Direction Dependency of Offshore Turbulence Intensity in the German Bight

A. Westerhellweg, B. Cañadillas, T. Neumann; DEWI GmbH, Wilhelmshaven

A. Westerhellweg

ENGLISH

Summary

This contribution concentrates on the assessment of the direction dependency of turbulence intensity in the German Bight. Turbulence intensity has been assessed on a 10 minutes basis as ratio between standard deviation of wind speed and the wind speed. Data of the two research platforms in the German Bight FINO1 and FINO3 have been evaluated. At the location of FINO1 a variation of turbulence intensity dependent on the wind direction was observed with higher turbulence intensity from north wind directions. The FINO3 data now after completion of the 1st operational year does not show such a distinct direction dependency. The comparison of the turbulence intensity at FINO1 and FINO3 shows differences for eastern and southern wind directions but high agreement for the main wind directions. The wave height and the atmospheric stability are the main factors for the turbulence intensity at far offshore locations like FINO1 or FINO3. The direction dependency of turbulence intensity at FINO1 correlates with the direction dependency of wave heights.

Introduction

At FINO1 the turbulence intensity varies with the direction with higher turbulence intensities from north wind directions (about 7%) and lowest turbulence intensities from east directions (less than 5%). This study assesses the reasons for this dependency and evaluates whether the turbulence distribution at FINO1 is valid all over the German Bight, i. e. whether FINO3 shows the same behaviour. For comparison purposes the turbulence intensity of the FINO2 platform located in the Baltic Sea has also been investigated.
In previous reports the dependency of turbulence on the fetch over open water has been studied. However, most of them have been carried out on near shore masts. In [1] the dependence of turbulence intensity on the fetch (free path length of wind over open sea) was analysed for offshore sites near the Danish coast giving the result that in general in a range of 0-15km (and under stable conditions up to 40km) onshore conditions play a role. In this distance the higher turbulence from onshore is still visible and therefore the turbulence intensity decreases with the distance to the shore.

