SEAWIND – project description:

MIDDELGRUNDEN, Denmark, 40 MW (20 x 2 MW)

Figure 1 Photomontage from Copenhagen, 4,3 km from WTGs

Project description

Just 1.6 km to nearest part of the Capital of Denmark, Copenhagen, and less than 5 km from the "heart" of Copenhagen, the royal castle Amalienborg. A row (arc) of 20 x 2 MW Bonus WTGs at 64 m hub height and 76 m rotor diameter. The spacing is 175 m, which is only 2.3 RD.
Grid connections from the trafo's in each WTG (30 kV) are made with 2 parallel 30 kV lines from a collection point in the middle of the Windfarm to the power plant "Amagerværket" just at the shore. This is only 2.7 km away. The foundation type is gravity made of steel with an ice-breaking cone made of concrete. The water dept is 3-10 m.

Organization and planning procedure

The planning started 1998 initiated by the local environment and energy office in Copenhagen, a "grass root" organization. Together with the local utility "Copenhagen Electricity", the development took form and with help from the Danish Energy Agency there were sponsored around 100 k€ to perform the needed investigations/planning. The project was given the final permission in 2000. This project was established in December 2000 – January 2001.

Facts on layout proposal and estimated investment costs

WTG size layout specification and price

Total installed power	**40**	**MW**	Distanse	in RD
Number of rows	1			-
WTGs per row)*	20		175	2.3
Number of WTGs	20		Hub height	RD (m)
Size of WTG	2	MW	64	76
Price information in this case are very rough estimates				
Price for WTGs, installed (k€)	**26,840**	**671**	**€/kW**	

Foundation, specification and cost estimate: **40 MW**

Type of foundation	Gravity							
Number of foundations:	20							
Water debt (m)	5	RD	HH					
WTG-size (MW, rotor diameter, hub height)	2	76	64	Debt#1	Debt#2	Debt#3	Debt#4	Debt#5
Ice risk (yes/no)	Yes							
100 year max wind gust (m/s)	?							
100 year max wawe height (m)	?							
Tidal difference (m)	?							
	For all k€	k€ per pcs.	€/kW	Per foundation, debt dependend				
Fixed price. design cost,								
Fixed price, building/shipping facilities								
Fixed ground prepare cost								
Variable ground prepare cost								
Variable, building cost								
Installation cost								
SUM	9,920	496	248					

Grid connection:

Division into components partly estimated		Number or length (m)	Voltage(kV)	mm^2	Material	Lines/cable	Prices k€ For all	Per unit or per meter, €	€/kW
Off shore									
	Sea cable, from wind farm to shore	5400	30	300	CU	Cable	540	100	14
	In row cables	0	30	300	CU	Cable	-	100	-
	Rows to collect point cables	3325	30	300	CU	Cable	333	100	8
	Cable roll out/Wash down, variable	6025					301	50	8
	Cable roll out/wash down, fixed cost						500	500,000	13
	Total number of WTG connectors *)	20					900	45,000	23
	Off shore HV station	0					-		-
	Connection (electrical work)								
	Other fixed costs						1,000	1,000,000	25
	Other variable costs								
On shore									
	From shore to HV-grid								
	HV station (if needed)								
	Connection (electrical work)								
	Compensation (reactive power)								
	Other fixed costs						1,000	1,000,000	25
	Other variable costs								
Total	*) Incl. Transformers in WTGs !!						4,574		114

Total budget for 40 MW wind farm

	k€	***€ per kW***	***Percent***
WTGs	26,840	671	58%
Foundation	9,920	248	21%
Grid connection	4,574	114	10%
Planning and permissioning	2,141	54	5%
Organisation, management	1,071	27	2%
Miscellaneous (e.g. risk)	1,606	40	3%
TOTAL	46,152	1,154	100%

