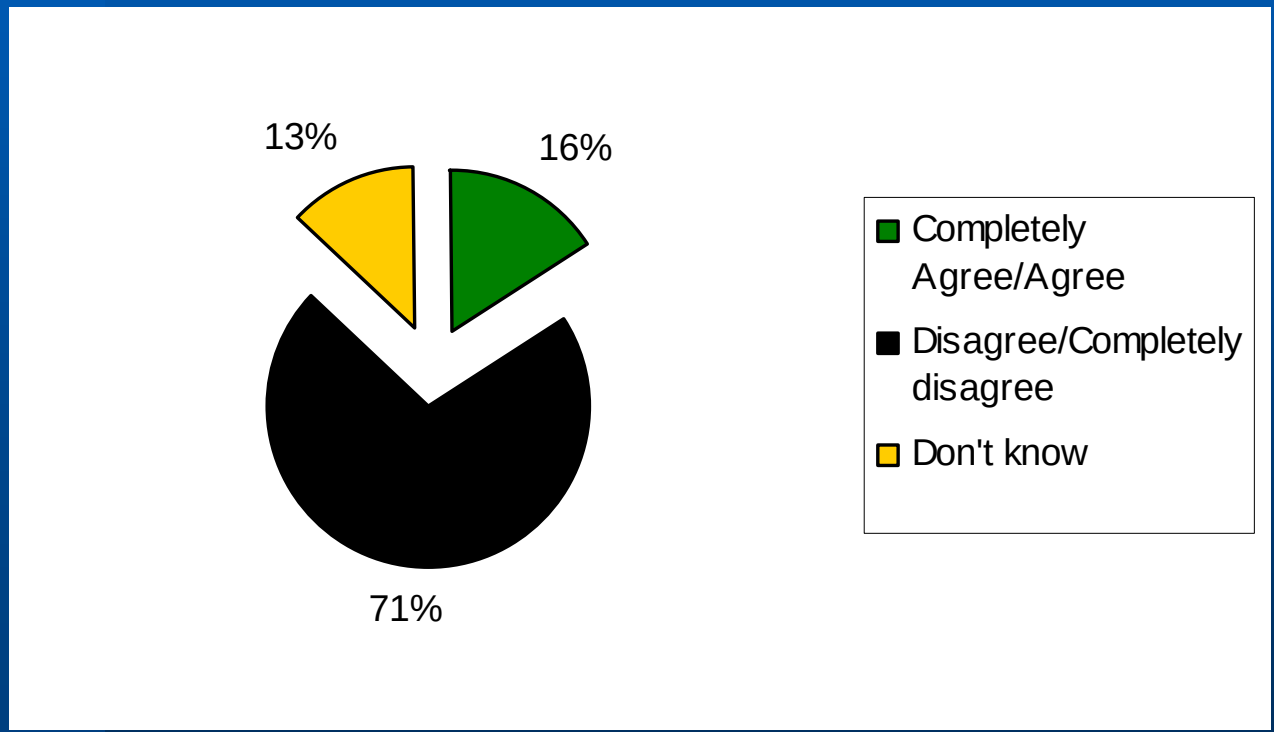
Danish opinion poll, ACN, 2006, Wild about wind

- **Should Denmark continuously erect new wind turbines, so that an increasing share of the electricity production is covered by wind power?**



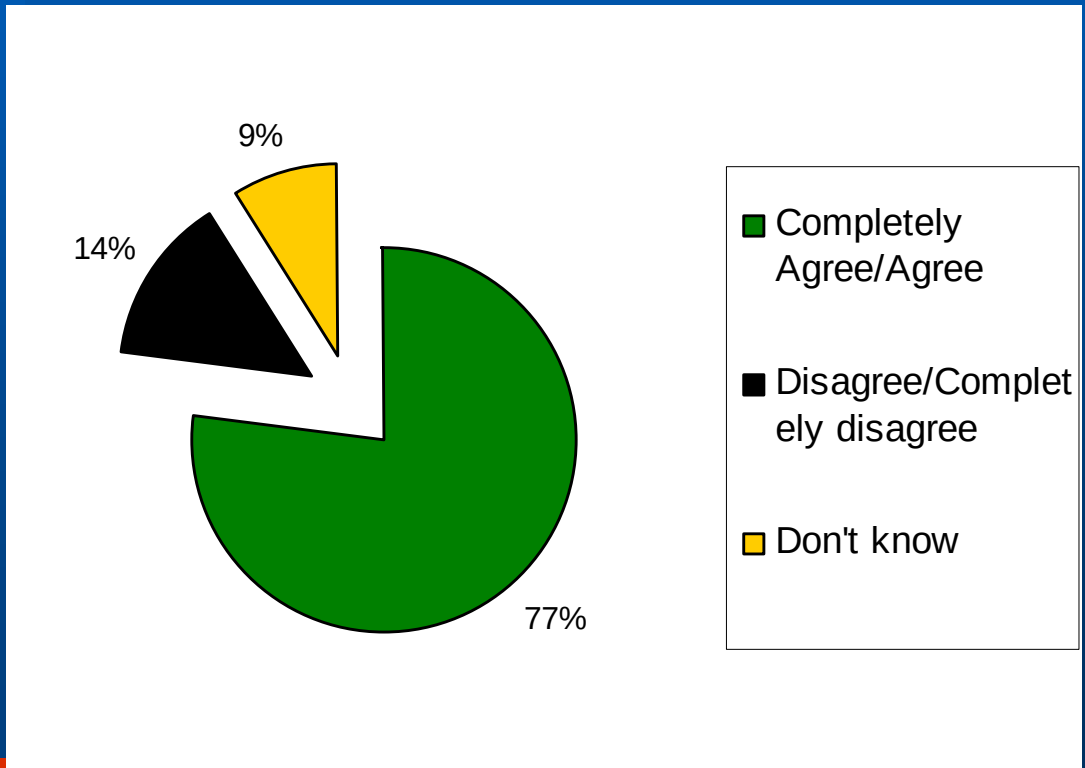
Danish opinion poll, ACN, 2006, Wild about wind

- **We should erect more wind turbines, but not in my local area ?**



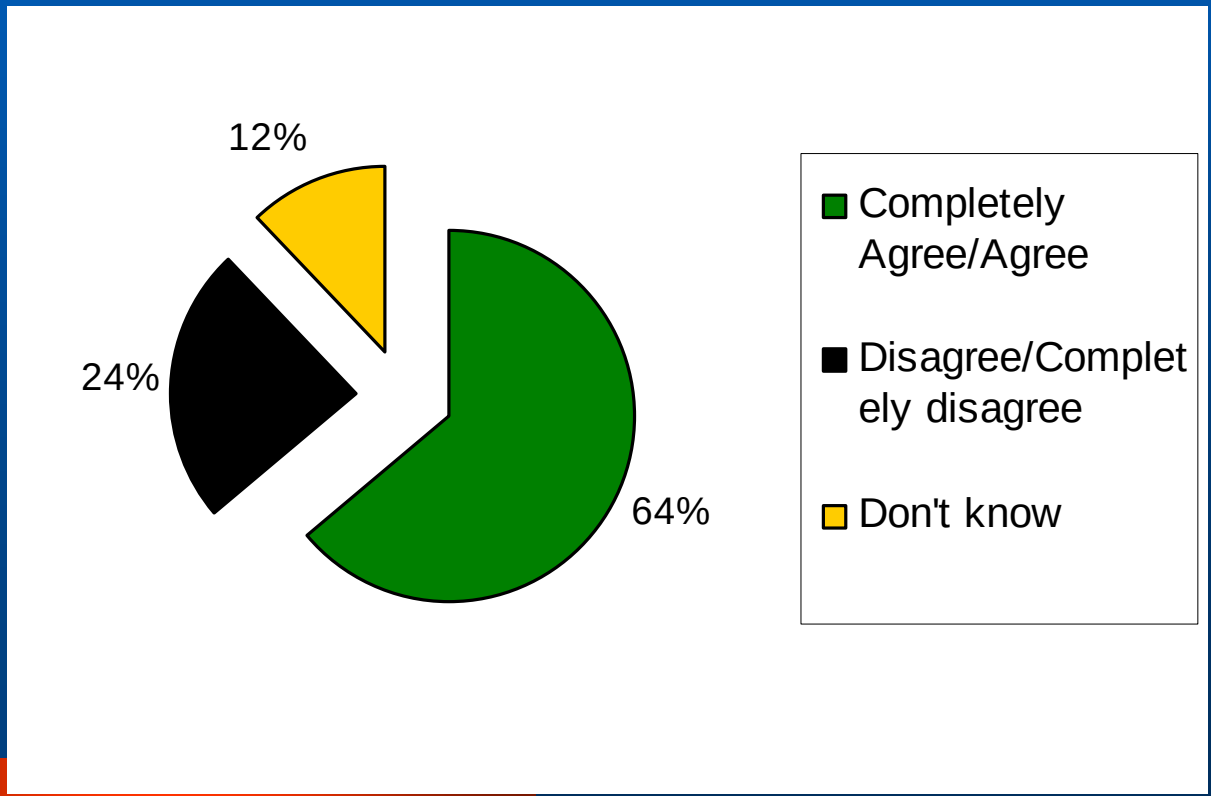
Danish opinion poll, ACN, 2006, Wild about wind

- **Wind turbines in the landscape is a positive symbol of Denmark?**



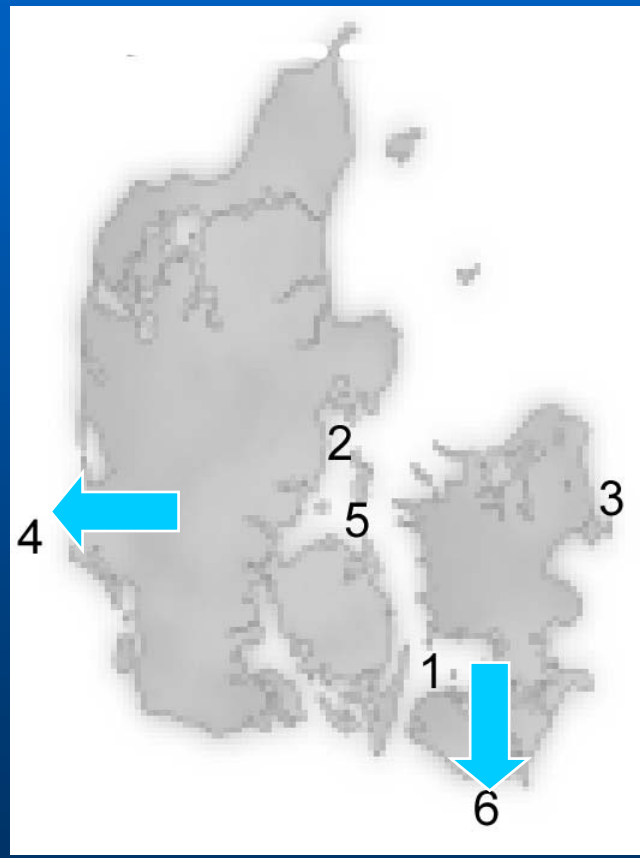
Danish opinion poll, ACN, 2006, Wild about wind