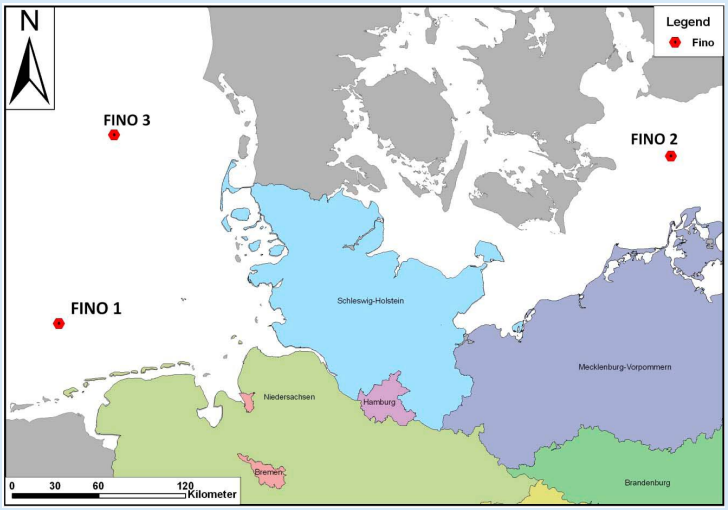


Fig. 1: Locations of the FINO research platforms

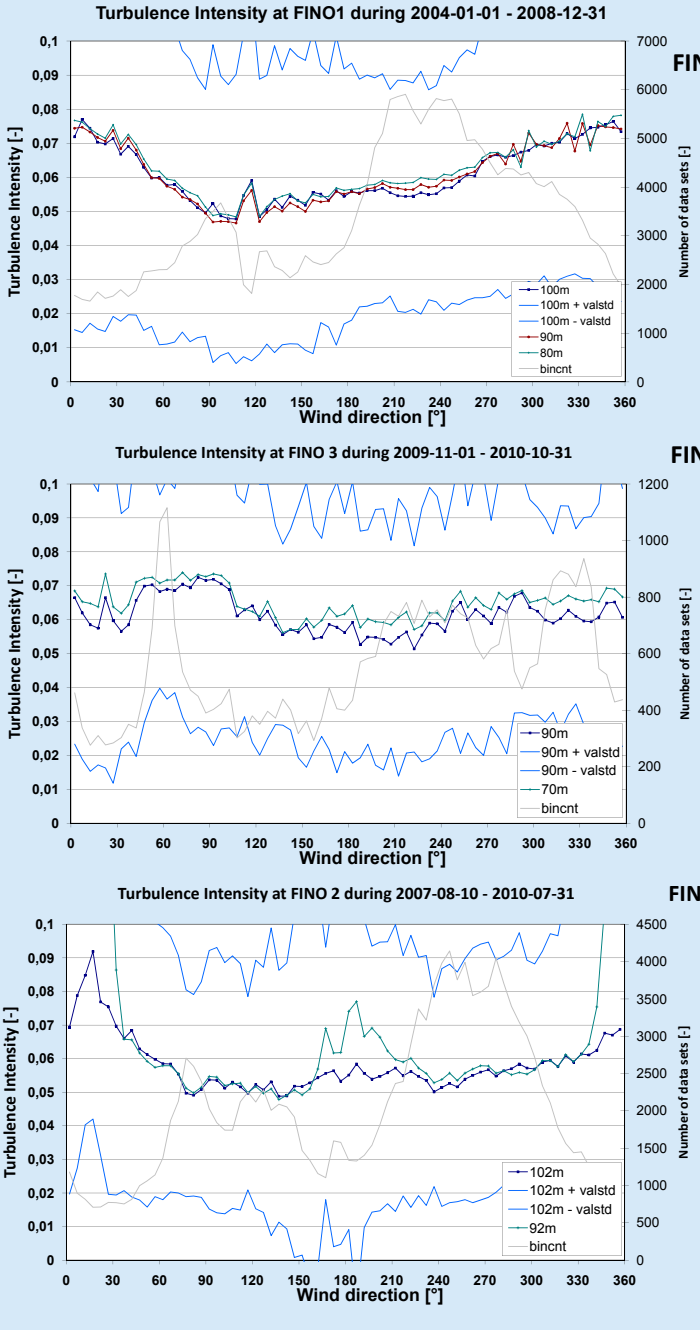


Fig. 2: Turbulence intensity versus the wind direction at FINO platforms.

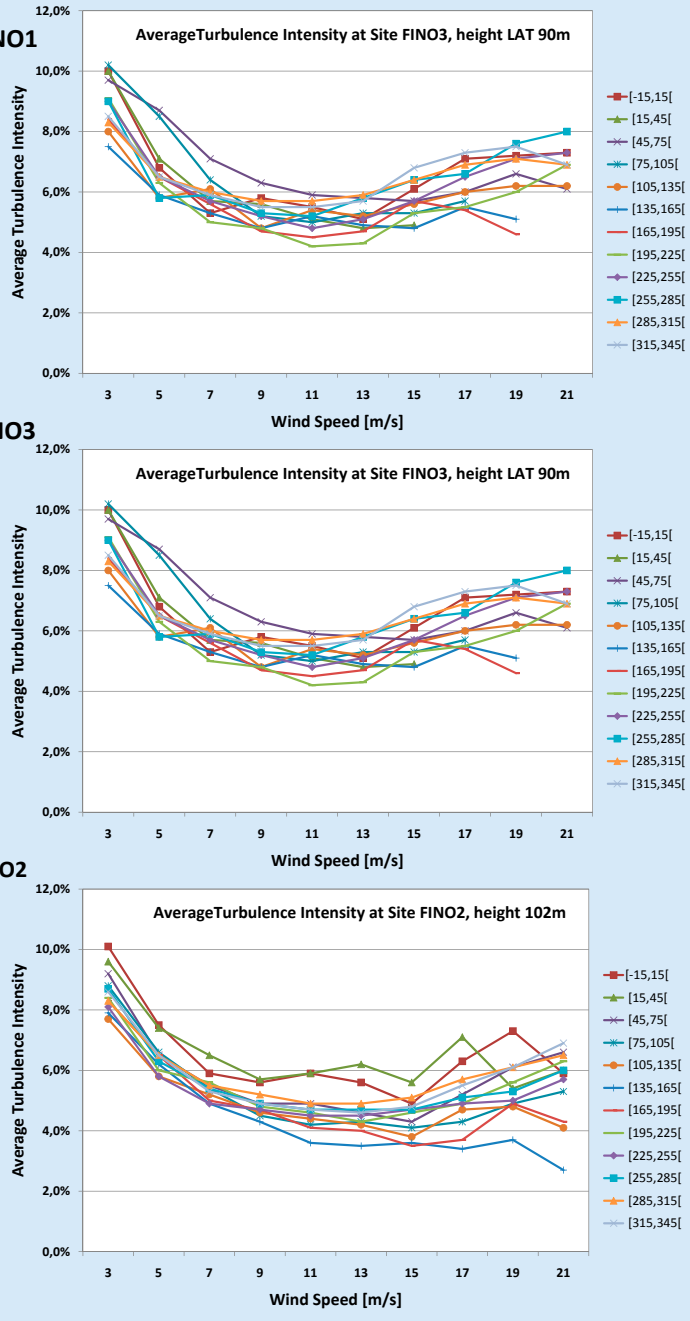
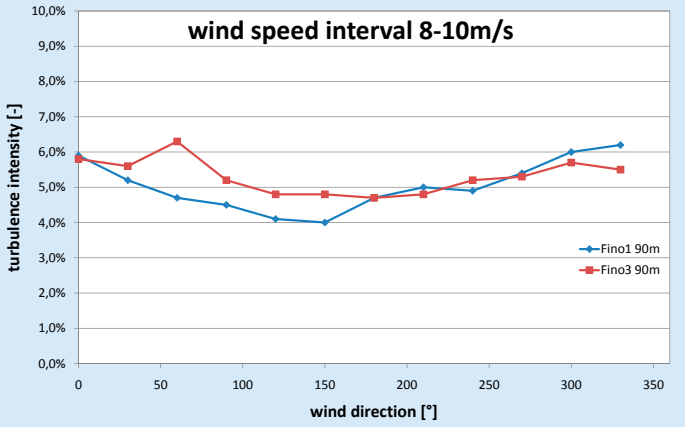


