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Project SEEWIND
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Table of Contents

1. Introduction

Wind farm sites in SEE and especially in the area of the Balkans provide excellent conditions for wind energy utilisation, but also pose a major challenge to the wind farm design and the wind turbine technology due to extreme wind speeds, turbulences and wind shear. In most cases those local wind systems are generated by different levels in temperature and air pressure between separate areas. In this area of conflict, the FP6 Research and Demonstration Project "SEEWIND - South-east European Wind Energy Exploitation" was launched in May 2007. The R&D project SEEWIND was coordinated by Energiewerkstatt and had duration of 90 months.
The project's main objectives have been the development and construction of the first multi-MW wind turbines in Bosnia, Croatia and Serbia and the examination of the operational experience gathered under the respective conditions at the various locations. To get more background information for operating wind turbines under these conditions, the "fingerprints" of the most dominating local wind systems have been assessed. Additionally, innovative technologies for measuring wind streams above complex terrain like SODAR and LIDAR and computer programs for micro-scale simulation of wind flow have been applied and examined. The objectives of the project can be listed as follows:

- To test innovative measurement techniques for complex terrain (SODAR / LIDAR)
- To gain more detailed knowledge about wind potential in South-East Europe
- To construct Multi-MW wind turbines at three different sites in Croatia, Bosnia and Serbia
- To gain knowledge in operating wind turbines at sites with complex terrain and under specific local wind conditions.
- To standardize and harmonize building codes for wind turbines in SEE
- To provide an impulse to wind energy exploitation in SEE

Financing of the project:

- Total budget: € 9.6 Mio.
- Funds from European Commission: € 3.7 Mio.

The pilot sites for the demonstration activities are located in three different countries on the Balkans. Each location is characterised by rather complex topography and specific local wind conditions.

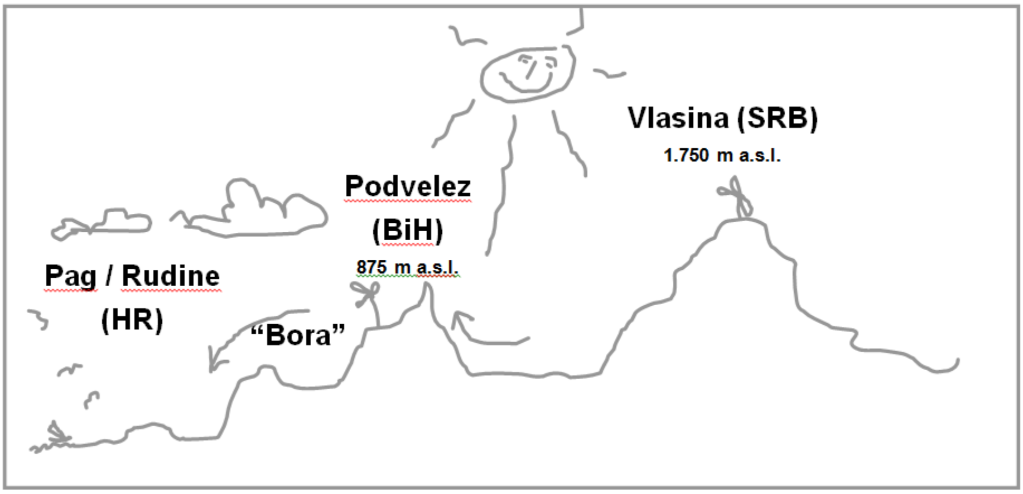

Fig. 1: Pilot sites in landscape profile

The first wind farm site **Podvelez** is located on a mountain plateau 700 m above the city of Mostar in Bosnia Herzegovina. The second site **Rudine** is located 20 km north to the City of Dubrovnik in Croatia on a ridge app. 2 km from the Adriatic Sea Coast. Both sites, Mostar and Rudine are affected by strong Bora winds. Originally this second pilot site was planned on the island of Pag, where the first wind farm of Croatia has been operating since 2004. After assessment of the site specific wind data, a change of the project location was necessary since IEC turbine class IA were exceeded and it was not possible to find a turbine manufacturer which was willing to deliver a multi-MW turbine to the island of Pag. The third site is located on the northern foothills of the Balkan Mountains in Serbia, closed to the border to Bulgaria. The site **Vlasina**, 1.750m above sea level, has strong and turbulent wind conditions with periods of heavy icing.

Fig. 2: Pilot sites located on the peninsula of the Balkans

The consortium of the project consists of 10 (11) members from 6 different countries:

- Energiewerkstatt, Austria
- German Wind Energy Institute, Germany
- Offshore and Certification Centre, Germany
- Meteotest, Switzerland
- Meteo Sarajevo, Bosnia Herzegovina,
- University of Mostar, Bosnia and Herzegovina
- lnstitute for Multidisciplinary Research, Serbia
- Adria Wind Power d.o.o., Croatia
- Vjetroenergetika d.o.o., Bosnia and Herzegovina
- Masurica d.o.o., Serbia
- Elektroprivreda BiH, Bosnia and Herzegovina

The work has been performed in 12 different Work Packages (WP)

- WP 1 Project Management
- WP 2 Dissemination of results
- WP 3 Wind measurements at pilot sites
- WP 4 Vertical wind profile in complex terrain
- WP 5 Local wind systems
- WP 6 Meso-scale simulations
- WP 7 Micro-scale simulations
- WP 8 Site development
- WP 9 Certifications & standards
- WP 10 Construction of pilot wind turbines
- WP 11 Evaluation of operational data
- WP 12 Power curve measurement

2. Project objectives

2.2 Overall Project Objective

The objectives of Project SEEWIND have been to gain experience in wind measurement, site development and operation of large scale wind turbines at sites in complex terrain and especially under the specific geographic and climatic conditions in the West Balkan area with the overall aim of increasing efficiency and reliability of wind turbine technology.

2.3 Scientific and technical objectives

The detailed scientific and technical objectives are listed in the table below:

	Objective	Deliverable to achieve Objective
1.	To gain experience with innovative measurement and simulation techniques in complex terrain and under specific local wind systems in SEE.	• Documentation of each SODAR and LIDAR measurement campaign • Results of each SODAR and LIDAR measurement campaign • Comparison of SODAR and LIDAR profiles • Rating of the suitability of LIDAR for measuring vertical profile of wind speed in complex terrain • Summary of the WP's main conclusions and their relevance to wind energy utilisation
2.	To improve the accuracy of energy yield prediction in complex terrain.	• Description of mean wind, turbulence, wind shear, flow inclination and extreme wind conditions at project sites • Energy yield assessment • Flow model comparison and verification results
3.	To gain knowledge about energy yield prediction at sites with specific local wind systems in SEE especially concerning extreme wind conditions and with regard to long-term behaviour of wind potential.	• Yearly reports (3 years) of long term measurements for each pilot site. • Reports on short term measurement campaign for each pilot site.
4.	To test a MW-scale wind turbine under extreme wind conditions at three different sites in West Balkans (Rudine II, Podvelez, Vlasina).	• Optimized wind farm outline for each pilot site • Reports on environmental impact statement for pilot sites • Reports on results of approval procedures • Investment cost for each pilot site based on tendering • Evidence of economic efficiency and financing plan for each pilot site

		• Documentation of construction works for each pilot site • Three pilot wind turbines at three project locations
5.	To generate knowledge about design parameters and power performance of operating wind turbines at sites in complex terrain and under the influence of extreme local wind conditions in SEE.	• Providing a high quality, high resolution data base for research purposes including report • Report on site calibration results with emphasis on the 3D information from the sonic and comparison with the calculated results • Report on power curve measurements with emphasis on nacelle anemometer based methods
6.	To increase efficiency and reliability of operating MW scale wind turbines at sites in complex terrain.	• Report on operational experience for each pilot site • Recalculation of economic efficiency for each pilot site • Costs for generating electricity from wind in SEE
7.	To standardize and harmonize building codes and related standards for wind turbine construction in West Balkans.	• Certification report on the assessment of site specific load assumptions for the wind turbines • Site Specific Certificate for the wind turbines • Compilation of the national building codes in a technical report
8.	To gain more detailed knowledge about possible wind potential in SEE	• Report with description of local wind systems and case study results • Long term 10-minute time series of wind data from Mostar met station • Website with 24 h wind forecast for pilot project areas • Report on the development and configuration of the meso-scale modelling system. • Validation of meso-scale simulation and assessment of the short term correlation • Meso-scale simulation of long term wind conditions over South East Europe
9.	To provide an impulse to wind energy exploitation in SEE.	• Web-site, webcam and folders for each pilot site • Information board and guided visitor tours at the pilot sites • Brochures about costs of wind energy generation and wind potential in SEE • Summary of final report ready to be published • Two conferences on wind energy in complex terrain • Wind workshop for companies • Socio-economic studies at the project sites

Tab: 1 Detailed scientific and technical objectives

3. Work performed and end results

3.1 Project Management – WP 1

The main objective of WP1 – Project Management has been to guarantee the timely and technically progress of the project according to its objectives.