- **In general, wind turbines integrates well into the Danish landscape?**

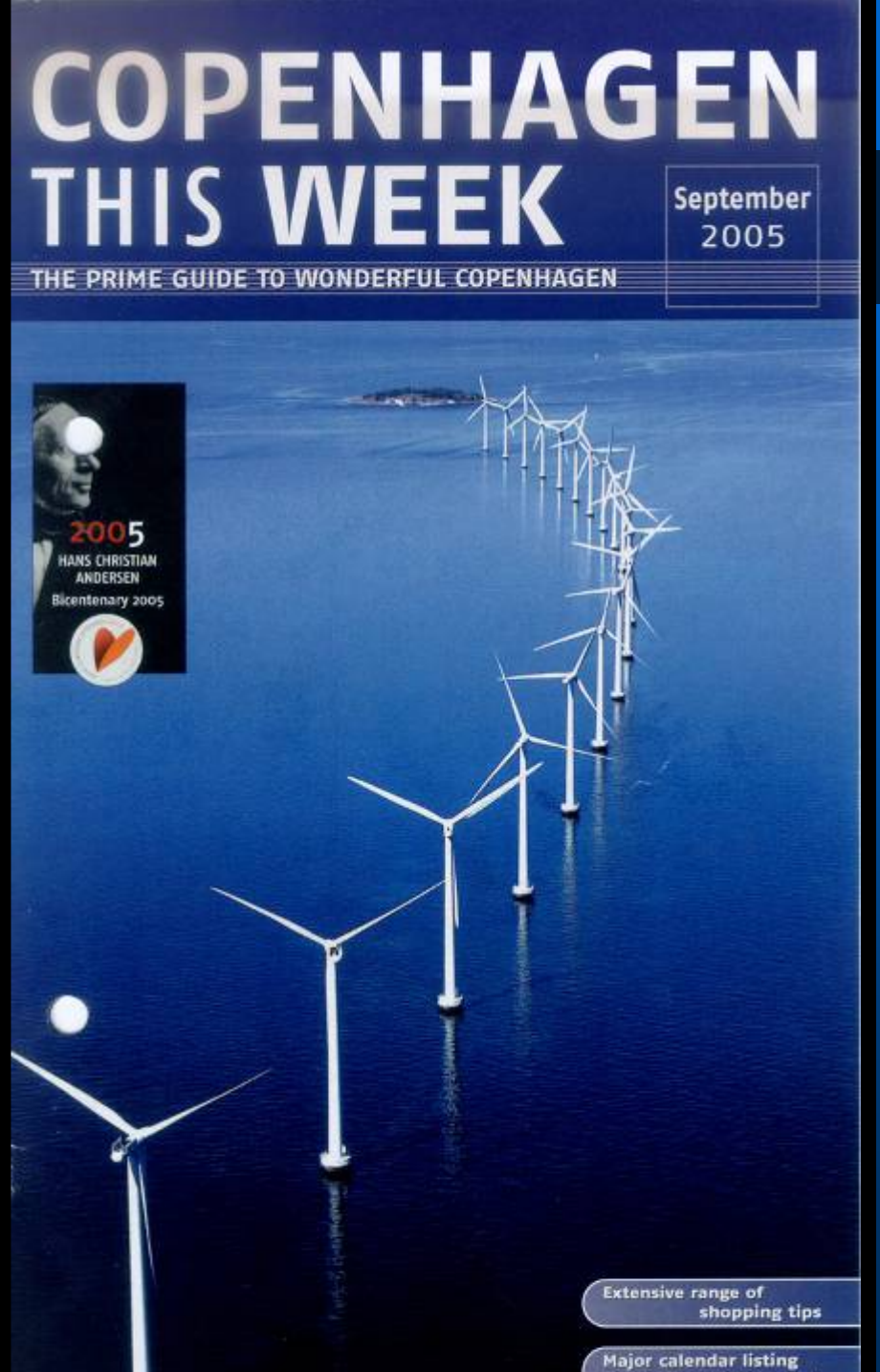


Offshore opinion poll 2006, 1400 persons

- People with direct views for turbines at Horns Reef and Nysted are more positive than people in general, and more positve towards extension of the farms
- Nysted, 9-10 km from coast, pay 1200 DDK to go 50 km from coast.
- People in general; 900 DDK to go 50 km from coast.
- Horns Rev, 14-20 km from coast, pay 600 DDK to go 50 km from coast.

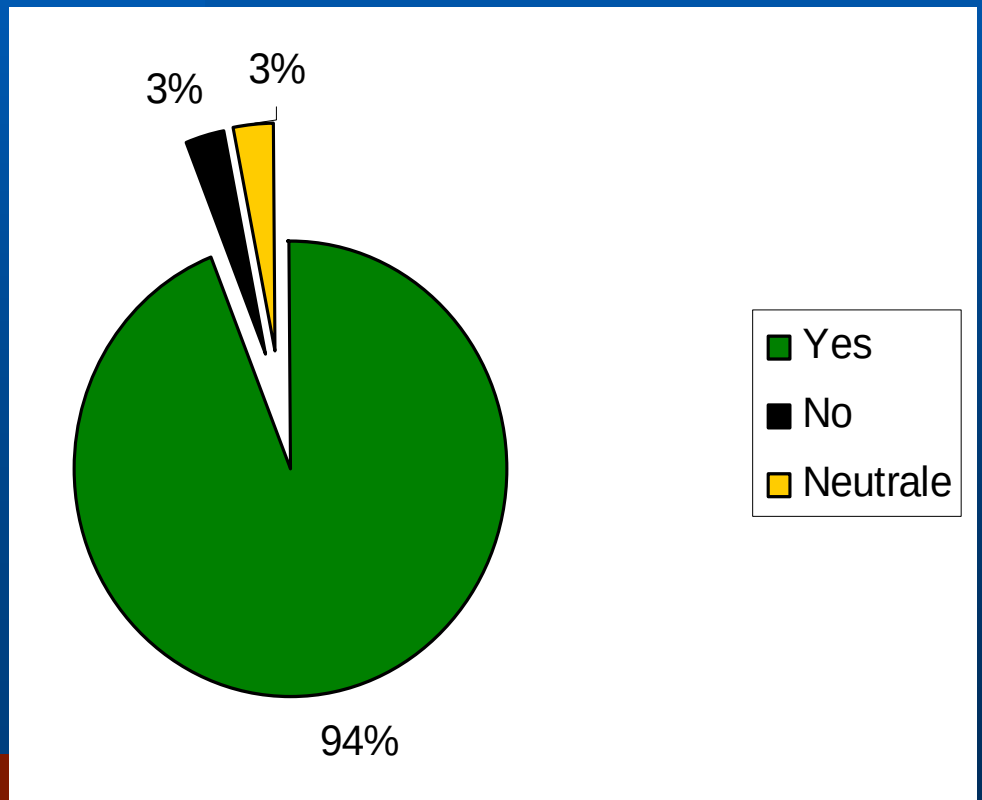


Tourist


COPENHAGEN
THIS WEEK
September
2005
THE PRIME GUIDE TO WONDERFUL COPENHAGEN
2005
HANS CHRISTIAN
ANDERSEN
Bicentenary 2005
Extensive range of
shopping tips
Major calendar listing

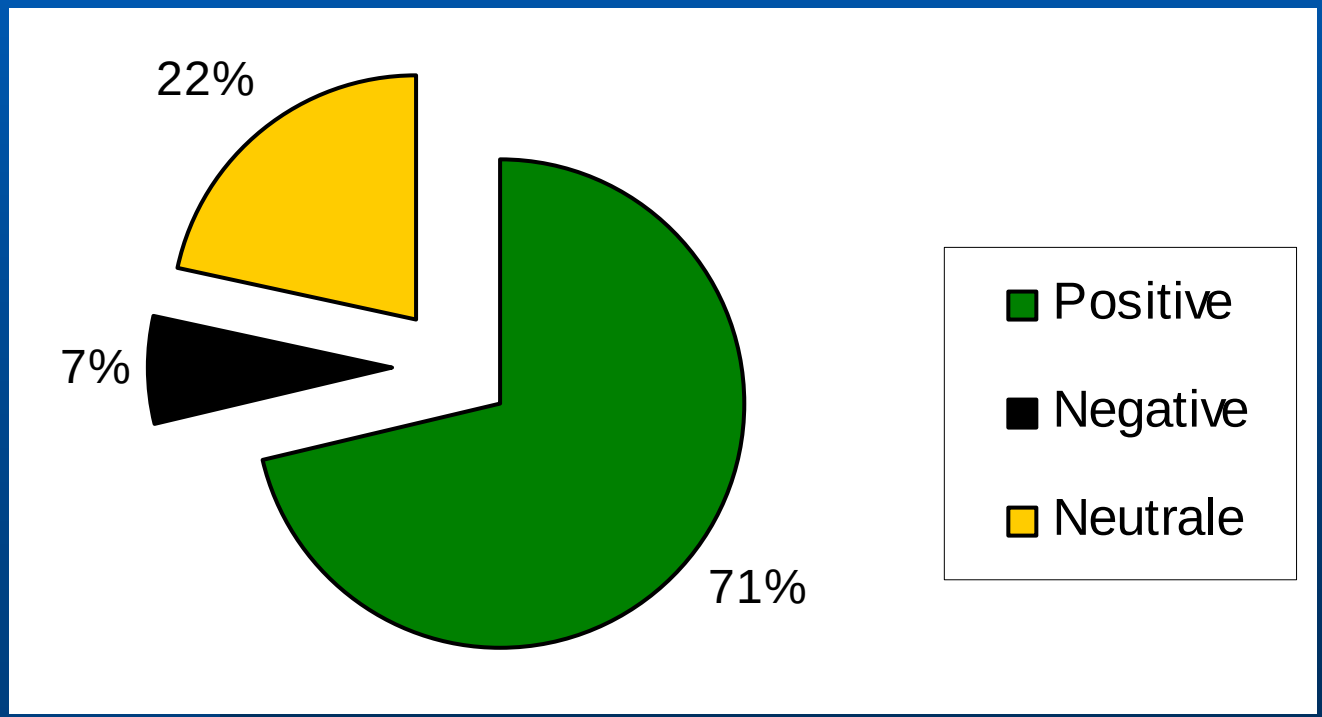
Tourist opinion poll about Middelgrunden, 2006