Fig. 3: Turbulence intensity versus the wind speed for the different wind directions at FINO platforms.



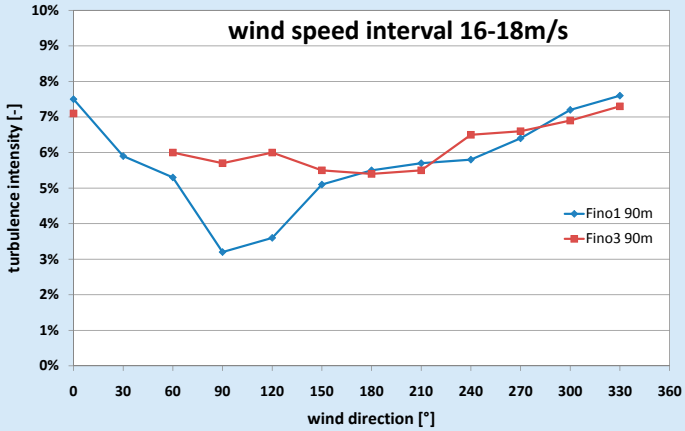
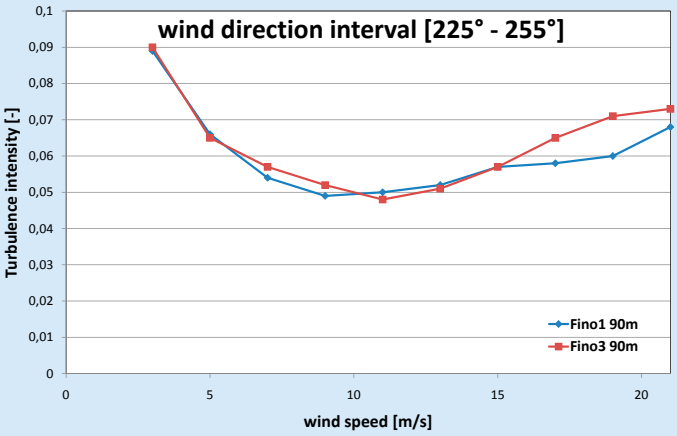


Fig. 4: Turbulence intensity versus the wind direction at FINO1 and FINO3 for medium and high wind speeds.