The main challenges to reach those objectives have been the serious delays in approval procedure and installation of the pilot wind turbines. Several project crisis and discontinuities lead to in total six amendments of the contract with the EC. The most significant changes have been two project extensions and the exchange of two contractors responsible for wind farm development.

Only with the continuous support of the project consortium and the EC, the contractor Adria Wind Power has succeeded to obtain the required permits, order the wind turbine and secure the financial contribution of the EC.

3.2 Dissemination – WP 2

Project Homepage

The web-site as an important source of information and dissemination of the SEEWIND project (www.seewind.org) went online on the 20th of October 2008. This tool supports both, dissemination and exploitation beyond and encourages the co-operation within the consortium.

Media briefing and meetings with authorities and politicians

Regular meetings with local and regional authorities and politicians have taken place to promote the importance of wind energy utilization and to inform about the proposed project. These meetings and the most important steps during the demonstration project will be accompanied with press releases and/or media briefing in order to inform the public about the feasibility and advantages of the use of wind energy in SEE.

Technical papers and publication in specific journals and magazines

In order to disseminate the knowledge generated in this project, results of research work have been published in specific journals, magazines and international conferences (see table below).

Planned/Actual dates	**Type**	**Type of audience**	**Countries addressed**	**Size of audience**	**Partner responsible & involved**
March 31-April 3, 2008	Poster presentation at EWEC 2008	Wind energy community	Worldwide	ca. 3000	MET-SW, EWS
August 26-30, 2008	Oral presentation at TMT 2008	Wind energy community	Worldwide	ca. 100	UNMO
November 26/27, 2008	2x Oral presentation at DEWEK 2008	Wind energy community	Worldwide	ca. 600	MET-SW, EWS
March 16-19, 2009	Poster presentation at EWEC 2009	Wind energy community	Worldwide	ca. 3000	MET-SW, EWS
May 5/6, 2010	Oral presentation at Ice and Rocks III	Wind energy community	South East Europe	ca. 100	MET-SW, EWS, MET-BiH, IMSI, DEWI
November 17/18, 2010	Oral presentation at DEWEK 2010	Wind energy community	Worldwide	ca. 600	MET-SW, EWS
2010	Scientific paper	Wind energy community	Worldwide		UNMO
November 7/8, 2012	Poster presentation at DEWEK 2012	Wind energy community	Worldwide	ca. 600	DEWI GmbH
Feb, 2013	Oral Presentation at EWEA ‘13	Wind energy community	Worldwide	Ca. 500	EWS

Tab: 2 Overview table regarding the publications

Conference on wind energy and extreme climatic conditions

The scientific results, especially specific information about complex terrain have been presented at a series of conferences called 'Ice & Rocks' which has been organized in intervals of 2 years at wind farm sites with extreme climatic conditions.. These conferences have been organized in cooperation with EWS, DEWI and Met-SW. The first of these conferences took place at the Gütsch test site (check under: http://www.meteotest.ch/cost727/index.html?eisundfels.html). The 2nd conference was performed on the 5th and 6th of May in Zadar: http://seewind.org/ice_rocks_iii/general_information/

Socio-economic study at the project sites

For two locations (VE together with EP BiH, IMSI together with Masurica) socio economic studies have been published with the aim to assess the impact of the project on the living standards at the project locations. These studies include a part of possible feasibility to spin-off companies in the wind sector in SEE.

Lecturing at University of Mostar

The knowledge and experience gained in wind measurements are the content of lectures at the Mechanical Faculty at the University of Mostar. Through the participation of the University of Mostar it is insured that the gained knowledge will be transported to students and thus future engineers. The lectures have started in April 2009.

3.3 Wind measurement at pilot sites- WP 3

Work package 3 has had two major objectives. The first objective has been the continuation of existing site wind measurements in order to obtain long-term wind data that can be used for site assessment (WP7). The second objective has been to establish back-up measurements for the calibration and verification of the SODAR and LIDAR measurement campaigns (WP4).

Despite the fact that the interaction between different parties and work packages has not been easy, the goals of the objectives have been finalised successfully. In some cases the measured periods have been longer than planned or the operators did additional mast measurements to reduce the uncertainties in the site and energy yield assessments. In the following figure the duration of the individual mast measurements is indicated:

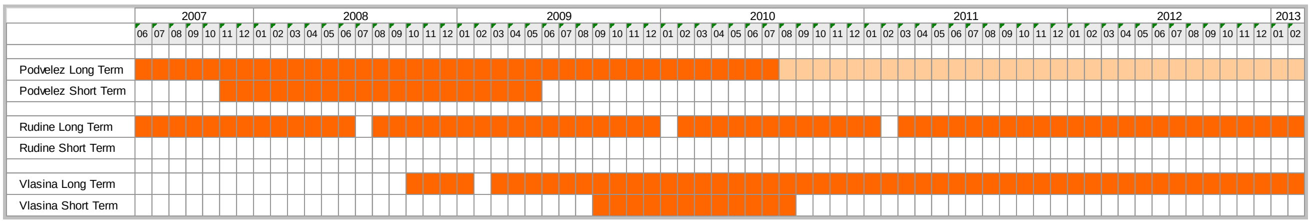

Fig. 3: Duration of the wind measurements within WP3

It turned out that under the site specific harsh conditions (ice, storms, and lightning) additional maintenance work and in some cases prolongation of the period have become necessary. Compared to the project start in May 2007, the measurement methods (heated sensors, 3D-Sonics and remote power supplies) are more enhanced and site specific at this point in time. Also the standardisation and acceptance of different sensors has changed within the years.
For all three sites it can be assumed that at the present day the technical recommendation would be to install higher masts (80-100m) and also more advanced sensors. Of course this at the same time leads to much higher costs and only makes sense at a project stage with higher chance for implementation of a bigger wind farm.
Looking in the three countries during the last 6 years of project SEEWIND, many companies have started to offer wind measurements and project development. Some impulse might also have come from the pioneering work of project SEEWIND.

Fig. 4 Podvelez /MaliGrad - Lifting 30 mast

Fig. 5 Podvelez /SvetaGora - damaged solar panel

Fig. 6 Rudine - 50 met mast

Fig. 7 Rudine - met mast foundations

Fig. 8 Vlasina /Viljekolo maintenance expedition

3.4 Vertical wind profile in complex terrain – WP 4

Knowledge of the shape of the vertical wind profile is an important issue particularly for site assessments and energy yield calculations. Strong efforts in the remote sensing technology yielded to state of the art wind measuring instruments like SODARs (SOund Detecting And Ranging) and LIDARs (LIght Detecting And Ranging). In order to gain more information on the vertical wind profile at the pilot wind park sites and to learn more about the performance of LIDAR and SODAR under harsh conditions and in complex terrain, the following measurement campaigns were carried out in WP 4:

- **Maligrad, Bosnia:**
  - SODAR: 30th of October 2007 to 4th of February 2008
  - LIDAR: 20th of November to 10th of December 2007
- **Rudine, Croatia:**
  - SODAR: 12th of February to 5th of May 2008
  - LIDAR: 9th of April to 5th of Mai 2008
- **Vlasina, Serbia:**
  - SODAR: August 19th and October 23th 2009

The following conclusions can be drawn from the measurement campaigns:

<u>Maligrad, Bosnia</u>

- The increase of wind speed with height is very small at the Maligrad site for both main wind directions. This is important information for the calculation of the expected energy yield at this site.
- There is good agreement between the vertical wind profiles measured by SODAR and LIDAR at the Maligrad site in Bosnia for the main wind directions.
- The vertical profile of the turbulence intensity stays almost constant with height at Maligrad for the prevailing wind directions.

<u>Rudine, Croatia</u>

- The increase of wind speed with height is very small at the Rudine site for all wind speed classes.
- There is a good agreement between the vertical wind profiles measured by SODAR and LIDAR at the Rudine site for the main wind directions.
- The vertical profiles of the turbulence intensities remain almost constant with height at Rudine for the main wind directions. Numerical values of the turbulence intensity from SODAR and LIDAR cannot be compared because they are dependent on the sampling rate

which is different for SODAR an LIDAR. However the data show that turbulence intensity is significantly higher for the wind direction sector north north-east compared to the wind direction sector south south-east.