- **Are you favorable to wind power?**



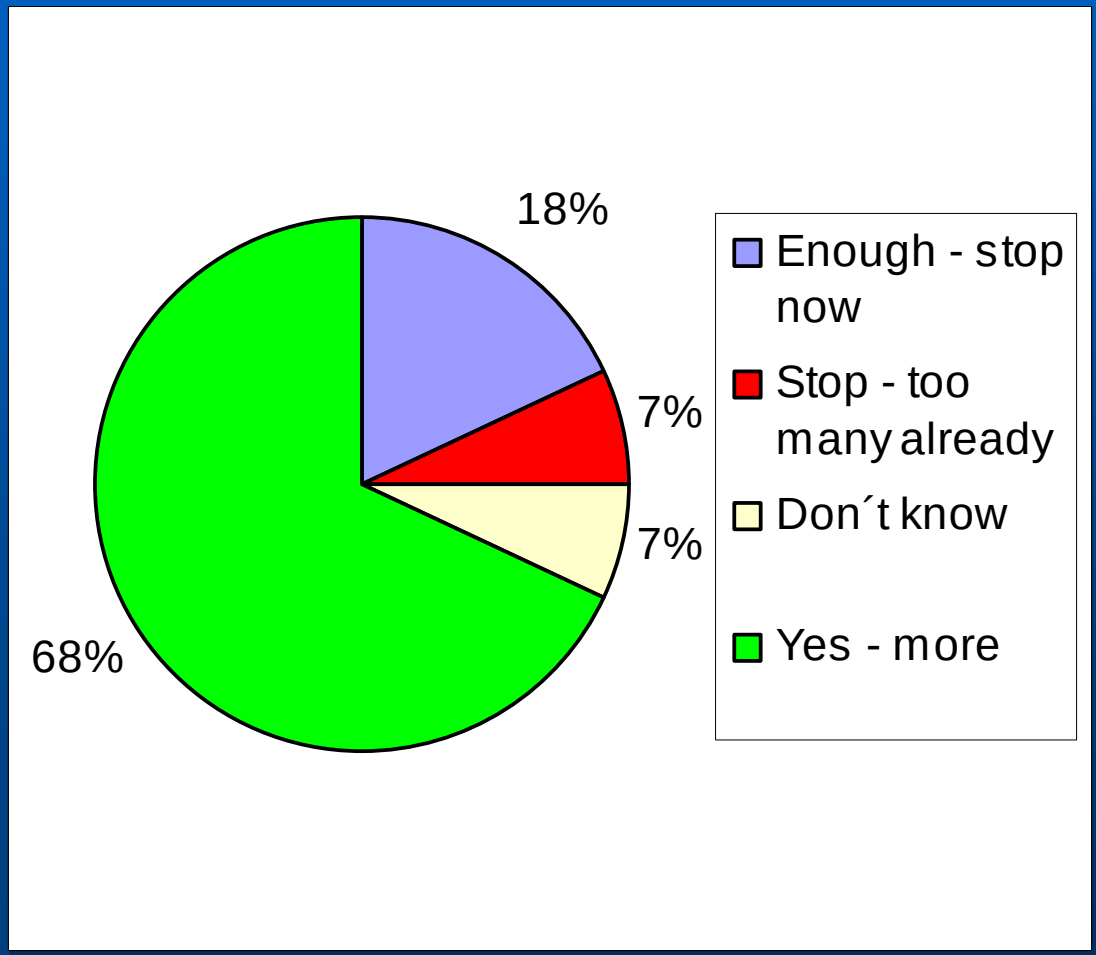
Tourist opinion poll about Middelgrunden, 2006

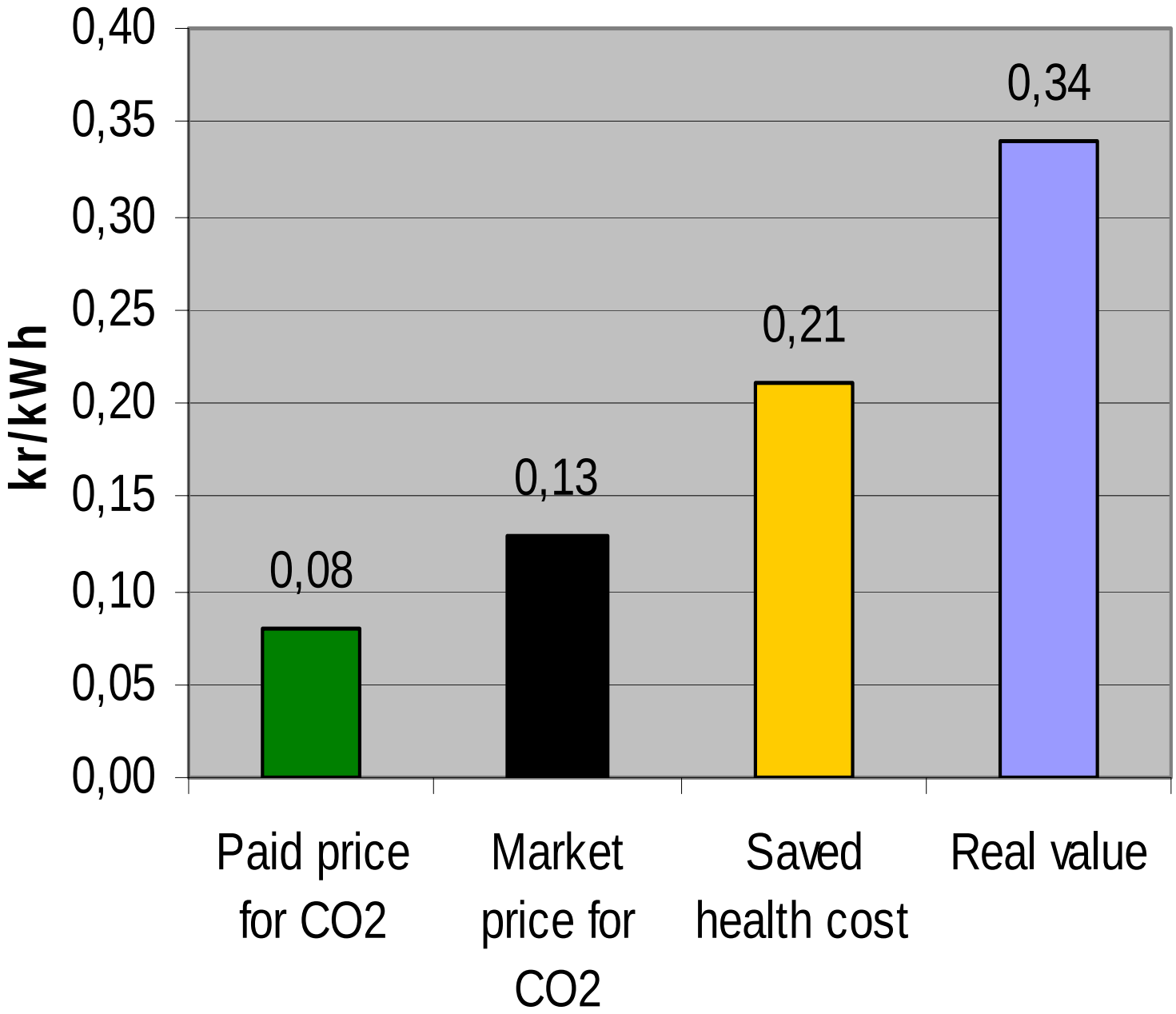
- **What is your impression of the turbines outside Copenhagen harbour?**



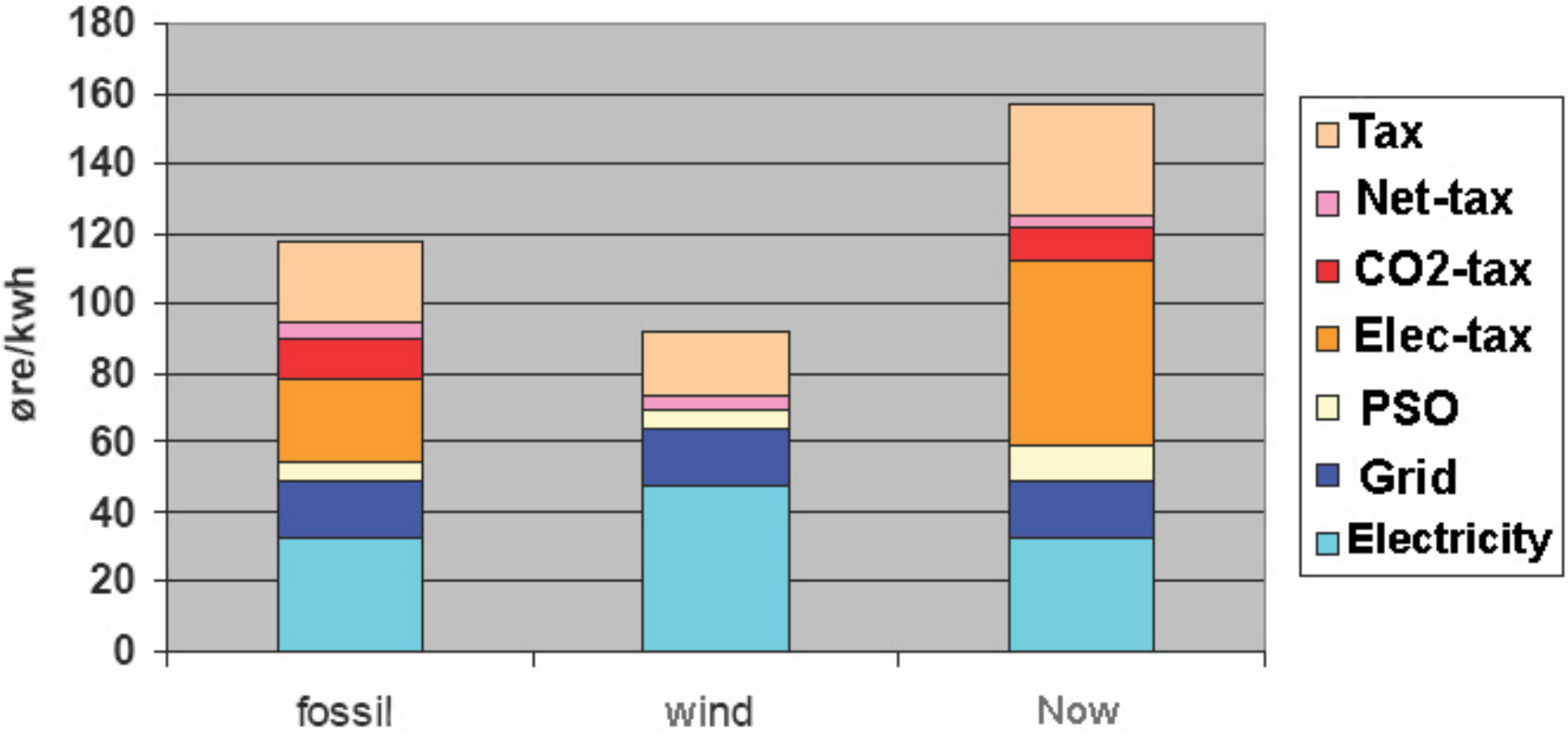
Danish opinion poll by Sonar, 2001

What do you think about wind power in Denmark ?