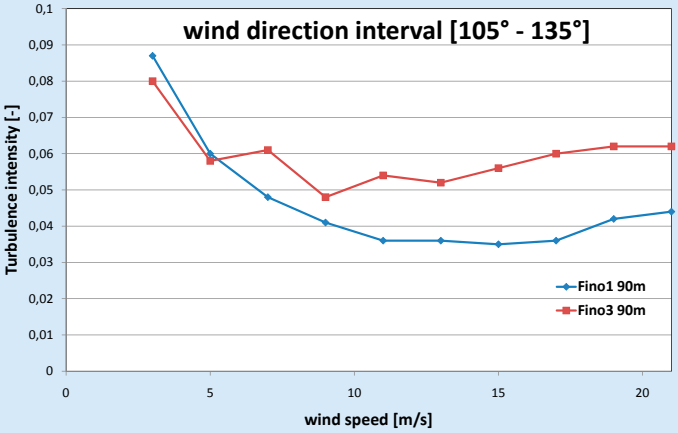


Fig. 5: Turbulence intensity versus the wind speed for the SW and NE wind directions at FINO1 and FINO3.

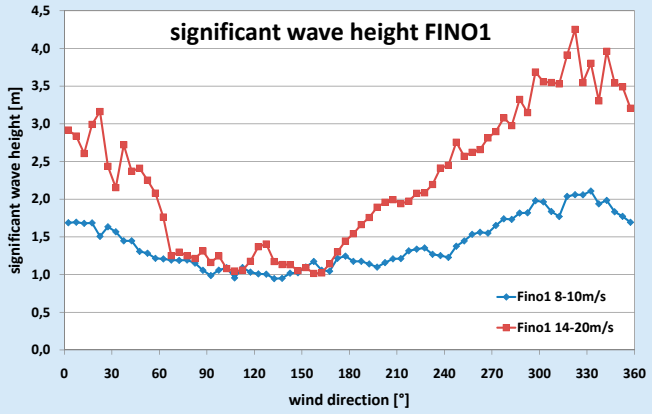


Fig. 6: Wave height versus wind direction at FINO1 for moderate wind speeds and high wind speeds, bin averages.

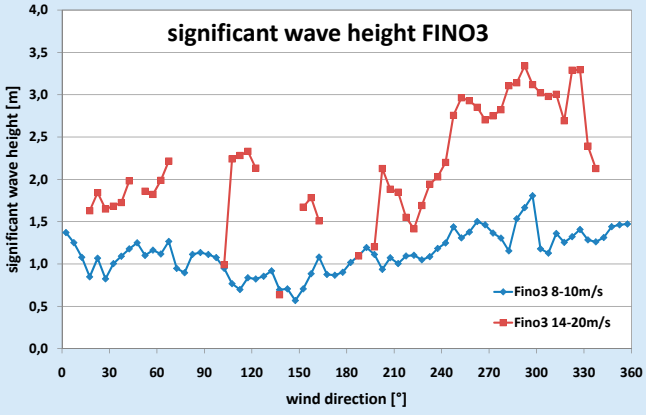


Fig. 7: Wave height versus wind direction at FINO3 for moderate wind speeds and high wind speeds, bin averages. For high wind speeds the data base is too small for a final appraisal of results.

At a greater distances the opposite effect is visible. All FINO platforms have a distance to shore greater than 38 km. At FINO1 (located in 45km distance to the island of Borkum) directions with the longest fetch (North and West) show higher turbulence intensity correlated to higher wave heights at these wind directions. Offshore like onshore the turbulence intensity is higher at low wind speeds and decreases with wind speeds up to a minimum of approximately 11 m/s. But in contrast to onshore from this minimum the turbulence intensity again increases towards higher wind speeds due to an enlarged surface roughness.

For the offshore platforms FINO1-3 [3] wind measurements are available for a period of 1-7 years, which gives the chance to investigate the interrelationships of the turbulence intensity to the different factors like wind direction, wind speed, fetch, wave heights and atmospheric stability. In the assessment of turbulence intensities always data of whole climatic periods of full years should be evaluated to avoid misinterpretation due to seasonal effects.

Data Base

The following 10-minute data sets of the FINO research platforms have been evaluated.