Vlasina, Serbia

- The SODAR system showed a good performance while the power supply was running.
- Data availability of the SODAR was significantly reduced due to the missing power supply during night hours. This was caused by absence of the local surveillance personnel during night time. Therefore, the reached data quality is less high than at the two other project sites.
- Wind and climatic conditions were less extreme during the SODAR measurement campaign compared to Maligrad and Rudine.
- The increase of the wind speed with height is very small at the Vlasina site. This is important information for the calculation of the expected energy yield at this site.

Data analysis for energy yield calculation

The wind potential analysis and energy yield assessment for the Rudine site in Croatia for work package 7 has been performed by DEWI under consideration of the 50 m measurement mast data. Due to the complex terrain and the difference between measurement height and hub height, the analysis of the wind profile was also a task for the energy yield assessment. Therefore an additional investigation of the SODAR and LIDAR data measured at Rudine was carried out by DEWI for several measurements and periods.

Within the context of the determination of the wind profile, it became clear that the absolute values of the SODAR measurements are not consistent to the met mast or LIDAR measurement. One main influence is the reduced availability with the increased measurement height. Even after filling of gaps or same and simultaneous comparison of available data, it can be detected that the absolute values of the SODAR measurement are not usable for determine the mean wind speed in hub height. Better results were obtained for the LIDAR measurement. The values measured at 50 were comparable to the wind speed values of the met mast Rudine. The big hitch of the LIDAR measurement was the short measurement periods.

After filling gaps, the comparison of the relative wind profile of the LIDAR and showed a good correspondence. The seasonal SODAR wind gradient has been long-term corrected under consideration of the respective solar angle to gain a representative wind gradient.

The gained results of the wind profile have been taken into account for the wind potential analysis and energy yield assessment in WP7 in 80 m hub height.

One goal of the work package was to rate the suitability of the LIDAR technology under harsh conditions. The following conclusions could be drawn:

<u>Strengths of ZephIR LIDAR</u>

- Relatively easy to deploy, still some fingering with cables and tubes
- Installed by one or two person(s) in half a day
- High data availability until 150 m above ground (>90%)
- High accuracy of absolute wind speed values (compared to SODAR)
- No manual data filtering necessary
- Withstanding harsh climatic conditions
- Not affected by surrounding noise due to high wind speeds (surrounding noise affects SODAR measurements)
- Low power consumption and no noise

<u>Weaknesses of ZephIR LIDAR</u>

- Uncertainty of accuracy of wind speed data in complex terrain
- Very expensive high-tech instrument
- Slow data transfer (problem has been solved with the newest generation of
- LIDAR)
- No data for wind speeds below 4 m/s (problem has been solved with the newest generation)
- Inaccurate vertical wind component
- Measurement affected by rain and low clouds

Remark: The technological development of LIDAR system did undergo a remarkable progress during the last years. At the time when the LIDAR measurements were carried out in this project, the LIDAR technique was something very new and innovative. At the time of writing this report, many technical problems and shortcomings found during the measurement campaign in this project were already fixed by the manufacturers, some of them also thanks to direct feedback from the results of this project. Today, LIDAR has become an accepted wind measurement technology.

<u>Temporal evolution of vertical profile</u>

The LIDAR data collected during the first reporting period at the Maligrad and Rudine sites was analysed with respect to the temporal evolution of the vertical wind profile during Bora events. The results show, that the averaging interval of the LIDAR of 10 minutes was not sufficient to capture patterns in the build-up of Bora events. In order to get suitable results, an averaging interval of 1 minute or even higher should have been chosen. Furthermore, the analysis showed that the LIDAR system used within this project was in many cases not capable to record wind speed below 4 m/s. Thus the data availability at the beginning of Bora events was too poor to get reliable findings. However, the obtained results indicate that there seems to be no significant temporal pattern during the build-up of Bora events. It seems that the vertical profile is mainly driven by the local topography.

3.5 Work package objectives and starting point of work – WP 5

3.5.1 <u>To describe the local wind systems in SEE</u>

For this objective leading partner was METEOBIH. Small elaborate (9 pages) was made describing characteristic of local wind systems in South-East Europe. Bora, Jugo (Sirocco) and Koshava has been described as main local wind systems in this region.

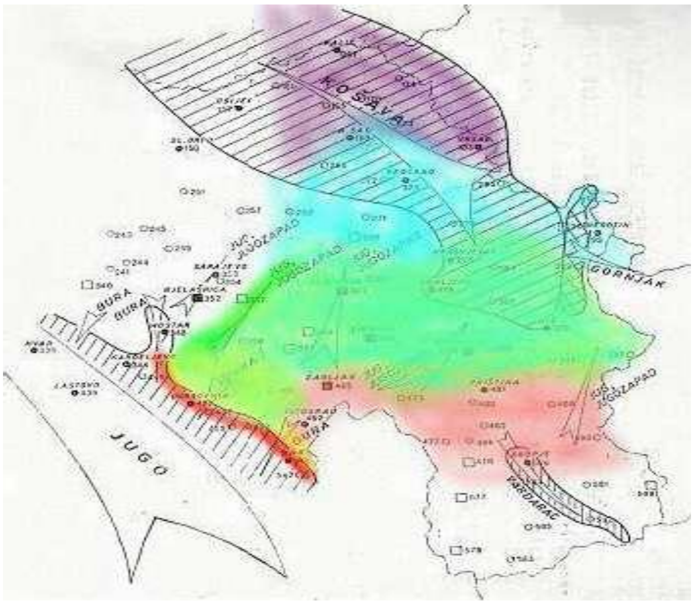

Fig. 9: Picture 1; Coridors of Bora, Jugo and Koshava

Within this objective comprehensive literature list has been collected. This list containes 67 titles.

3.5.2 <u>To describe the local wind systems at the pilot wind parks</u>

Meteotest was leading partner for this objective. As there was no pilot wind parks till the end of the project, Meteotest made a document (25 pages) describing all local wind systems in the region. They describe atmospheric driving forces for all known local wind systems as well as most significant factors as seasional influences and topography.

Fig. 10: Picture 2; All local wind systems in the SEE region

3.5.3 <u>To re-evaluate the wind data of the met station Mostar (Podvelez, BiH)</u>

Meteobih was leading partner for this objective. We re-evaluate hourly wind data from the clasiccal meteorological station Mostar, which is the nearest met. station to the choosen site. Using digitizer, we success to exctracted 10-minute values from the paper forms from mechanical anemograph, for the period of 10 years.

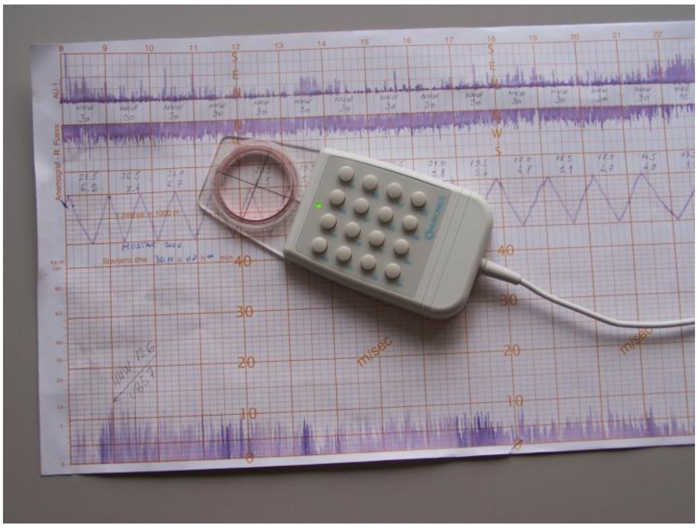

Fig. 11: Picture 3; Re-evaluation of hourly wind data to 10-min data using digitizer.

10 minutes data has been forwarded to Meteotest and DEWI for micro and meso scale modeling.