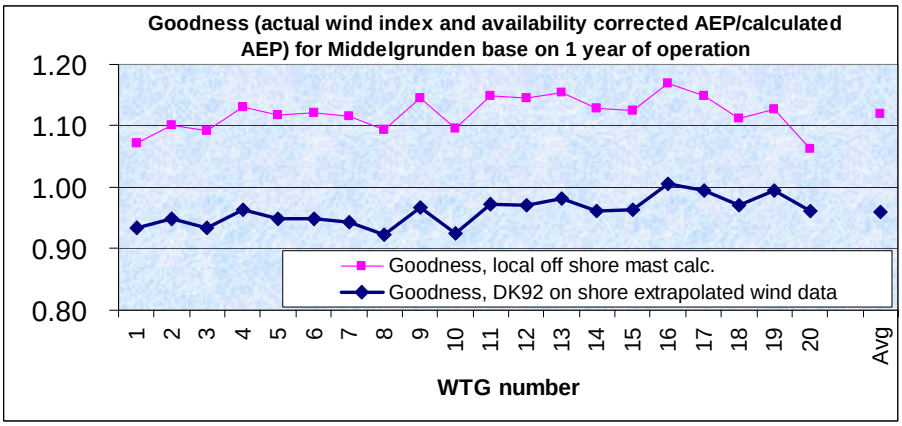
Note: There has been added some subsidy in the planning phase. NOTE: In this description, the WTG transformers are not included in WTG price, but in grid connection.

Energy production, operation cost, PPA and economic feasibility.

There were established a measure mast, 50m off shore near the site and measured for around 1 year. Unfortunately, the quality of the measurements was quite low due to low availability. Off shore measurements are more critically to perform than onshore.
Based on as well local measurements as general wind data for Denmark, calculated mean wind speed for the site is around 7.4 m/s, slightly higher based on local mast. But especially the array losses are calculated much different due to different wind direction distribution.

Based on local measure mast: 4500 MWh/year/WTG – array loss 14%
Based on general wind data for DK: 5200 MWh/year/WTG – array loss 7%

Experiences so far show around 5000 MWh/year/WTG as expected long-term energy production, corrected for availability and wind index.



This means that calculations based on general experience from on shore wind data gives a more precise estimate for this wind farm than local off shore measurements – but the wind farm are close to the shore, so it might not be a general conclusion that on shore extrapolations is better or good enough.

Power purchase agreement

Power purchace agreement			
	øre/kWh		€c/kWh
For first 10 year, base price	33	fixed (until 2003)	4.44
CO2-bonus, extra all 20 years	10	fixed (politically decided)	1.35
First 12000 full load hour, extra	17	fixed (untill 2001)	2.29
Marked price after 10 year	23	Estimated	3.10

Operation costs and economic feasibility

Based on onshore experience following figures have been used in the calculations:

Operation cost	onshore		offshore estimate	
Insurance	5	€/kW/y	10	€/kW/y
Service and maintenance	10	€/kW/y	18	€/kW/y
Adm. and management	3	€/kW/y	5	€/kW/y
SUM/year	18	€/kW/y	33	€/kW/y
	Per WTG:		1.3	€c/kWh/y
Decommissioning	25	k€/WTG	0.6	€/kW/y

Figure 2 Operation cost used in calculation. The resulting 1.3 €c/kWh is a little higher than expected for large-scale projects. The decommissioning costs is set very low here, while

access is very easy and there should be good reasons to believe in that instead of decommissioning, repowering would be more likely.