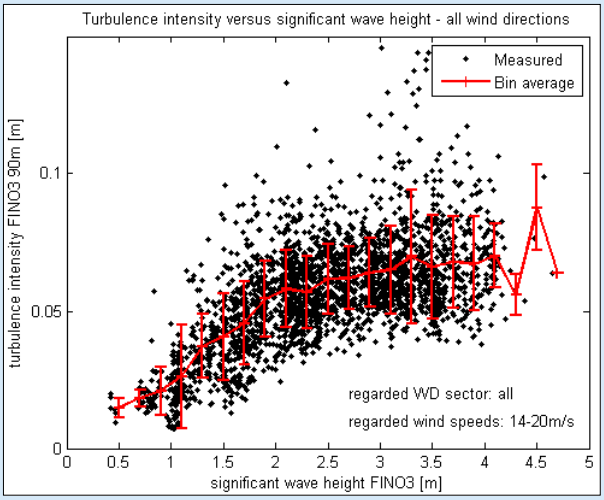


Fig. 8: Turbulence intensity versus significant wave height at FINO3 for high wind speeds

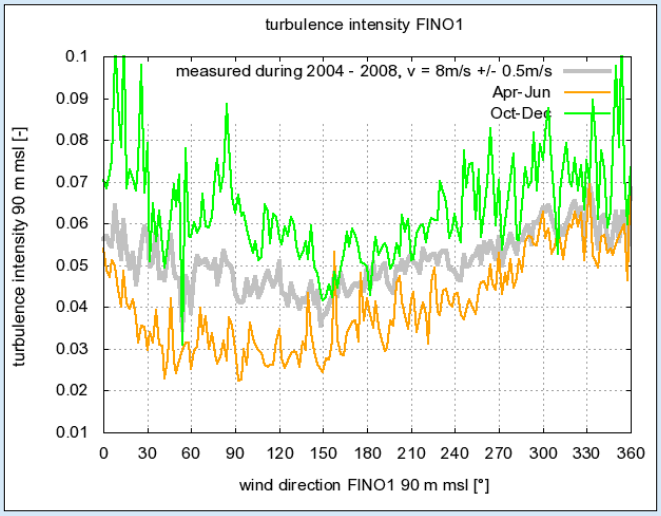


Fig. 9: Turbulence intensity for wind speed bin [7.5;8.5m/s] versus the wind direction at FINO1 for the 2nd and 4th quarter measured over a period of 5 years.

- FINO1: 5 years, 2004-2008, 91.5m LAT, mast correction of wind speed, standard deviation of wind speed: in the direct mast shadow the sigma of the top anemometer at 103m LAT was applied.
- FINO3: 1 year, Nov2009–Oct2010, 90m LAT, combined from 3 anemometers at one height.
- FINO2 (for comparison): 3 years, Aug2007–Jul2010, 102m, top anemometer.

Dependency on Wind Direction

FINO1 shows significant differences of the turbulence intensity for different wind directions whereas at the position of FINO3 a much more homogeneous picture is seen. Additionally the turbulence intensity distribution in the Baltic Sea measured at FINO2 is depicted (Fig. 2).

Dependency on Wind Speed

The turbulence intensity has a minimum at approx. 11m/s and increases for higher wind speeds at both locations. At FINO3 the increase is homogeneous for all wind directions whereas at FINO1 large differences for different wind directions are visible (Fig. 3).

Comparison for Different Wind Speeds

For moderate wind speeds (8-10m/s) the turbulence intensity is approximately the same for both FINO platforms for western directions but is lower at FINO1 for eastern wind directions (top Fig. 4). For high wind speeds (16-18m/s) the differences for eastern wind directions are even higher. For FINO3 one wind direction sector (30°) is missing in the graph because of a lack of data (lower Fig. 4).

Comparison for Different Wind Directions

For the main wind direction section at FINO1 (225°-255°) the turbulence intensity shows high agreement at both FINO platforms (top Fig. 5). For south-eastern wind directions there are distinct differences (lower Fig. 5).

Dependency on Wave Height

Under offshore conditions, there is an increase of turbulence intensity for high wind speeds due to an enlarged surface roughness. The turbulence intensity correlates with the wave height, as an example FINO3 turbulence data is plotted over the significant wave height for high wind speeds in Fig. 8. At FINO1 the wave height data show a similar direction dependency like the turbulence intensity with highest wave heights at northern wind directions. This direction dependency is visible at moderate wind speeds (8-10m/s) and even stronger at high wind speeds (14-20m/s). In the eastern wind directions the wave heights remain low for high wind speeds (Fig. 6). This seems to be a distinctive feature of FINO1.
The assessment of the wave heights at FINO3 suffers from the lack of data, only 7 months have been evaluated (2010-02-25 2010-09-29). However with the evaluated data base the wave heights are in the same range as at FINO1 for moderate wind speed, for high wind speeds the data base is too small for a final appraisal of results.