3.5.4 To make wind forecast for the pilot sites

Leading partner for this objective was Meteotest. They set WRF model (Weather Research and Forecasting Model) as new-generation mesoscale numeric weather prediction system. After some optimization, daily wind forecast has been provided on daily basis, available on project web site (www.seewind.org)

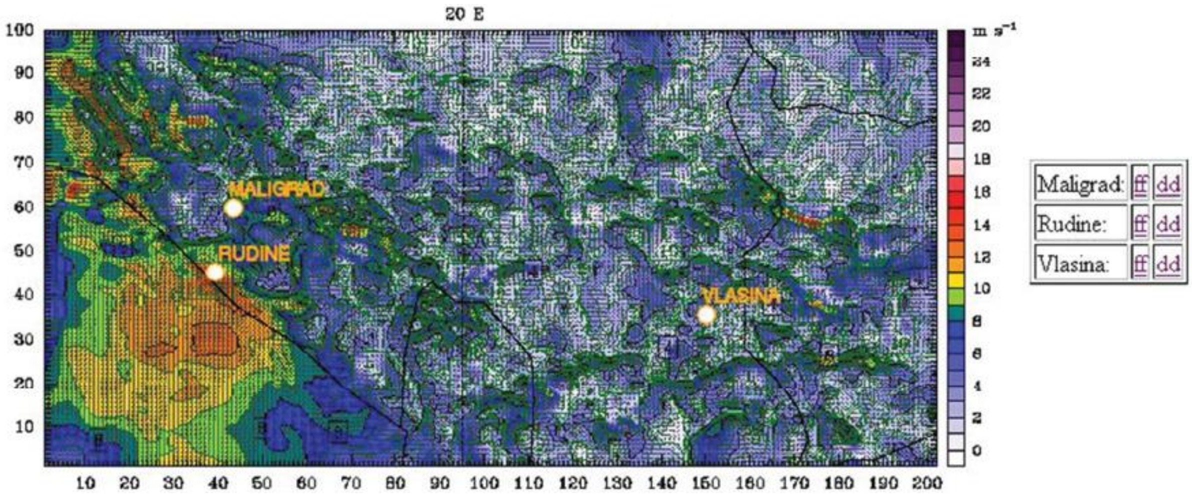

Fig. 12: Picture 4; Wind forecast based on WRF model

Model setup and the wind forecast has been evaluate with the result of LIDAR and SODAR measurement.

3.6 Meso-scale Simulations – WP 6

WP6 was aimed to improve our knowledge of the possible wind potential in SEE and to provide some valuable tools to be used for the identification and for the assessment of the wind potential in the area. The tools have been produced with the use of the mesoscale model MM5. In particular the objectives of the work Package were:

- to refine the setup and our understanding of the applied mesoscale model,
- to validate the result of the simulation with the help of the available wind data at the pilot sites,
- to apply the model for the production of a wind map useful for a first estimation of the wind potential and as base for wind energy project scouting.

The project work developed in three different stages directly connected with the objectives above.
A first task has been a survey of the existing reanalysis products (ERA40, ERA15, NCEP/NCAR reanalysis project) to be used as a source for initial and boundary conditions of the mesoscale simulations. In this stage special consideration has been paid also identify the optimal model set-up with regard to domain size, nesting configuration, grid resolution and physical parameterization. The set up in particular has been investigated in connection with WP5 (short term power forecasts) which also makes extensive use of a mesoscale modeling.
The second step has been the simulation of the atmospheric dynamics for a period of one month and correlation of simulation outcomes with existing measurements. The validation process provided an overview of the quality of the correlation scores, and contributed to apply small adjustments to the simulation configuration.
The third task has been the setup of the adjusted modeling system on a high performance computing (HPC) platform in order to run a long term simulation of 9 years useful both of wind mapping purposes and for the generation of long term time series.
The final, long term simulation has been performed with a help of an IT provider who hosted the HPC resources and which has been subcontracted for the purpose.

The two main achievements of the WP were the calculation of a long term wind map for SE Europe, which describes the wind potential in that area and at the same time the provision of long term information on the wind potential at the three project sites. The first aim has been fulfilled, especially as the wind map is used for a first estimation of wind potential and to plan further measurement campaigns. The second aim lead to partially usable results since the correlation with site data generally has been found to be not as strong as expected and did not significantly improved the already existing sources normally used in the wind energy industry. However, it has to be said that no better tools are yet available on the market both for wind mapping and for long term scaling. It is here confirmed that the best option regarding long-term assessment of the wind potential is still the use of data of met stations, yet not always available.

The long term wind speed calculated at heights 50 m a.g.l. and 100 m a.g.l. are presented in Fig. 13 and respectively.

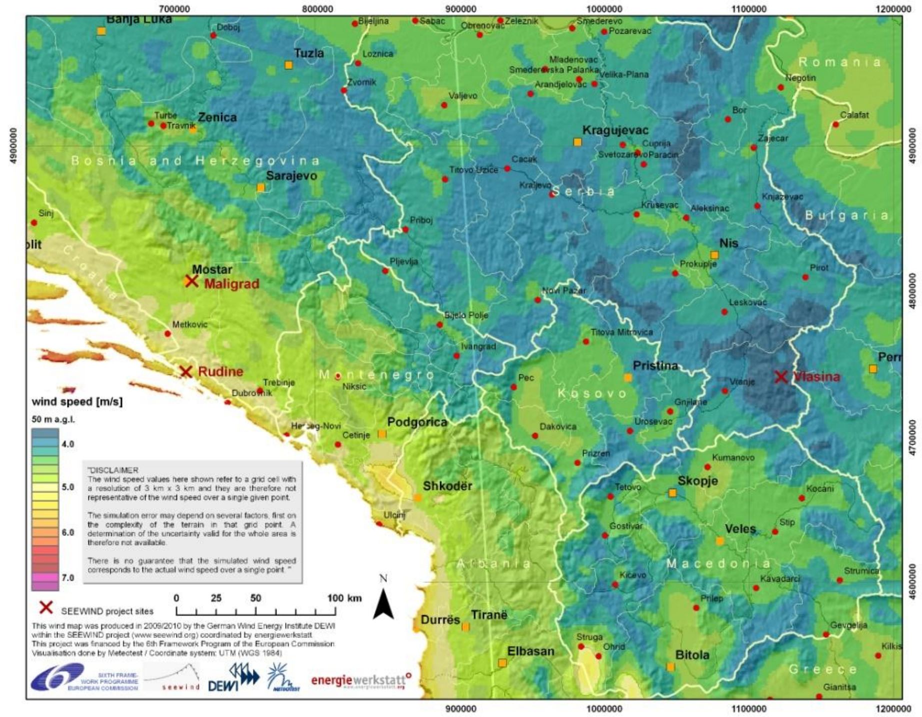

Fig. 13: Long term wind speed calculated at 50 m a.g.l. valid for the period 2000-2008

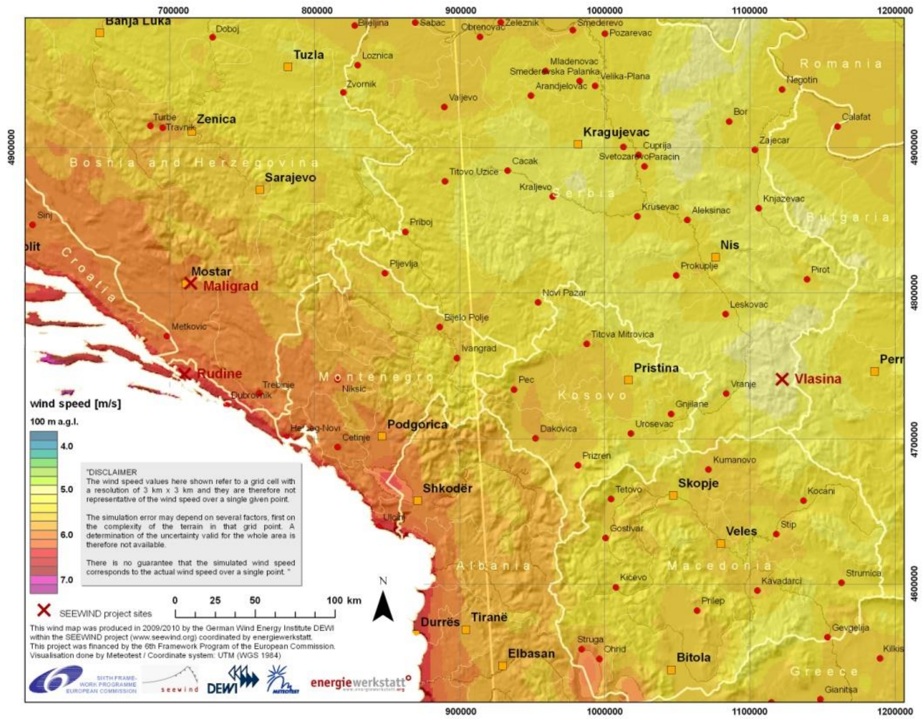

Fig. 14: Long term wind speed calculated at 100 m a.g.l. valid for the period 2000-2008

3.7 Micro-scale simulations - WP 7

As defined in the scope of work (annex I “Description of Work”), the main task of WP 7 was to perform the necessary investigations and evaluations concerning the site-specific wind conditions at the target sites. The defined tasks for WP 7 include the evaluation of the wind measurement data, long-term correction and the calculation and simulation of the site-specific wind conditions for each target site, as well as an energy yield assessment for the planned wind farm configurations, concluded by a comparison of the flow models.
Energy and site assessments have been performed for the Wind farm site Rudine, Croatia, including evaluation of Lidar and Sodar data, Wind farm site Podvelez, Herzegovina, for which also the local wind system Bora was investigated, and Wind farm site Vlasina in Serbia, which had an exposed position at 1’700 m a.s.l. (see Fig. 15 to
Fig. 17).