Source: Danish Environment Ministry, ExternE



Source: Prof. Mikael Skou Andersen
Danish Environment Institut

Environmental Impact Assesment EIA

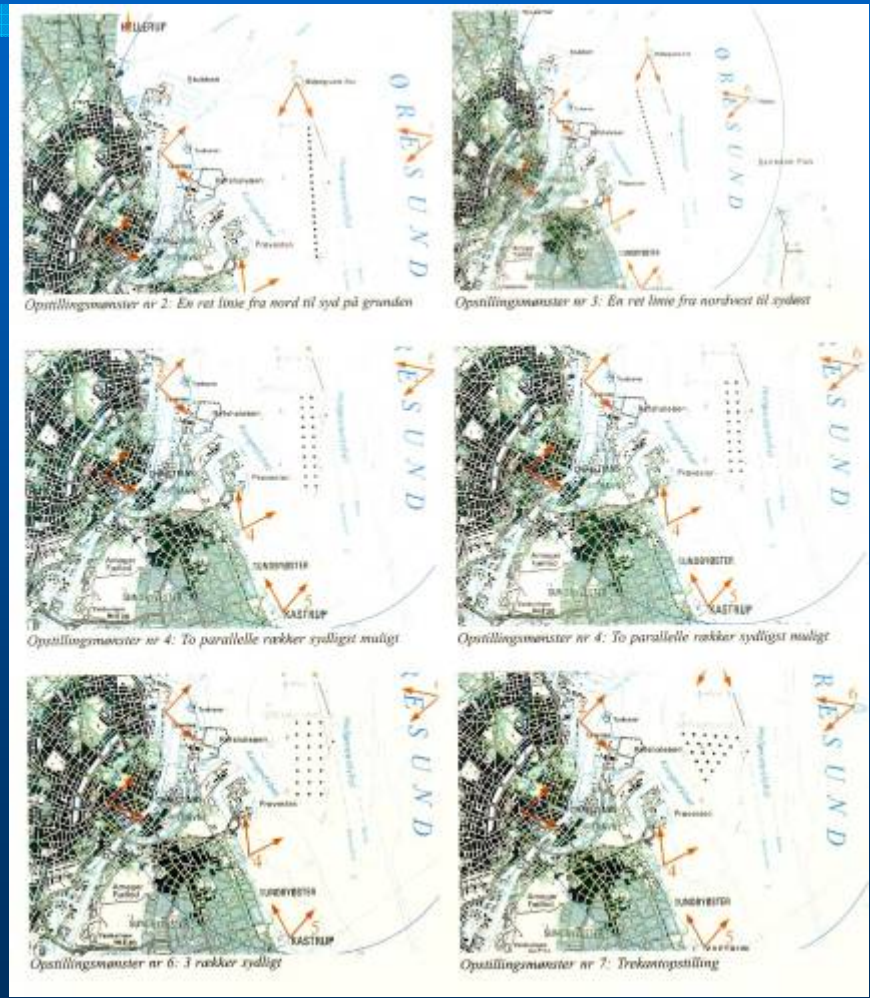
- **Visual impact**
- **Risk of leaking: debris and heavy metals contamination from the former dumpsite**
- **Noise propagation**
- **Influence on the free flow of water i Oresund**
- **Risk of collision with vessels**
- **Impact on flora and fauna**
- **Fishing**
- **Risk of shipwrecks and findings of archaeological interest**

Benefits for the Environment

- 89.000 MWh per. Year
- 3% of electricity in Copenhagen
- Gives clean air :
- 261 tons SO2
- 234 tons NO2
- 76500 tons CO2
- 4950 tons cinders and ash

Visual impact 1

- Several configurations were testet using computer image
- Visiual background for the Littel Mermaid
- Opposition to all configuations, except straight-line
- A straight-line type meant fewer turbines than could be supported bv the area

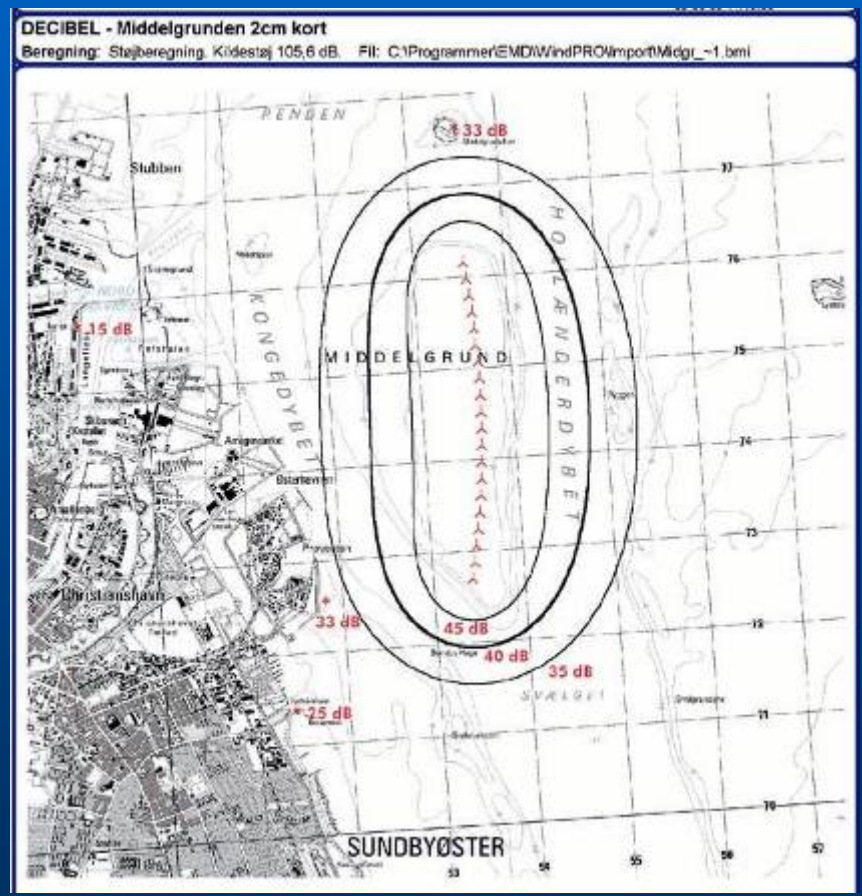


Visual impact 2

Visual impact 3

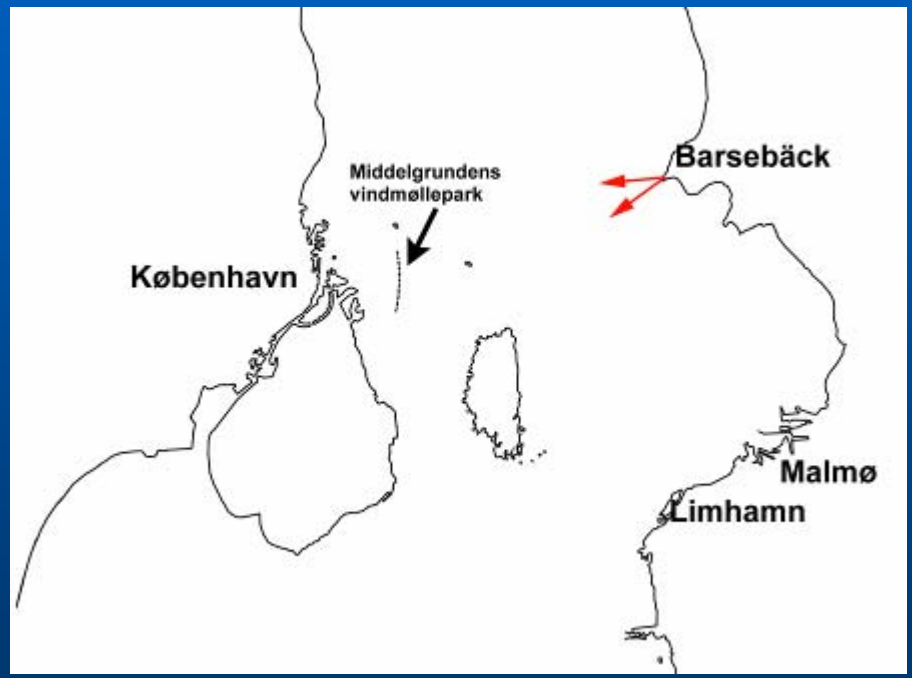
Noise propagation

- **Regulation: Noise levels below 40-45 dB at nearest neighbour**
- **Fact: You can´t hear after 500 m.**



Impact on the free flow of water i Oresund

- **The Baltic Sea is refreshed by water from the Danish straits**
- **Reduced flow by 0,0012%**
- **Compensation treament was not justified**

