

Effects of large-scale distribution of wind energy in and around Europe

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Outline



- How to achieve high penetrations of wind energy in Europe?
- Distribution of wind energy all over Europe leads to smoothing of the wind power production profile
- Areas south of Europe are typically anti-correlated
- Especially two areas have also very high resource:
- North-western Africa (Southern Morocco, West-Sahara, Mauritania)
- South-western Gulf of Suez (Egypt)
- How does offshore fit to this?





Europe



The wind resource - Europe





Europe now



- High penetrations achieved in a few regions:
- Schleswig-Holstein, Jutland/Funen, Navarra
- All of them are around 27%
- All have fair wind resource and good state support schemes
- Not the best wind resource in Europe!
- The combination of fair wind resource and decent support is getting scarce (counties are full)
- Therefore, push offshore is underway especially in DK, DE
- (Also in UK, but there due to planning trouble)





Smoothing



Data from 60 meteorological stations





Cross-correlation versus distance





- Calculate cross-correlation coefficient between every pair of stations
- Result: Cross-correlation decreases with distance
- Exponential fit has shape parameter of ca. 700 km
- Leads to significant smoothing of generation

Smoothing enables high penetration



Run generation profile through power model for all Europe

Results:

- Wind energy can easily supply up to ~20% of the European demand. At this stage,
- Less than 13% of the wind energy production is surplus, while it
- Replaces fossil fuel capacity with more than 10% of the installed capacity and
- Replaces 60% of all fossil fuel in Europe
- ...if the grid can transport it, and
- a common market access is in place!



Northwestern Africa



The wind resource – Europe+ Mean Yearly Production of WECS hub height ~ 80m



, ₹ ar Load Hours 1500 = 20 🏢 -20

G. Czisch, ISET/IPP; Meteorological Data: ECMVVF (1979-1992)

Saharawind





Idea: very high wind speeds on the northwestern coast of Africa are exploitable locally and as exports to Europe.

The area is ideal for large-scale wind power:

- High wind resource
- Low population density
- Energy transfer by HVDC is possible over this distance

Wind resource in West-Sahara





- Calculated resource from Reanalysis shows good wind
- Measured resource near Dakhla is very high (ca 4500 FLH)
- Also very even (not many winds below 3 m/s or above 18 m/s)
- Estimated cost below 3 €c/kWh
- The whole region can generate ca. 1000 TWh
- Enough to cover half of the European demand
- Would need large cables
- Cable cost is ca 1 €c/kWh

Smoothing between North and South

- Winter winds predominant north of the Alps
- Sommer winds highest in trade wind region
- Therefore, the common profile is relatively even

Monthly Mean Electric Production of Wind Power within Selected Favourable Regions at Land Sites and

Electric Demand







Egypt



Wind Atlas for the Gulf of Suez



- Meteorological measurements
 - Design, procurement and installation of 10 met. stations
 - Site selection, operation, maintenance and data analysis
- Micro-scale modelling (WAsP)
 - Terrain descriptions for 15 met. station sites
 - WAsP modelling of 15 met. stations sites
- Meso-scale modelling (KAMM)
 - Terrain descriptions for the Gulf of Suez
 - NCEP/NCAR wind climatologies as input
 - KAMM modelling of the Gulf of Suez
- Satellite imagery
 - Collection of satellite data and images
 - Methodology, analyses and reporting



Gulf of Suez – Wind resource



- KAMM/WAsP Mesoscale modelling
 - domain rotated 30°
 - 60 x 81 grid points
 - 5 km grid point spacing
 - 28 vertical levels from0 to 6000 m a.s.l.
- Climatological data
 - NCEP/NCAR reanalysis data from 1965-98
- Current wind farm: Zafarana

KAMM/WAsP modelled wind climates



Station	WAsP wind climate		KAMM wind climate	
	<i>U</i> [m/s]	<i>E</i> [W/m ²]	<i>U</i> [m/s]	<i>E</i> [W/m ²]
Abu Darag	9.9	821	9.4	669
Zafarana	10.4	966	9.9	761
Ras Ghareb	11.6	1216	10.3	952
Gulf of El-Zayt	11.5	1266	9.4	774
Hurghada	7.6	421	6.2	323
Ras Sedr	8.5	515	7.6	318
El Tor	6.3	276	6.2	378

Current Zafarana wind farm

• Wind farm built 2002

4570 Full Load Hout

- Danida/KfW support (soft loans 3% over 15 years)
- 60 MW of Nordex turbines (picture from Nordex-online)
- Still more than 10006/kW/investment cost
- Tariff paid = 2.9 USc/kWh leads to IRR = 5.36%
- This is without CO₂ value
- 10\$/tCO₂ leads to IRR = 9.5%
- Numbers from UNEP Collaborating Centre at Risø (download from uccee.org/WindCDM)

Gulf of El Zayt



- Resource is even better than Zafarana
- Plenty of land available (>20GW possible!)
- Winds highest in summer

(good for air conditioning around the Mediterranean)

- Fairly steady
- Close to Egyptian main power line
- Relatively short measurement period



Probably the best wind farm site in the World...



Site	Mean wind speed and AEP		Capacity factor and hours	
	U [m/s]	AEP [MWh]	CF [%]	<i>N</i> [h]
Abu Darag	9.6	2772	52.7	4620
Zafarana	9.7	2804	53.3	4673
St. Paul	9.2	2564	48.7	4273
Ras Ghareb	11.0	3457	65.7	5762
Gulf of El-Zayt	11.6	3654	69.5	6090
Gulf of El-Zayt	11.3	3516	66.8	5860
Gulf of El-Zayt	11.7	3622	68.9	6037

2.9 USc/kWh * 4673/6090 ≈ 2 €c/kWh!







Discussion



Development possibilities



- Size of investment would be huge (Germany spends more on electricity than Morocco GDP)
- Driven by market, not by aid concerns
- Can reach sizeable parts of national income
- Building that much wind power there warrants a wind turbine plant
- Ie, a win-win situation!
- We get cheap eco-friendly electricity and
- a new market for our wind power industry...
- ...they get technology transfer and stable income.



The power line



Wind from North-western Africa could be implemented in three steps:

- Fill up the existing power line to Spain (350 MW)
- Extend the line to 700 MW
- Build dedicated HVDC line, potentially bypassing Spain entirely:
 - 4 GW, 4500 km (Morocco-Kassel), means 10% losses
 - Needs appropriate size wind farm (ca 6-8 GW)
- Could be filled with power from solar chimneys or other solar technologies

(Solar chimney: 1000 m tower, 200 MW) Picture: Schlaich, Bergemann & Partner, from sbp.de

Other problems





- In Egypt, the main bird migration routes pass that area
- However, birds often just fly around turbines
- In Morocco, the status of West-Sahara is not clear yet
- However, a large financial interest might speed up the process

Conclusions



- There is huge potential south of the Mediterranean
- Can be exploited very cheaply locally (<3€c/kWh),
- and transported for a still competitive price to Europe
- The price of southern wind power can be the same order as the price from offshore wind power
- Where does that leave offshore wind power?