Within this work the long-term mean wind speed, turbulence Intensity and extreme wind speeds have been assessed.

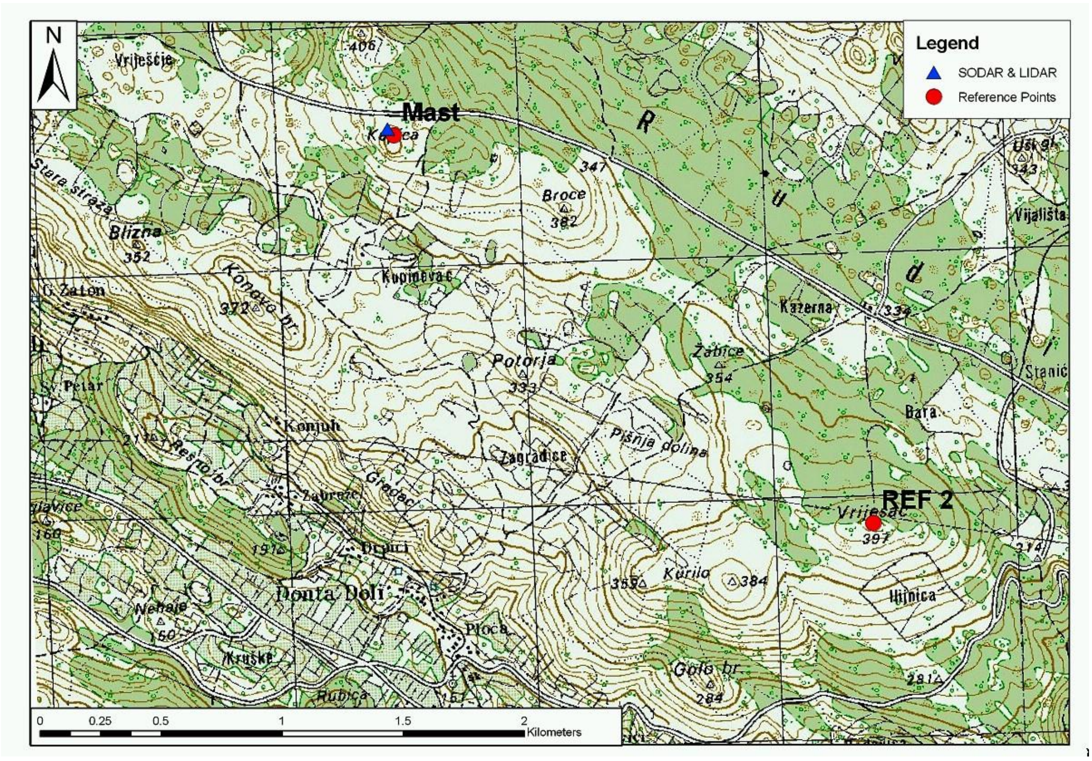

Fig. 15: Overview of site Rudine (Croatia)

Fig. 16: Overview Map of site Podvelez (Bosnia)

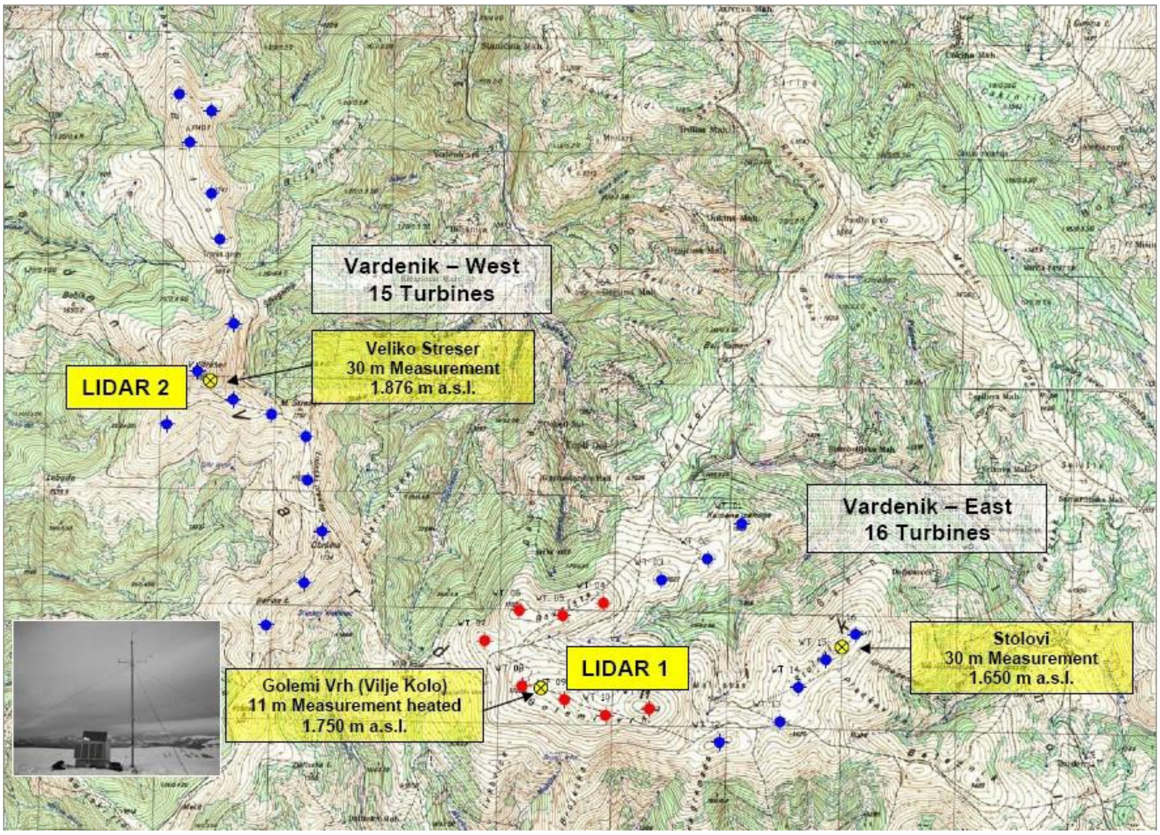

Fig. 17: Overview Map of site Vlasina in Serbia

All wind farm sites are located in complex terrain or are located nearby highly mountainous regions and directly influenced by the existing local wind systems (in this case the Bora/Koshava).

The performed site assessment for the site Rudine shows a general suitability for class I wind turbines and partly also class II wind turbines at the site, depending on the planned hub height. Further investigations will be performed in this issue. For this wind farm DEWI evaluated significant variations of the wind potential within the planned wind farm site under consideration of using state of the art CFD calculations. During the year 2008 LIDAR and SODAR Campaigns have been taken place by Meteotest CH. After the end of measurement the wind profile of the LIDAR and SODAR measurement has been determined and compared. Apart from the fact that the availability of the SODAR data drops down by increasing the measurement height, the kind of the wind profile measurement with LIDAR and SODAR can be confirmed. A second big disadvantage of the SODAR measurement is the high uncertainty of the absolute wind speed value. The LIDAR values are even more comparable to met mast data. The gained results regarding wind profile have been taken into account of the wind potential analysis and energy yield assessment for the whole wind farm area in hub height.

Those results of the comparison between SODAR and LIDAR data were presented at the SEEWIND meeting in Dubrovnik. The final configuration of the wind farm Rudine was missing for several months.