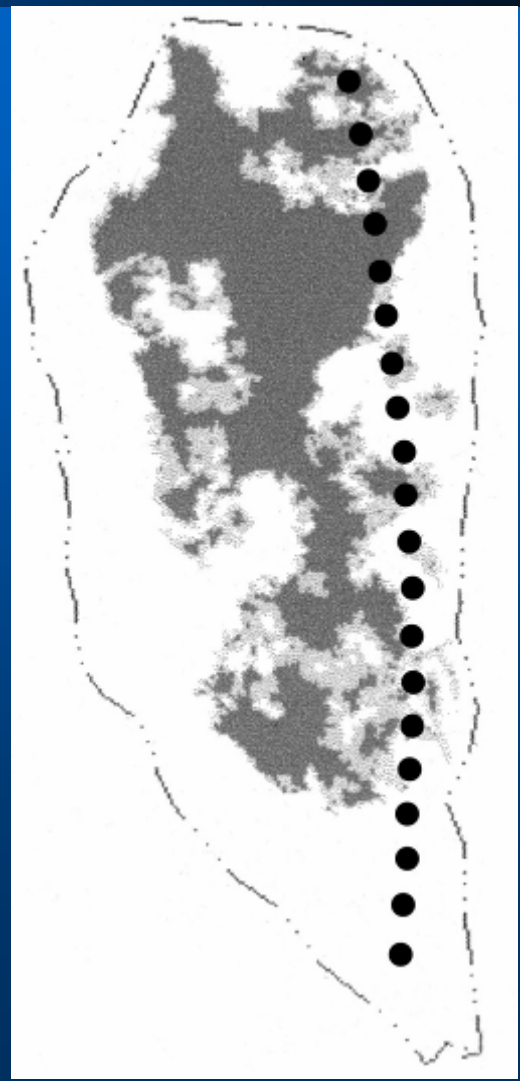


Risk of collision with vessels

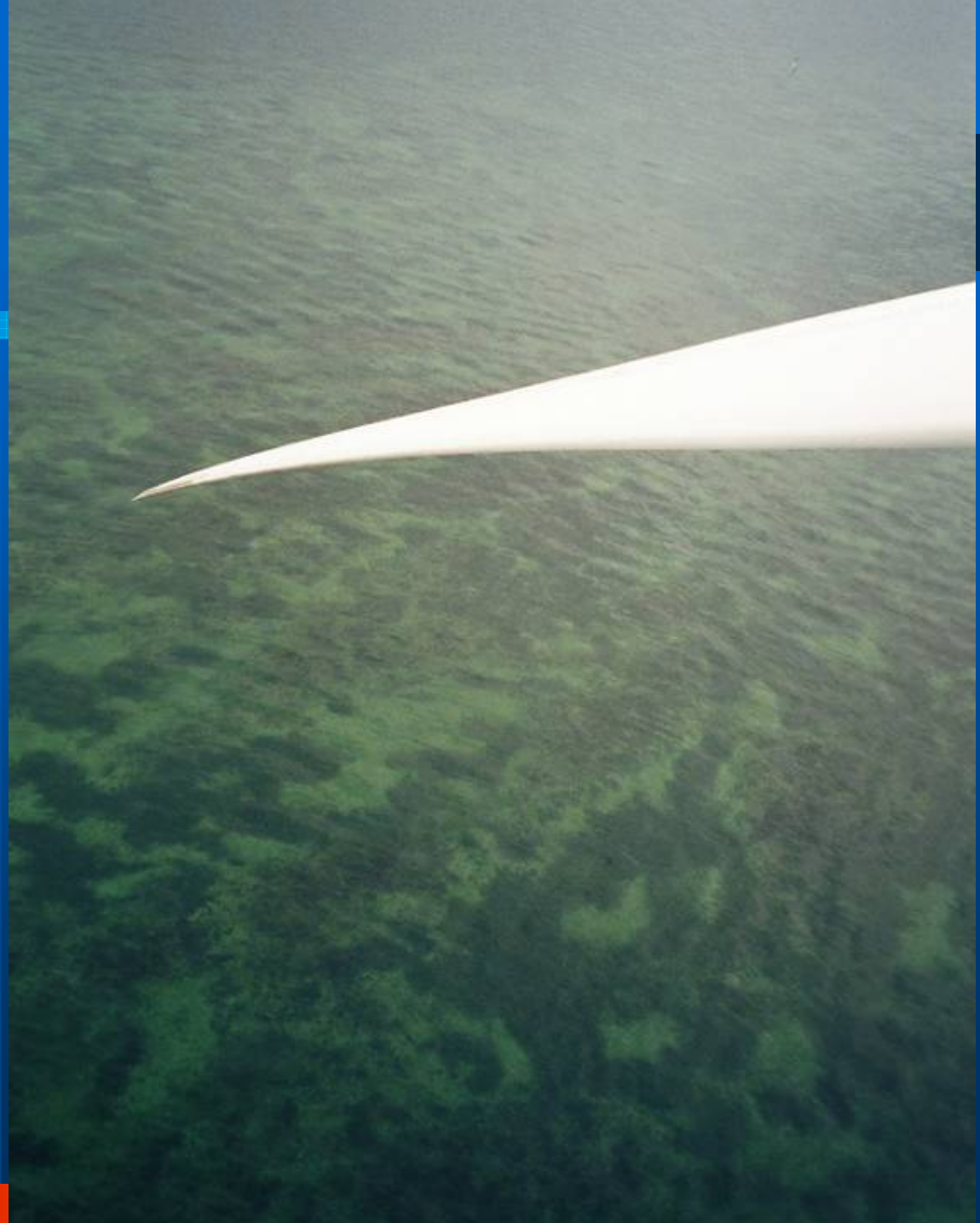
- **Result; Reduced risk of oil spill.**
- **Oresund is a busy seaways, 20.000 ships a year.**
- **Simulations have shown 8% risk of one collision to turbine pr. year.**
- **But reduced ground collison 120% to 40% a year because the low water will become visible**

Impact on flora and fauna

- No negative influence after 3 years
- Vegetation was to be controlled prior to construction, three months after, and on yeare after
- Tree months later the sea bed had more or less recovered, and the faundations were covered with seaweed
- Conclusion: The faundations served as minireefs



Fine recovery of eelgrass after the construction



Birds at Middelgrunden

- No effect on birds
- Or positive effect
- Birds often collide with high voltage lines, masts, poles, and windows in buildings. They are also killed by cars and shot.
- Birds are seldom bothered by wind turbines, however.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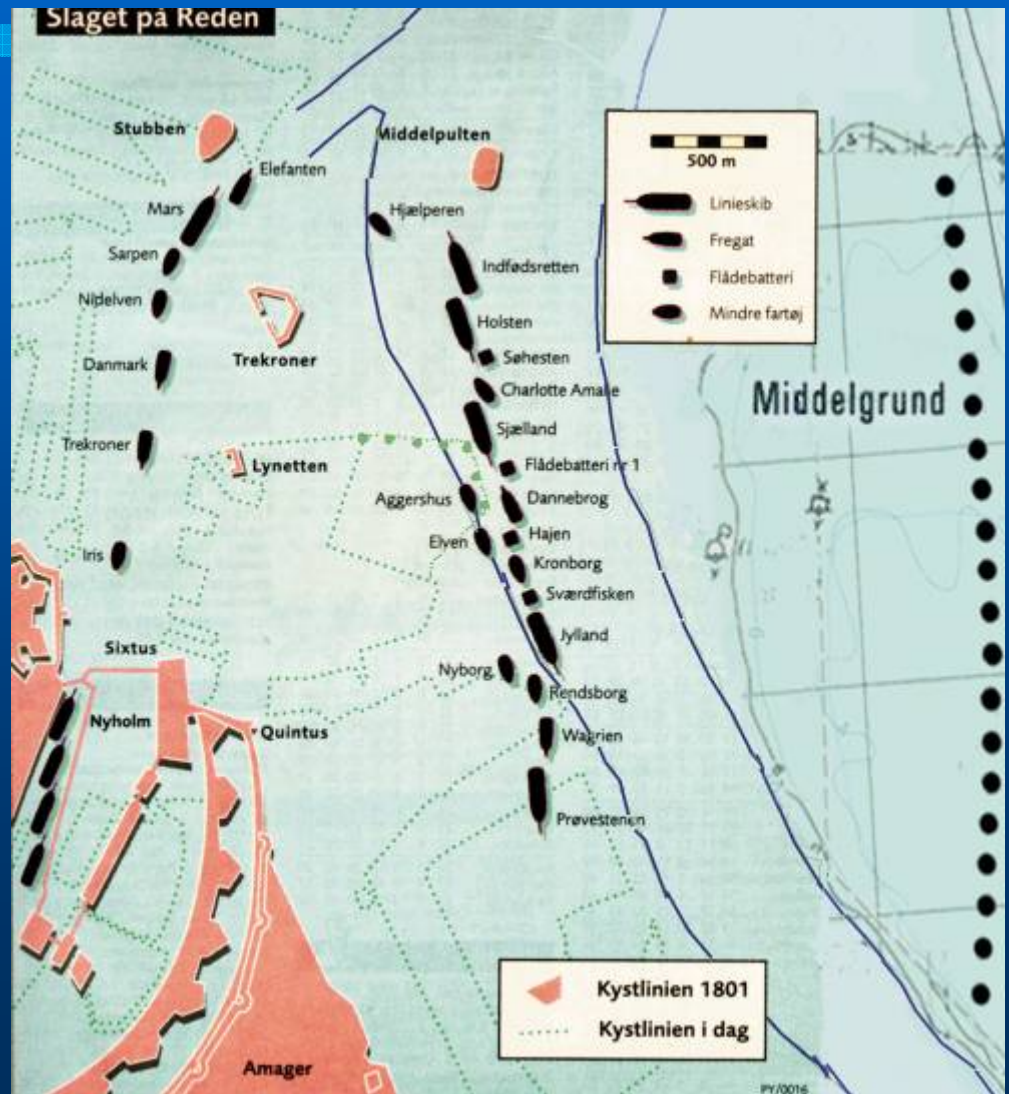
Fishing in the area

- Compensation for ”no fishing” during the construction
- Fishing allowed around the cabels
- Better fishing place becaus of the faundations ”minireefs”

Risk of shipwrecks

- Many shipwrecks in the area
- No archaeological sites was found
- Could have delayed the construchen with 1 year