Seasonal dependency

The offshore turbulence intensity strongly depends on the atmospheric stability. In autumn the air is colder compared to the warm water leading to an instable surface layer with higher turbulence. In contrast to this in spring stable conditions are connected to lower turbulence intensities. Fig. 9 shows the turbulence intensity for the 2nd and the 4th quarter compared to the whole data set. Because wind speed distribution differs between different seasons only the turbulence intensity of a small wind speed bin is depicted. At both FINO platforms a distinct sensitivity of the turbulence intensity on the season is visible.

Conclusions

Turbulence data of two research platforms in the German Bight, FINO1 and FINO3 have been evaluated for dependencies on wind speed, wind direction, wave height and atmospheric stability based on a 5-year and a 1-year measurement,

respectively. It is shown that FINO3 shows a different directional behaviour compared to FINO1. Whereas FINO1 shows higher turbulence intensity at northern wind directions and lowest turbulence intensity values when the wind comes from eastern directions, FINO3 shows a more homogeneous behaviour for the directional dependency.
While for eastern and southern wind directions this different behaviour can be seen, for the main wind directions, South-West to North West, the comparison shows a high agreement.
The wave height and the atmospheric stability are the main factors for the turbulence intensity range at far offshore locations like FINO1 or FINO3.
For eastern and southern wind directions the wave heights are particular low at FINO1 leading to a low turbulence intensity. The direction dependency for the wave heights could also observed for FINO3, but on a much smaller level, which is in agreement with the more homogeneous turbulence intensity for different directions. As the wave height data for FINO3 did not comprise a full year this should be assessed for FINO3 in more detail as soon as a full year wave height data will be available. The seasonal dependence for a specific wind speed range shows the influence of the atmospheric stability on the generation of turbulence intensity.

Acknowledgements

The data evaluated here is from the FINO Project [3]. The FINO project is funded by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU).

References:

[1] Barthelmie R. J.: Monitoring Offshore Wind and Turbulence Characteristics in Denmark, Proceedings of the BWEA Wind Energy Conference 1999.

[2] M. Türk, S. Emeis: The dependence of offshore turbulence intensity on wind speed, Journal of Wind Engineering and Industrial Aerodynamics, 98 (2010) 466-471, 2010.

[3] FINO: Forschungsplattformen in Nord- und Ostsee, www.fino-offshore.de.

Successful DEWEK 2010

High quality of conference contributions attracted over 600 wind experts from 28 countries

ENGLISH

2010 has been a year of anniversaries for DEWI: Apart from the 20th anniversary of the company, the German Wind Energy Conference DEWEK also took place for the 10th time. Everything started in 1992 with the first DEWEK, held in the auditorium of the Fachhochschule (University of Applied Sciences) Wilhelmshaven, with 250 participants and 32 oral and 34 poster presentations. By the end of the first half of 1992 almost 1,000 wind turbines with an installed capacity of 142 MW were already in operation, and the still small wind "industry" was impressed by the commissioning of the first wind turbines of the 500 kW class. After the first event at the Fachhochschule the next conferences were held in the municipal hall of Wilhelmshaven, until in 2006 a relocation became necessary. Since then the DEWEK takes place every 2 years in the Congress Centrum Bremen, and the market development shows that this move has been an important step in an environment that has changed radically. Compared with 1992, at the time of the DEWEK 2010, more than 21,000 wind turbines with an installed capacity of 27,000 MW are in operation in Germany, and the DEWEK has established itself as an international technical-scientific conference.
More than 600 participants from 28 countries attended the 10th German Wind Energy Conference DEWEK which took place on 17 and 18 November 2010 in Bremen. "Building a German Offshore Wind Industry" was the title of a contribution by Ronny Meyer, managing director of Windenergie-Agentur Bremerhaven/Bremen e. V. (wab) in the opening session, which followed the opening words by the Lord Mayor of Wilhelmshaven, Eberhard Menzel, and by Dr. Stefan Birkner, State Secretary in the Ministry of the Environment and Climate Protection of Lower Saxony. Main topics of the lecture were the concentration of wind energy companies in the northwest, the formation of a network and an outlook on the further development of wind energy. What is the situation of wind energy research in the northwest? An overview of this subject was given by the new director of the Fraunhofer Institute for Wind Energy and Energy System Technology (Fraunhofer IWES), Prof. Dr.-Ing. Andreas Reuter. The opening session