On the 23rd of February the report DEWI-W SO07-038.03 regarding Final Assessment at the site Rudine has been provided. The results of the delivered report led to further questions of Adria Windpower. Arised questions have been highlighted in an addendum and in the presentation on the SEEWIND meeting in Sarajevo. Main figure of the discussion were the plausibility of the determined wind profile regarding wind sector, respectively wind system, the presented Weibul-fit, extreme wind speeds and measurement mast position in the maps. The explanatory notes from Adria Windpower and the company RP Global have been considered for the latest issue of the report DEWI-W SO07-038.04 delivered on the 3rd of June 2010. Currently the developer is performing a 2nd measurement campaign in order to investigate wind shear and the vertical wind profile. However these assessments are not considered anymore within the frame of the SEEWIND project.

The performed site assessment for the wind farm site Podvelez (Herzegovina) defines a general suitability for wind turbines of the class IA and IB for the site. Comparable to wind farm site Rudine the site is located in an exposed hill position and located in complex terrain. Next to this the existence of a long-term reference wind measurement (Sveta Gora, 10 m measurement height) is a relevant feature for this site. For this wind farm site DEWI already performed a CFD calculation.
For the Serbian Site Vlasina all in all five wind potential analyses (instead of planned 1-2) have been performed. The last one (DEWI-W SO08-042.05, dated 2010-04-26) considers the complete

measurement periods, apart from Viljekolo 3 (partly collapsed). All other measurement have been dismantled or are collapsed. Six of seven data sets are measured data from met mast and one from a SODAR measurement. In comparison to the latest status report two measurement masts have been installed additionally. Unfortunately the 30 m measurements have been dismantled after one year. That means no overlapping period for the new measurement Viljekolo 3 (80m) or Ravnica (60m) is existing. Without a sufficient overlapping period it's not possible to improve the terrain model by all available data. That means the only ongoing measurement and reference for time series correlations was the 11 m of Viljekolo 2.

Finally the 12 months of data of the measurement masts Stolovi and Strešer, 2 months data of SODAR measurement, and 2 months of Ravnica and 5 month of Viljekolo 3 and 25 months of Viljekolo 2 have been taken into account. Data gaps have been filled completely vice versa. Finally a time series of 2 years (04/2009-03/2011) have been gained for Viljekolo 2, Viljekolo 3, Stolovi and Streser. Therefore the data of the Serbian long-term station Nis was not needed anymore.

According to the last recommendations additional measurement with higher measurement heights have been installed at the site. But the benefit is very low due to the missing overlapping period and the low data availability. Anyhow, the additional data stets have been evaluated and considered for the wind potential analysis and energy yield assessment.

The gained time series have been applied as input for a CFD calculation. The data of the SODAR campaign have been analysed and evaluated. Finally, the wind profile measured calculated by CFD has been confirmed by SODAR within the uncertainty limits. But it has to be mentioned that the SODAR data are affected by a too short period and many data gaps. Furthermore the representativeness of these data is limited to the area around the mast Stolovi. A second SODAR measurement near Streser was recommended but has not been performed.

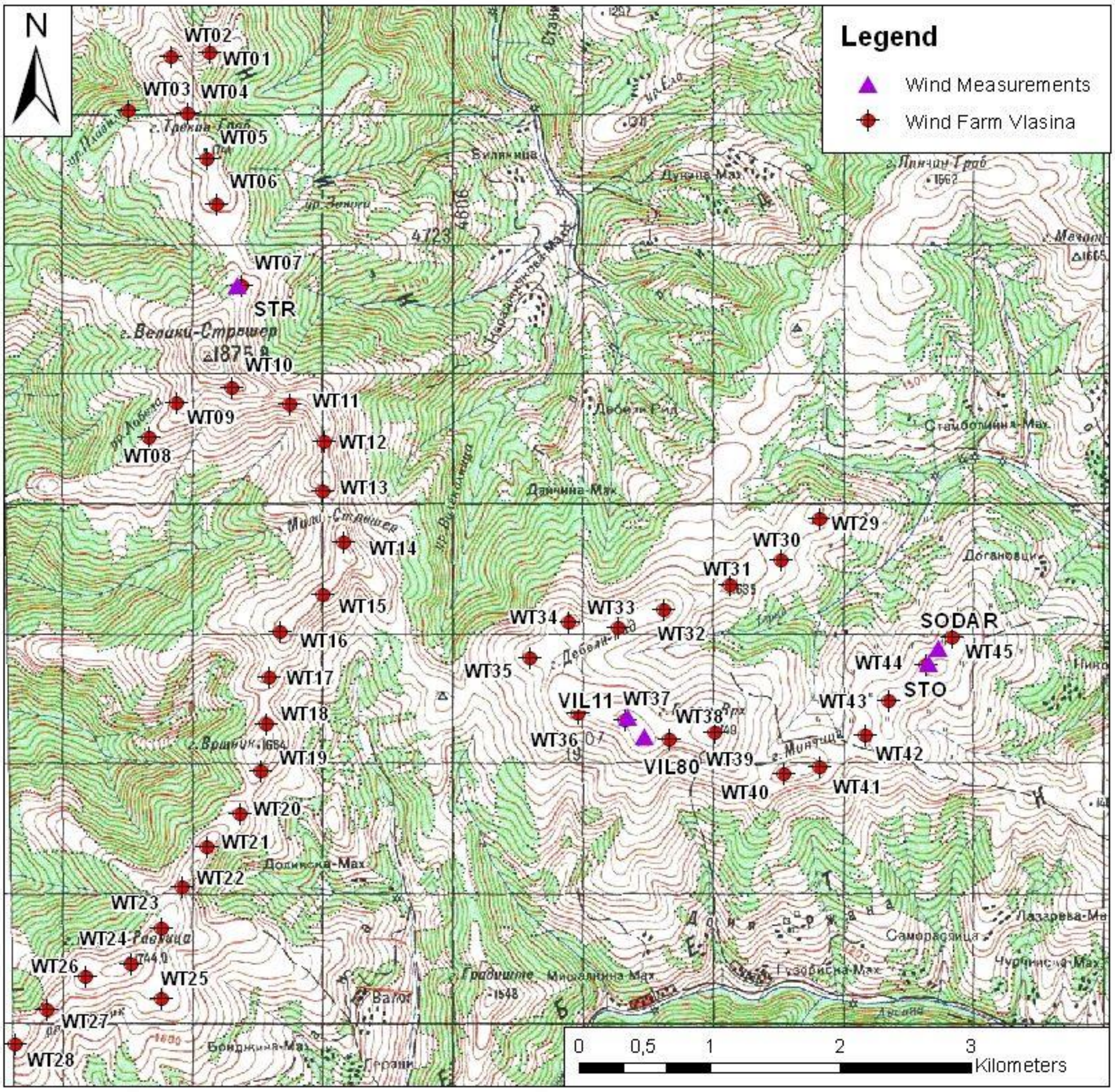

Fig. 18: Updated Wind farm configuration Vlasina

The latest report of wind potential analysis and energy yield assessment considers a different layout in comparison to the previous reports. In **Fehler! Verweisquelle konnte nicht gefunden werden.** the latest layout with additional turbines in the south-west of the wind farm site is presented. In an additional requested report only 2 turbines (WT 37 and WT 38) are considered. Due to the small distances to the measurements Viljekolo the overall uncertainty is distinctly lower (22%) than for the large wind farm area (31%).

In connection with the long-term corrected wind potential the update of the WTGS Class assessment has been performed. Two new configurations have been and one new turbine type (Nordex N90LS Gamma) has been taken into account. For both configurations the defined limits regarding wind farm turbulence are exceeded. In addition, the extreme wind criterion is exceeded at same position of the large configuration.

Due to remaining low measurement quality the uncertainty is still very high. Therefore DEWI is considering the latest and final report still as a pre-assessment. For a significant reduction of uncertainties several high quality measurements with hub heights of 60 m or more meter height and at least one year measurement period are needed.

As all assessment were connected with high uncertainties, the conclusions that can be drawn from the flow comparison are very limited.

The comparison between WAsP and CFD showed moderate to high deviations according to the terrain type. An increase of the complexity of the terrain leads to an increase in the deviations between the models. Therefore, the complex terrain Vlasina shows the highest deviations in general.

The difference between WAsP and CFD varies with the elevation of the terrain mainly. The mean wind speed at lower elevation than the measured height is usually overestimated by the usage of WASP, otherwise, for higher elevation it can be regarded as underestimated by WASP.

The comparison of the overall values results of the energy yield calculations showed a moderate, respectively a good agreement for the sites Podvelez and Rudine for the overall values. Nevertheless, the comparison of the wind potential showed for some certain turbine location high deviations.