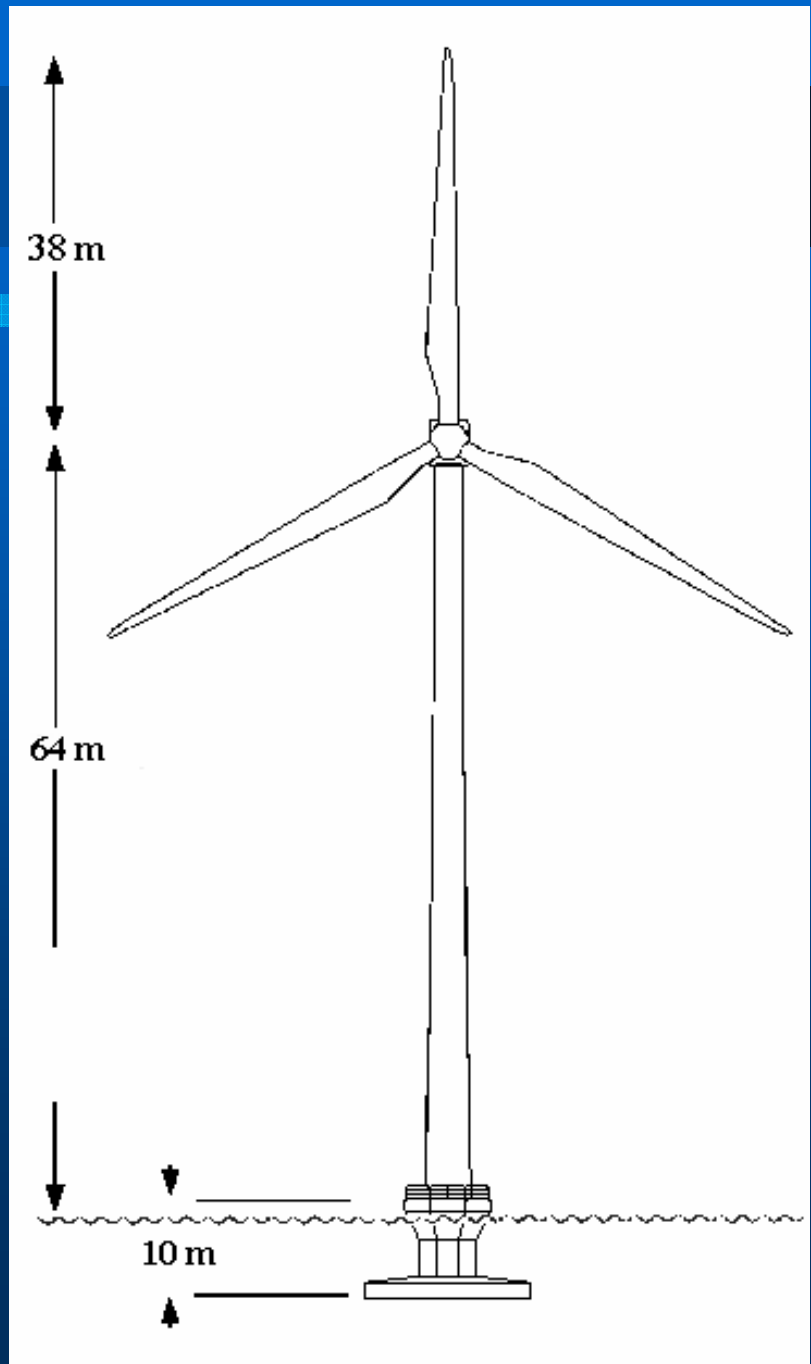


Shadow

- Distance to housing min. 500 m
- No problem at Middelgrunden

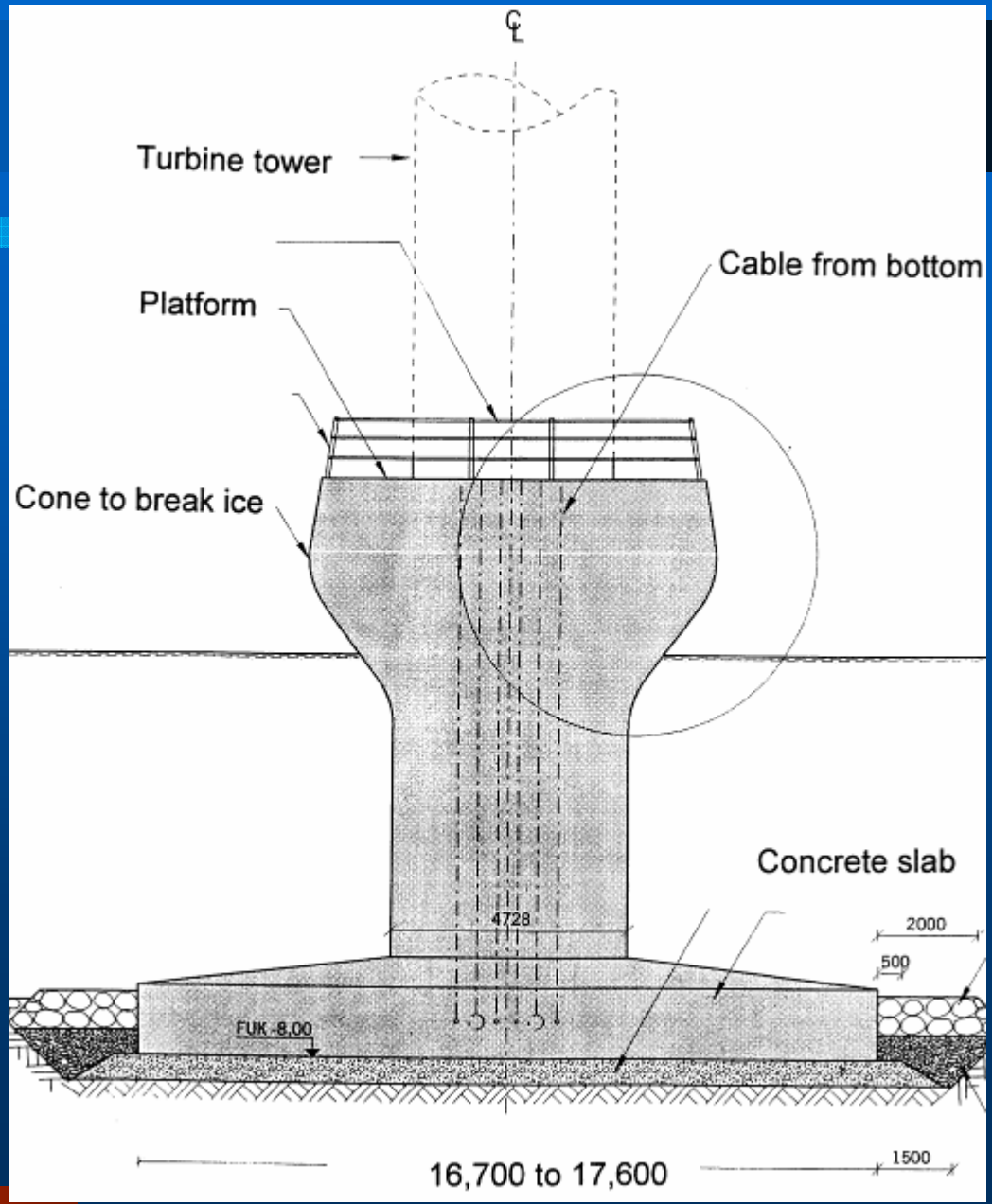
Bonus 2MW

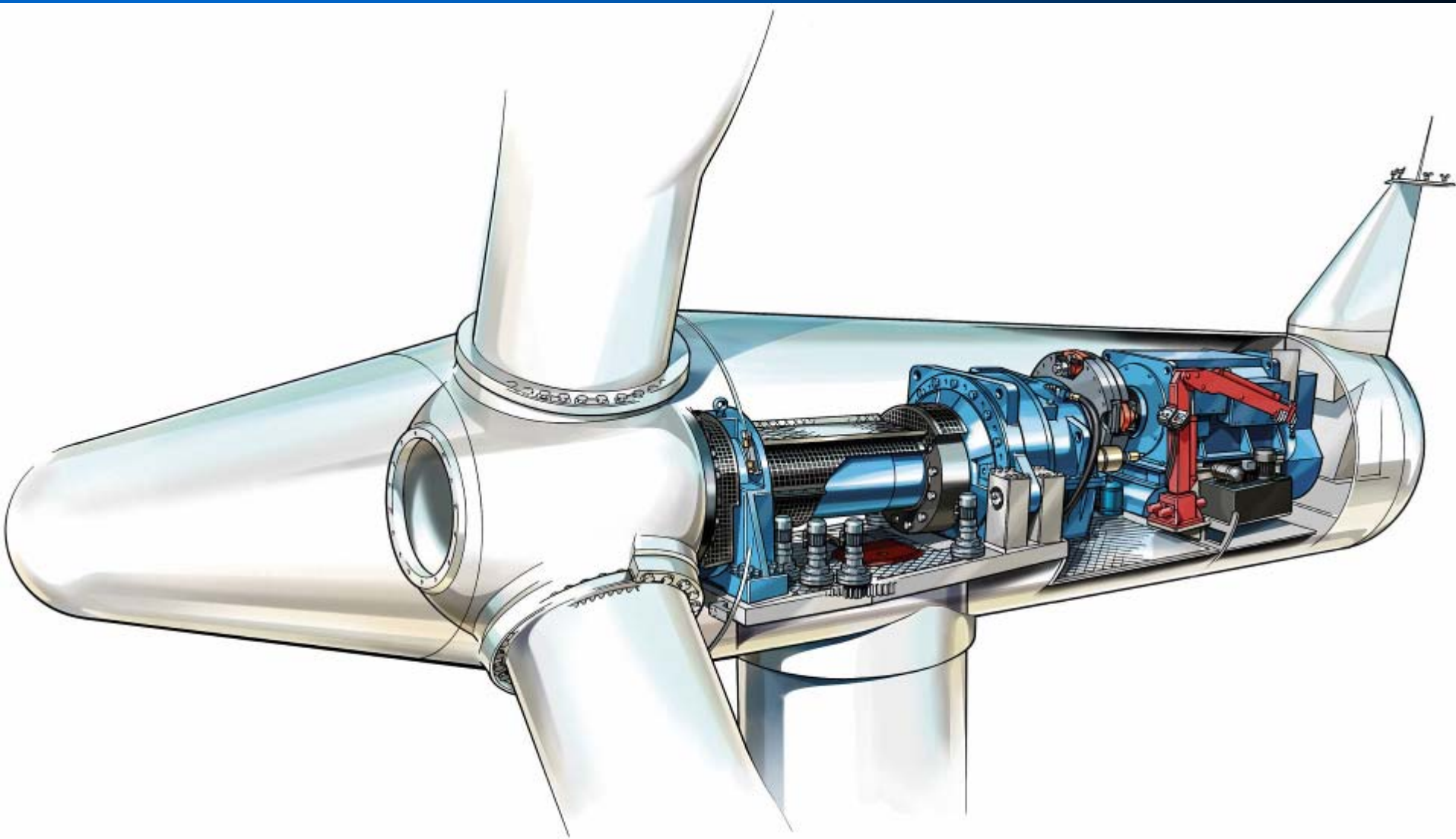
- Tower 64 m
- Top 102 m
- Rotor Ø 76 m, equal to the wings of a Boeing 747
- 18 RPM/12 RPM