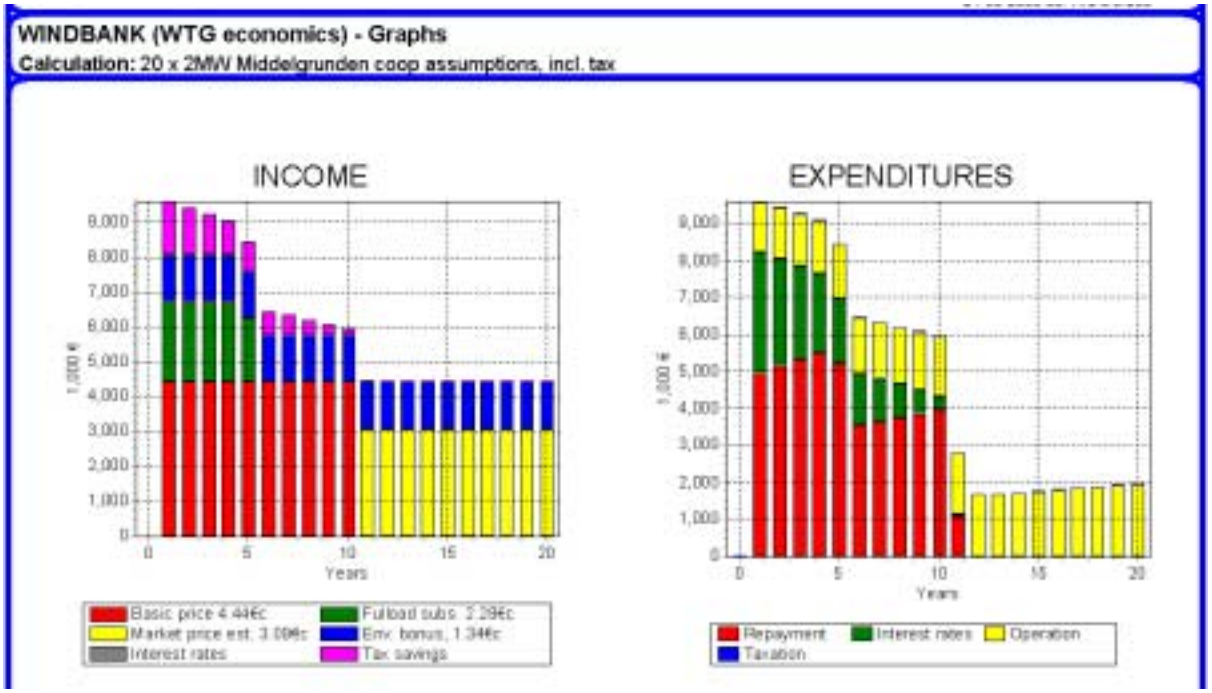


Figure 3 With 5000 MWh/y per 2 MW WTG, 7% interest rate, tax regulations for coop owned shares, O&M cost of 1.3 €c/kWh and the PPA for DK at the time of installation, a 10.4 year pay back time is expected.

RATIOS

		/kW	/m2	/MWh
Preliminary expenses	€	1,154	509	462
O/M costs	average €/years	34	15	14
Energy production	kWh/Years	2,500	1,102	-

Minimum life span for redemption of loan	10.4 Years
Simple pay back time	8.9 Years
Net present value for share	173 €
Net present value in % of investment	37.5 %
Production price at calculation interest 6.0%	0.06 €/kWh

Figure 4 One share is here 1000 kWh/year, an investment of 462€. Note that only 2500 kWh/kW is produced due to Copenhagen relative close in main wind direction and relative small rotor area /kW.

Environmental aspects:

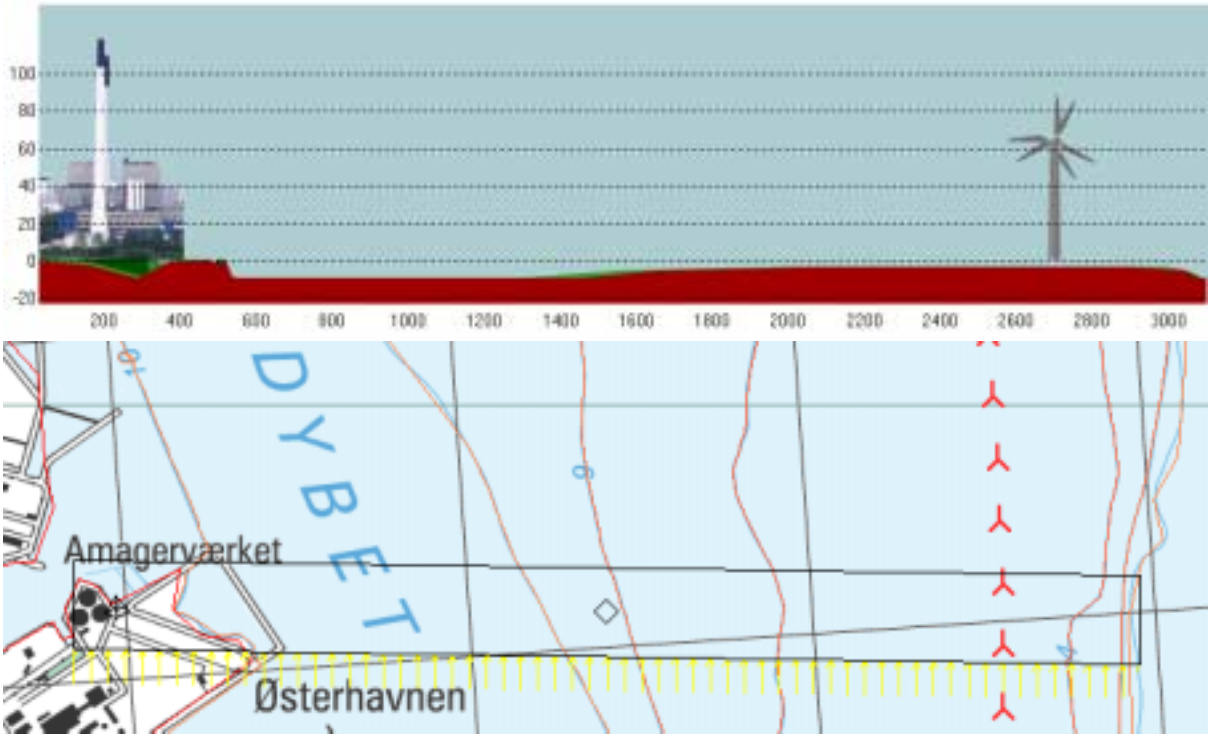


Figure 5 The terrain profile (water dept with factor 5 oversize) shown for a part of the Windfarm clearly showing the low water ground which keep the water dept around 4 m for most of the WTGs. The proportions of the Amager Power plant are shown for comparison (actual size might differ – no information on the height is found).

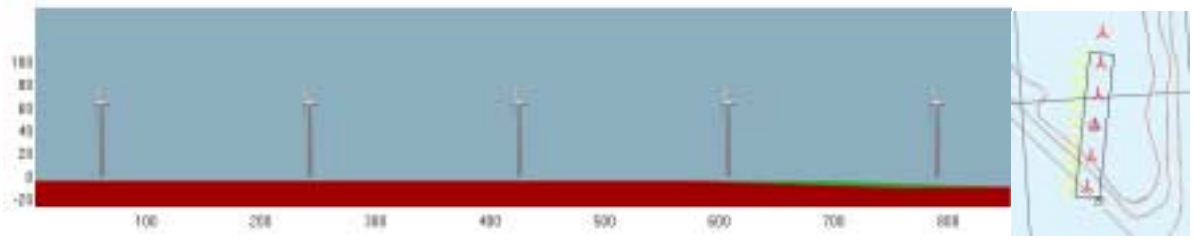


Figure 6 The 5 WTGs most south - WTG no. 20 is outside the 4 m dept with around 10 m, which increase the cost.

Visual impact

The visual impact was considered to be the only “real” environmental problem. Therefore several photomontages were made from many different spots as a part of the approval process, see example on front page.

Of other possible concerns was the sea traffic and air traffic (location only 5.3 km from the main Airport of Scandinavia, Kastrup), but all aspects were handled in a positive dialogue – light marking on top of nacelle secures visibility for the air traffic.

The methodology and presentation of this case study is established as part of ALTENER Contract No. 4.1030/Z/01-103/2001. For further information and discussion please contact the project coordinator Green Globe Energy I/S or EMD on e-mail: hansb@post8.tele.dk or euroscan@post.tele.dk or pn@emd.dk.