3.8 Site Development – WP 8

Site development has been carried out at the three pilot sites Podvelez, Rudine and Vlasina. The main aim of this work package has been to obtain all required permits for the construction and operation of the respective wind farm.

In a first step, the layout of each wind farm has been optimised based on the results of micro-scale simulation and other restricting factors such as accessibility and infrastructure. Subsequently all necessary documents and plans for approval procedures have been prepared. In parallel, the environmental impacts have been assessed according to international practices. The assessments have focused on the issues noise, shadowing, visibility and ornithology.

In the following, the results of the work package 'Site development' are listed for the three separate wind farms.

Podvelez:

- The urban technical approval was obtained in October 2007
- The Environmental Approval was issued on the 10th of June 2008
- The Concession Contract with the municipality (as the land owner) was signed on the 11th of March 2011

Rudine:

- The Environmental Approval was issued on the 15th of March 2008
- The Site Permit for the location was issued on the 5th of May 2011
- Energetic Approval issued and valid
- The Building Permit for the wind farm and the substation was issued on the 15th of August 2012
- Entry into grid connection quota is expected soon

Vlasina:

- Environmental Impact Study was finished in September 2010
- Preliminary grid connection approval by national grid operator was issued in 2010

3.9 Certification and Standards – WP 9

Wind turbines are subject to environmental and electrical conditions including the influence of nearby turbines, which may affect their loading, durability and operation. In addition to these conditions, account has to be taken of seismic, topographic and soil conditions at the wind turbine site. It shall be shown that the site-specific conditions do not compromise the structural integrity. The different national building codes and related international standards in Bosnia, Croatia and Serbia as ex-parts of the same country are result of differnet posibilities for further requirements for building permissions.

Work package objectives and contractors involved

O-9.1 To work out Site Specific Certificates for the intended wind turbines to be appropriate at the Podvelez, Ravne and Vlasina sites
Contractor: DEWI-OCC offshore and certification centre GmbH (OCC)

O-9.2 To contribute to harmonize national building codes and related international standards in Croatia, Bosnia/Herzegovina and Serbia/Montenegro
Contractor: University of Mostar (UNMO)

3.9.1 Work Performed Work package O-9.1

The aim of this work package was to provide a site specific certification to support the wind turbine operators during the approval process with local building authorities and the negotiations with banks and insurance companies. Due to the fact that a site specific certification was not requested by the local building authorities nor any of the wind turbine operators as expected, it was decided to save the budget by not providing site specific certification. The work contributed to the project was therefore limited to the participation on the GA meetings in Mostar, Zagreb and Belgrade.

End Results

No site specific certification was required.

3.9.2 Work performed Work package O-9.2

Contacts with the many public authorities, institutions and persons in Bosnia, Serbia and Croatia have been established for assist for the investigation of approval procedure.

- Most of the work has been concluded before end of 3rd reporting period, but codes and standards in Bosnia, Serbia and Croatia were under investigation, also in 4th period because of delaying of project SEEWIND and possibilities for new acts on RES in Serbia, Bosnia and Croatia.

- There was a certain attempt to improve legal procedure in Croatia and there is in legal procedure in Federation of B&H (harmonized version in Parliament now) the law on RES, already 2 years, but complex political state in F B&H, particular in last year, was conditioned adoption of this law in Parliament. After adoption, it needs to do about 15 different rules.

End Results

There are no standards like the IEC 61400-1:1999 and the DIBt:2004 in Bosnia, Serbia and Croatia
The technical report concerning of the national building codes in Bosnia, Serbia and Croatia was done. It is attachment of this report.

3.10 Construction of pilot wind turbines – WP 10

Work Package 10 has focused on the following three aspects:

<u>Call for tender:</u>
Both the turbine installation and the construction works for the roads and the grid have been subject to a tendering procedure. Based on the results economic efficiency calculations have been performed and assignment-decisions taken. Details can be found in Deliverable D10-1.
<u>Calculating economic efficiency:</u>
Before starting construction work for each of the pilot turbines the economic efficiency has been calculated. These calculations take into account the detailed costs of investment, the costs for service and repairs, the costs for financing and also the income by funding and selling electricity. Details can be found in Deliverable D10-2.
<u>Wind turbine construction work:</u>
The work on infrastructure and construction of wind turbines will be carried out keeping in mind experience gained from similar projects in Austria and Switzerland or, in the case of Rudine, based on experience in the construction of wind turbines in Croatia. The wind turbines will be erected using conventional mobile cranes. At each of the pilot sites difficulties arising from the gradient or the radii of roads have to be solved.

Podvelez: - Wind turbine tender was started in May 2011 and cancelled in June 2011 due tom the decision of the new management board of EP BiH

Rudine: - Wind turbine tendering procedure finalized, contract signed with GE on the 14th of March 2013 (for more info see Deliverable D10-1)
- Detailed economic efficiency calculations have been performed for various scenarios (for more info see Deliverable D10-2)
- Construction works for roads, cables and foundations started in summer 2014

Vlasina: - The turbine tender for WF Vlasina was started in February 2011, closing date was the 5th of March 2011
- Based on the costs for the offered turbine types and the expected energy yields, profitability calculations for the individual turbine positions have been performed

3.11 Evaluation of operational data – WP 11

Due to the delay in turbine installation, the activities of this work package could not be started.

3.12 Power Curve Measurements – WP 12

3.12.1 Introduction

In the course of the Seewind research project, it was planned to perform two power curve measurements according to IEC 61400-12-1[1]. These power curve measurements should be performed on two of the newly erected turbines in Bosnia Herzegovina, Croatia and Serbia in different complex terrain situations to observe site specific effects. The results of an IEC 61400-12-1 conform measurement, should be compared to a power performance measurement using nacelle anemometry.

Deviating from the original work package it has been decided on the General Assembly Meeting in Sarajevo, Bosnia Herzegovina (2010) to measure instead both power curves at the site of Rudine, Croatia using one permanent reference mast for two neighbouring turbines of the same type.

As a preparation of the power performance measurement a site calibration has to be performed in advance. In the course of this objective the site calibration factors obtained from cup anemometers and 3D sonic anemometer should be compared in addition.

In the following, performed activities and results are briefly summarised[2], further an overview of the contributions of the project partners is given:

3.12.2 Contributions of the Project Partners

Adria Wind Power was responsible for the erection and operation of the permanent met mast which has been used during the site calibration campaigns and is planned to be used during the power curve measurement. Further Adria Wind Power delivered log books of the measurement of the permanent mast.

Energiewerkstatt has erected and operated the temporary met masts for the site calibration campaigns, partly in cooperation with DEWI. Furthermore Energiewerkstatt was involved in the data monitoring and conditioning of the data of the temporary met masts.

The University of Mostar were also involved in data monitoring and conditioning in cooperation with the project partner Energiewerkstatt.

[1] IEC 61400-12-1 Ed.1: Wind turbines - Part 12-1: Power performance measurements of electricity producing wind turbines, December 2005.

[2] Detailed information are given in the deliverables D-12.1 and D-12.2 (DEWI report number: DEWI-GER-SO-12-00042_D-12-1_D12-2)

DEWI was responsible for the final conditioning of the measurement data of the permanent and temporary met masts, beyond others the data bases have been merged and revised. Furthermore DEWI has evaluated the site calibration and delivered the corresponding reports according to IEC 61400-12-1. Evaluations on top of the IEC have further been carried out with regards to the sonic anemometers and the inflow angle at the site.

3.12.3 Site Calibration Measurements

The aim of the site calibration measurements was to determine the flow distortion correction factors of wind speed from the future locations of the wind turbines to the location of the meteorological reference mast, according to IEC 61400-12-1. For this purpose a temporary met mast was installed at the future location of the wind turbine WT-27 resp. at the location of the WT-18. The masts have been used to establish wind speed ratios based on 10 minute averages of wind speed measurements at hub height.

The required reference mast has been erected by Adria Wind Power in the end of August 2010. It has originally been equipped with 3 cup anemometers in different heights and other meteorological sensors as wind vanes. In end of December 2010 a 2D sonic anemometer has been mounted on the top of the reference mast in addition.

The temporary met masts for the site calibration have been erected by Energiewerkstatt at the planned WT positions. It should be noted that the site calibrations for WT-27 and WT-18 have not been performed contemporary but one after the other.

For the first site calibration campaign Energiewerkstatt has erected a met mast on the planned position of wind turbine 27 (see Figure 19) between 28th September 2010 and 30th September 2010. It has been equipped with 4 cup anemometers in different heights and a 3D sonic anemometer, as well as with other meteorological sensors as temperature and humidity sensors.