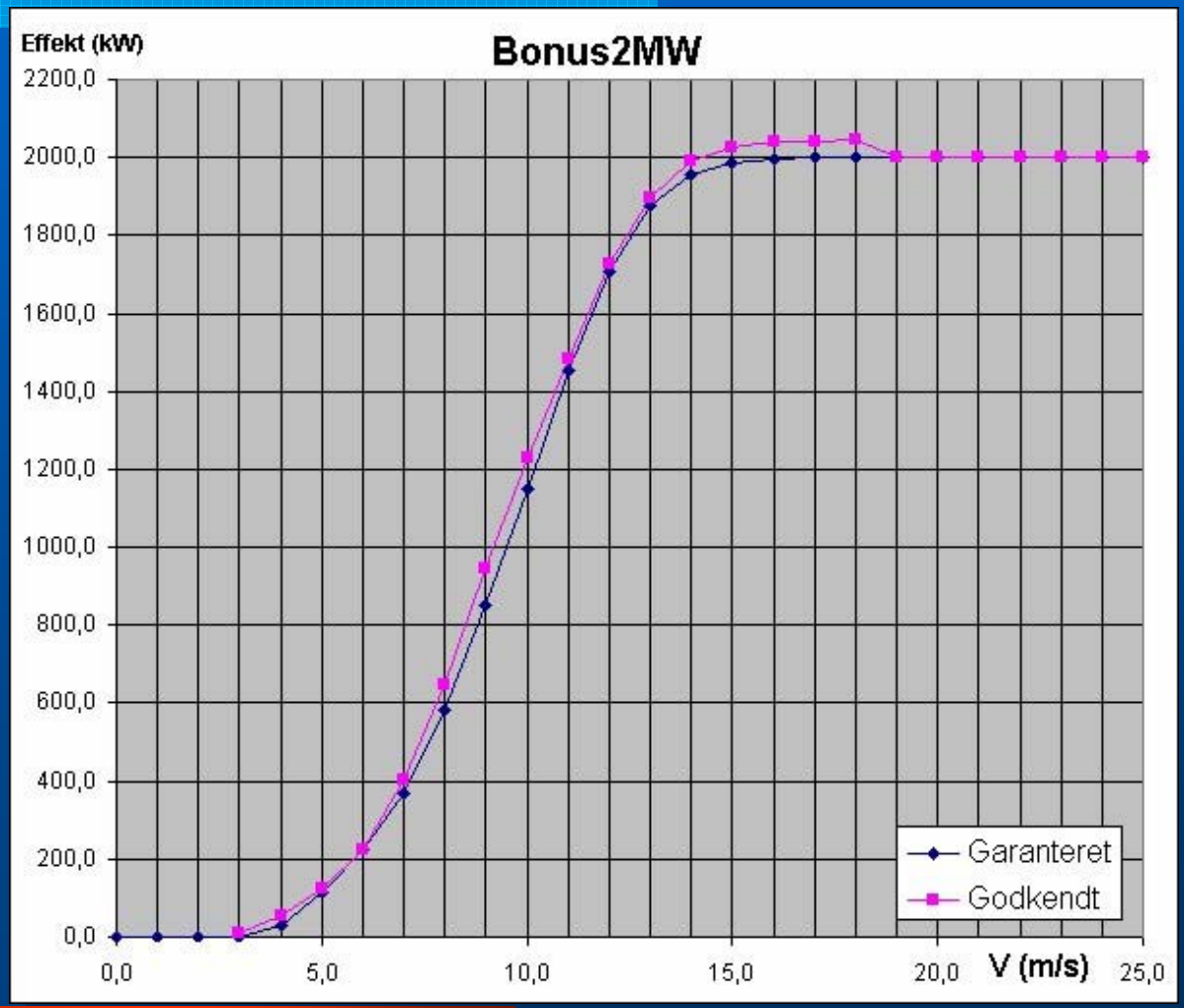
Fundation

- 1800 tons
- Concrete
- Gravity



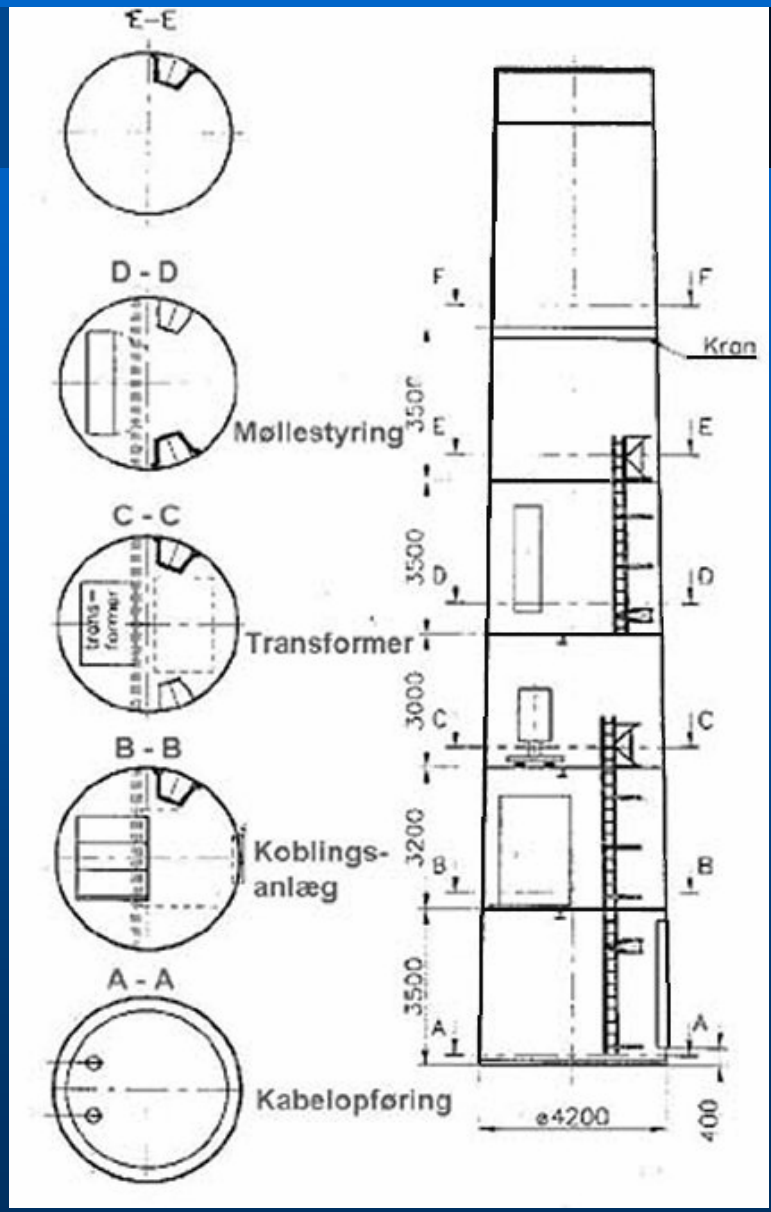


Windspeed to power ratio



Tower

- 8 levels in the tower
- Level 1: communication
- Level 2 : shiftgear
- Level 3 : transformer
- Level 4 : controle system
- Top and bottom have a dehumidifying plant



Grid connection - seacabel

- Twin 30 kW sea cable are drawn to power plants on the coast
- Local connection from turbine to turbine
- Turbine No 10 servs as cable hub for all cables

The cost of the wind farm

	EUR (mill)
Wind turbines	26.68
Fundations	12.94
Grid connection, (from land to farm)	PSO, not included
Grid connection, off-shore	4.51
Design, advice and planning	2.98
Wind-turbine co-operative	0.80
Other costs	0.64
Total	**48.55**

(Middelgrundens Vindmoellelaug I/S, final account 2003)

Key figures (40 MW)

Investment	47,700,000 Euro
Investment/kW	1,193 Euro/kW
Yearly production	100,000,000 kWh

Calculation

** Calculation rate = 5%*
** Lifetime = 25 years*
** Service = 0.01 Euro/kWh*

Calculated production price 0.044 Euro/kWh

Economy for shareholder

Sales price of electricity

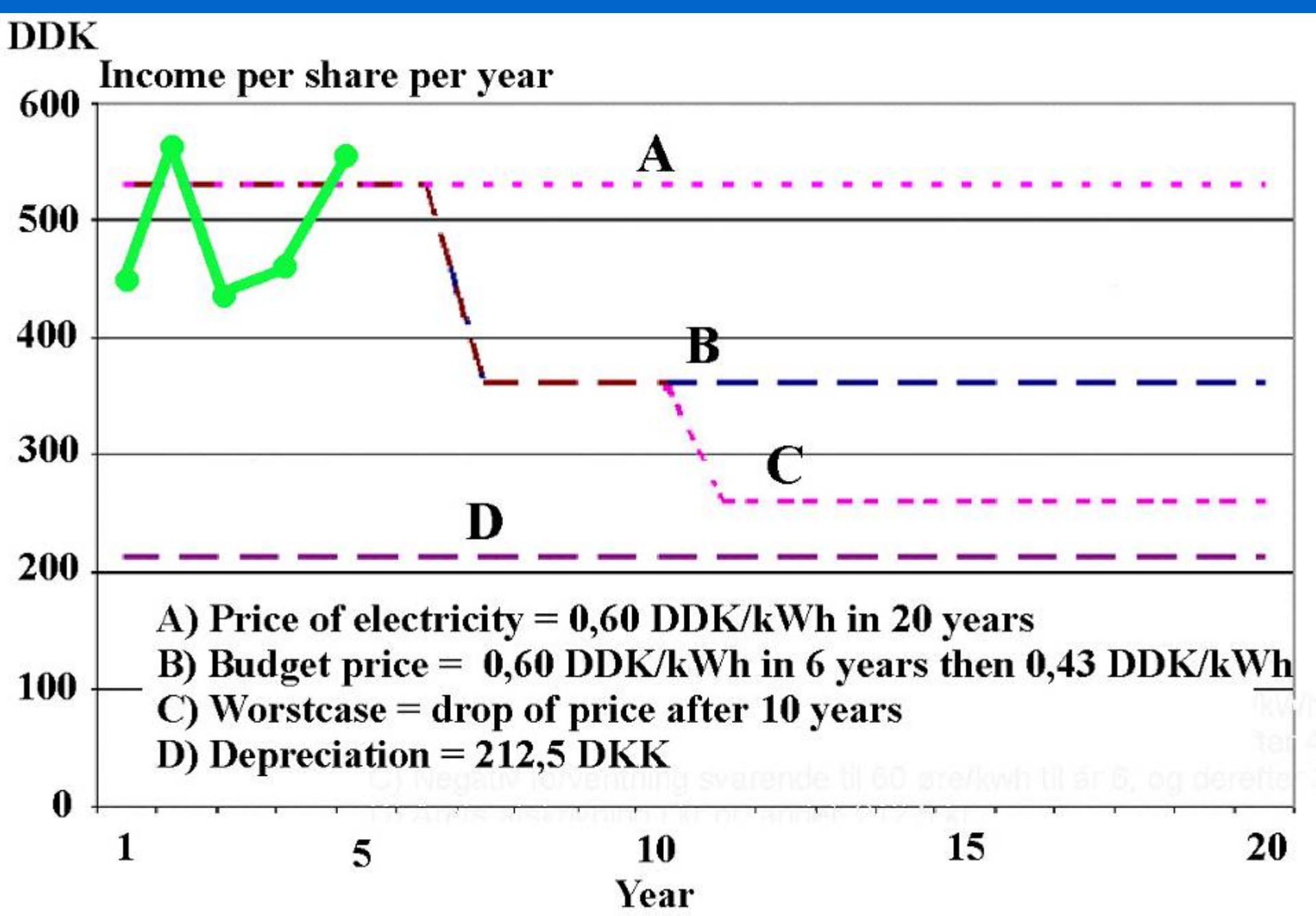
Year	**Fixed**	**Added price for renew. energy**
0-6	0.044 euro/kWh	0.036 euro/kWh
6-10	0.044 euro/ kWh	0.014-0.036 euro/kWh
10-25	Market price	Green label certificate to be traded
10-25	Max 0.049 euro/ kWh	(New decision in 2002)

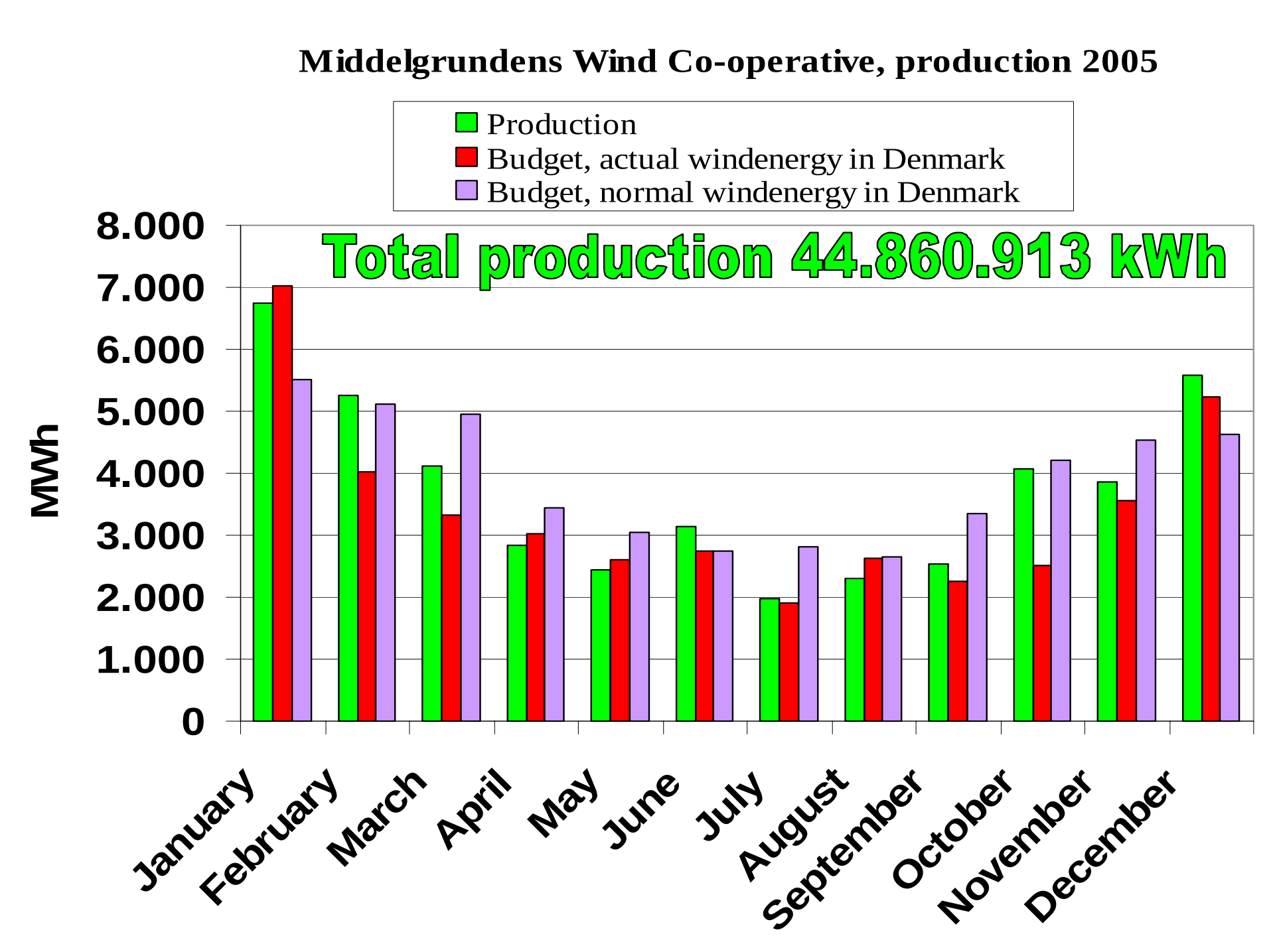
Economy for shareholder (6 years)

1. Share = 1000 kWh/year, Price of share = 570 Euro

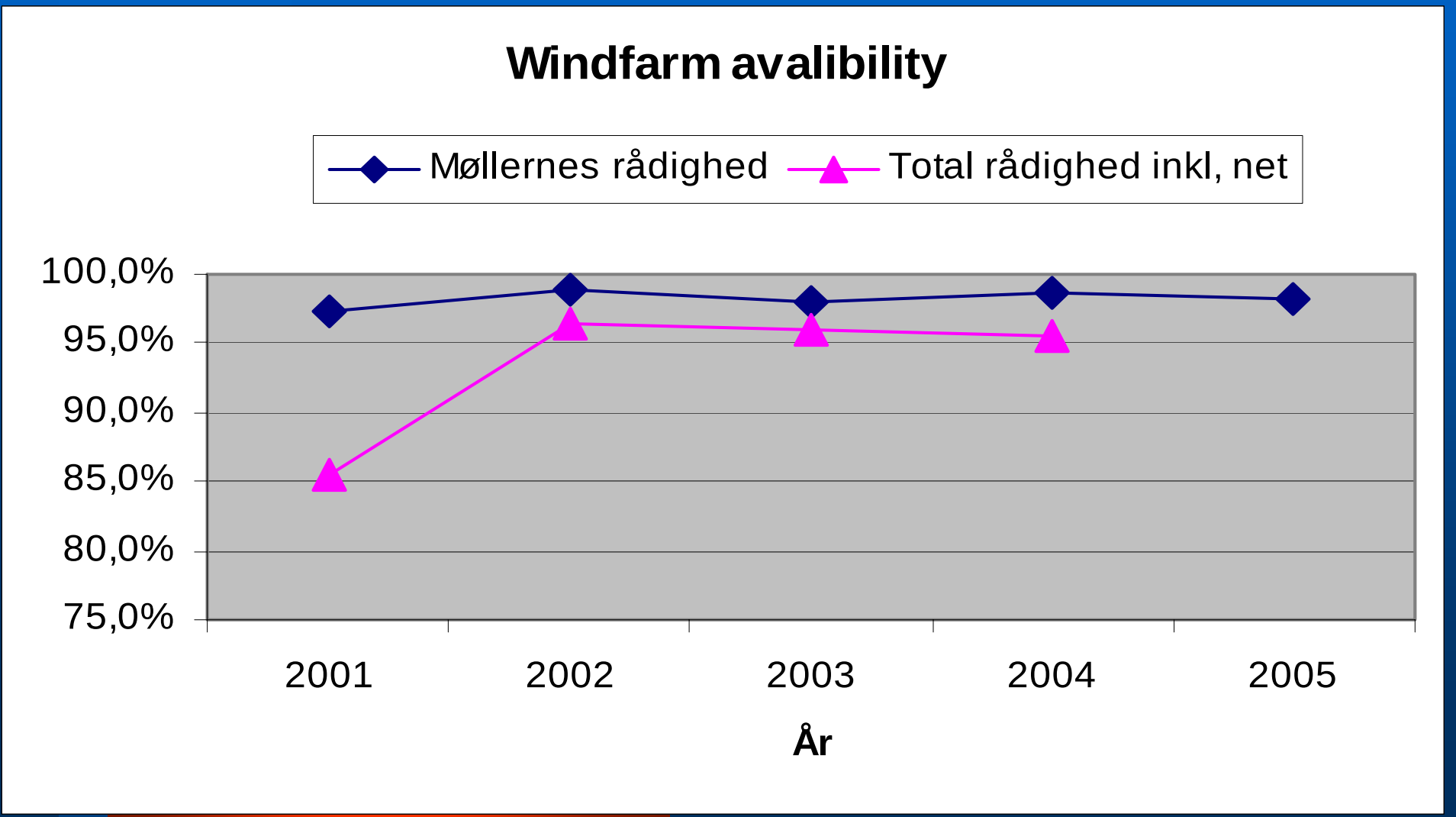
Selling price of electricity	44 Euro
Added price	36 Euro
Income/year	80 Euro
Maintenance cost	-10 Euro
Net income/year	70 Euro

Simple pay back time	8 years
Annual depreciation	5%
Rate after depreciation	7.5%


DDK
Income per share per year
600
500
400
300
200
100
0
A
B
C
D
A) Price of electricity = 0,60 DDK/kWh in 20 years
B) Budget price = 0,60 DDK/kWh in 6 years then 0,43 DDK/kWh
C) Worstcase = drop of price after 10 years
D) Depreciation = 212,5 DKK
1
5
10
15
20
Year


Middelgrundens Wind Co-operative, production 2005
Production
Budget, actual windenergy in Denmark
Budget, normal windenergy in Denmark
Total production 44.860.913 kWh
MWh
8.000
7.000
6.000
5.000
4.000
3.000
2.000
1.000
0
January
February
March
April
May
June
July
August
September
October
November
December

	2002	2003	2004	2005
Turbine avalibility	98.7 %	98.1%	98,7%	98,3%
Total avalibility incl. grid	96.4 %	95.9%	97.2%	



Lessons learned

- Long planning proces (starts in 1993)
- Conflicts (NIMB, fishing, historic landscape, utility. policy)
- Myth and facts
- New liberalised electricity law
- No single authority and no planning procedures
- No regulation on private off-shore
- Organization of 8500 members (public awareness)
- Public dialog important (public awareness)
- Visual impact (from 27 to 20 turbines)
- Co-operation important (Wind turbine co-operative, municipality and utility)
- Policy (parliament, local parliament,commitment of mayor)

Recommendations

- People must be involved in relevant part of process
- Problems with acceptance can be avoided
- Contact for interest groups and authorities in early stage
- Dissemination of appropriate information in right time
- Many reservations were based on the fear of negative impact
- We took relevant and critical reaction into account by changing the design of the windfarm

Why private and local turbines ?

- More actors in the market gives you more turbines !
- **Local and private took the initiative for 81% of all turbines in Denmark**
- **Local people create local dialogue and acceptance and prevent the NIMBY effect**
- **Local ownership raises public awareness**
- **Local ownership solves problems and conflicts**
- **Private investment promotes cheaper and better technology**

Why private and local turbines ?

- **Local production saves 10 % energy (less transmission loss)**
- **Local production demands less transmission lines**
- **Local production makes sustainable development understandable**
- **Gives people opportunity to act for sustainable development**
- **Local turbines give power to democracy and less power to the market**
- **Local turbines give price stability on electricity market**

Conclusion

- **Feed-in tarif, grid connection law, and local investment has formed the basis for wind power success in Denmark**
- **Middelgrunden windfarm showed that offshore can be done for low cost and with no enviromental problems**
- **Demonstration value was and is big**
- **Local demonstration projects is still very important !**
- **Now it is a green landmark for Copenhagen and local people are proud of Middelgrunden**

The 20% windscenario for USA

- **Denmark have 20% wind – can you do the same?**
- **To achieve 20 % wind energy you need 250-340.000 MW.**
- **You need 15.000 MW/y for 20 years – or 20 times the "Cape Cod" project each year for 20 years.**
- **So you really have to do something – time is a factor – and you´ll have to start now!**
- **You need examples of how you can do it (policy, technology, economy, democracy, involvement)**
- **If you save 50% you "only" need 50% wind energy to achieve the same wind penetration**
- **We have done it in Denmark today – you can do it if you want!**

Recommendations for US context

- **Wind is the cheap and clean – push for local projects !**
- **20 % windenergy is achieved in Denmark – you can do the same**
- **Danes are positive for more wind – hope US will do the same**
- **Off-shore wind is a realistic options, especially close to loadcenter**

More at www.middelgrunden.dk

Thank you for your attention !