One of the anemometers has been damaged during the installation, the main and backup anemometer on top of the mast have been destroyed probably by lightning strikes only weeks later on 26th of October and 08th of November 2010. Due to this, the time period and amount of data for a cup anemometer based site calibration was limited. Nevertheless sufficient data to cover at least the two main wind directions at the site, which are NNE and SE, have been collected.

The site calibration factors obtained from the sonic anemometers were calculated for the period of end of January to end of March 2011 (see Figure 20).

However, as a sonic anemometer was not installed on the reference mast for the time period for which the cup anemometer based site calibration has been performed, the sonic anemometer based results could not be compared directly to the cup anemometer based data.

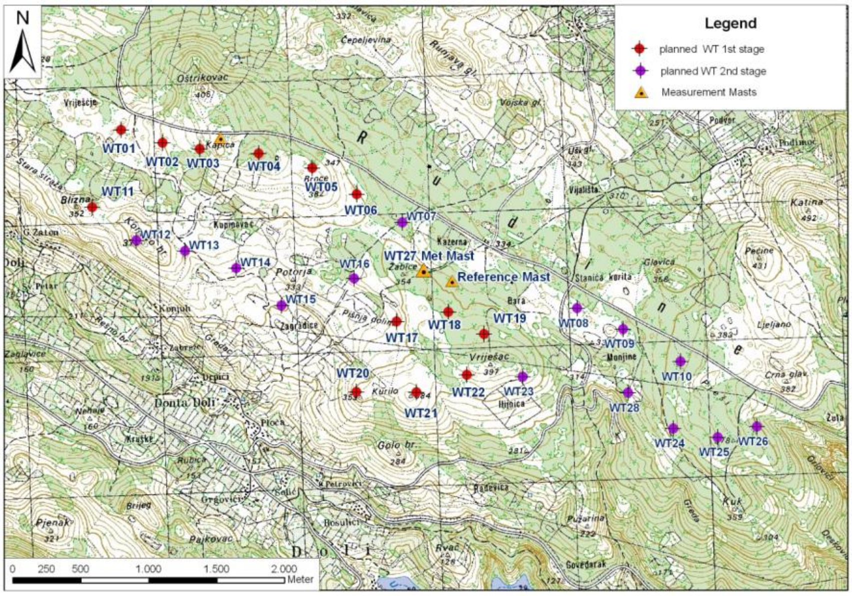

Fig. 19: Overview of the test site and the surrounding terrain

Beside of this the vertical wind profiles on both masts (reference mast and WT mast) have been calculated for the available time periods.

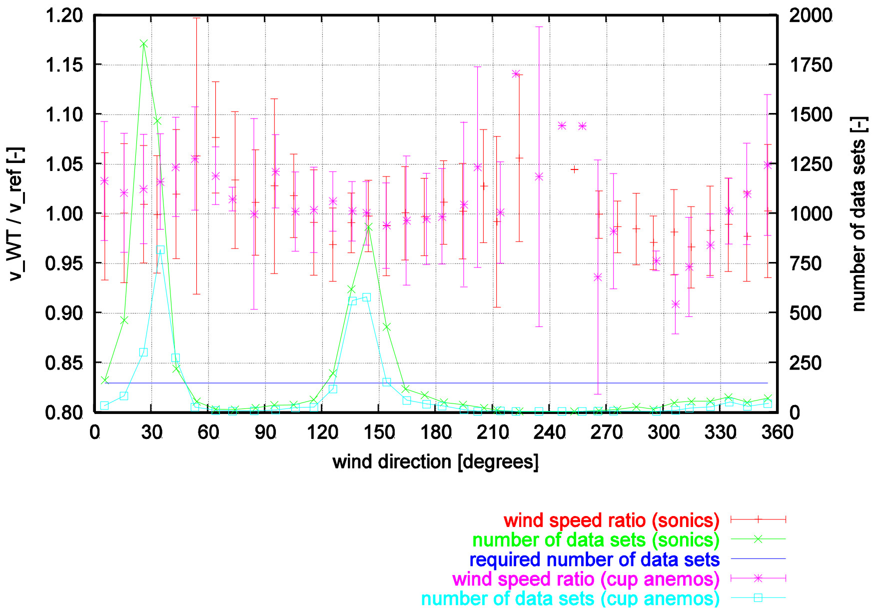

Fig. 20: Site calibration factors determined with cup anemometers and the sonic anemometers for the planned position of the WT-27

In addition the vertical inflow angle on the WT mast has been determined with help of the 3D sonic of the WT-27 met mast (see Fig. 2121).

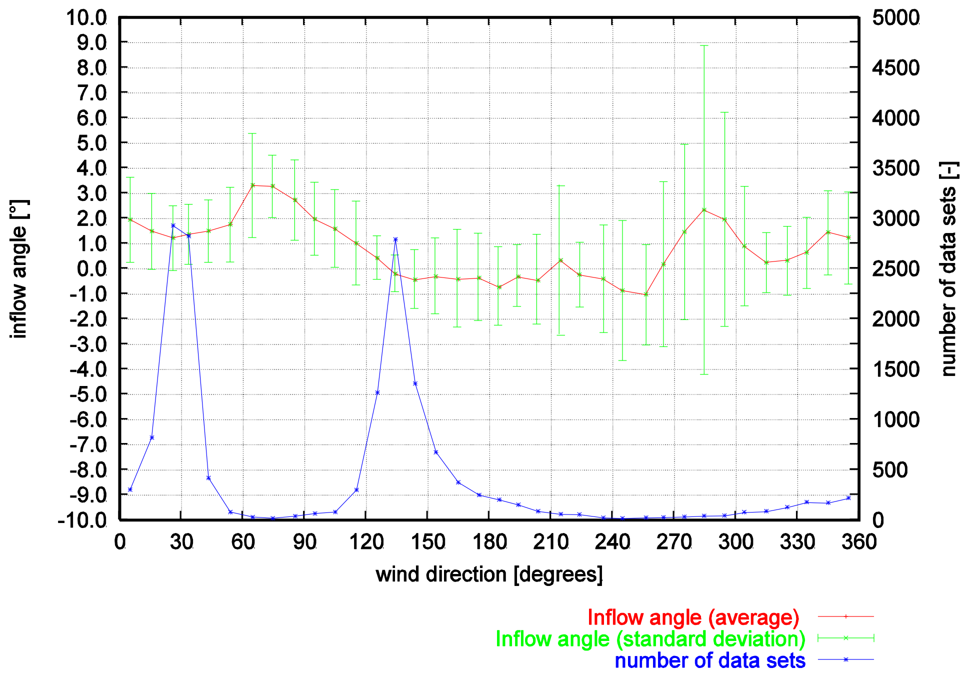

Fig. 21: Inflow angle (bin width: 10°, anemometer type: Gill Windmaster 3D sonic) for the WT mast 28

In end of March 2011 the temporary erected WT mast (WT-28) has been dismantled by the team of Energiewerkstatt, it has been equipped with new cup anemometers and has been erected at the second turbine position (WT-18). After completion of the site calibration the mast has been dismantled by Energiewerkstatt on 06th of June 2011. The site calibration has been evaluated using the cup anemometers and in addition by using the sonic anemometers. The corresponding site calibration factors are presented in **Fehler! Verweisquelle konnte nicht gefunden werden.**.

Sector from (excl.) [deg]	Sector to (incl.) [deg]	Wind direction [deg]	Number of data sets [-]	Site calibration factor [-]	Statistical uncer-tainty [-]	Site calibration factor [-]	Statistical uncertainty [-]	Difference between SCC and [-]
0	10	5.4	298	1.03210	0.00263	1.02232	0.00279	0.00978
10	20	15.2	491	1.02773	0.00200	1.01876	0.00200	0.00897
20	30	25.9	945	1.03512	0.00159	1.01960	0.00156	0.01552
30	40	34.8	1631	1.02801	0.00112	1.01014	0.00111	0.01787
40	50	44.0	668	1.01104	0.00251	0.99469	0.00262	0.01635

Tab: 3 Overview of the wind speed ratios respectively site calibration factors determined by cup and sonic anemometers

Further the results have been applied to wind speed data taken on the reference mast subsequent to the site calibration campaign. In this way the calculated wind speed data for the future wind turbine position WT-18 by means of cup and sonic anemometers have been compared (seeFig. 22), which is far more meaningful as the pure site calibration factors.

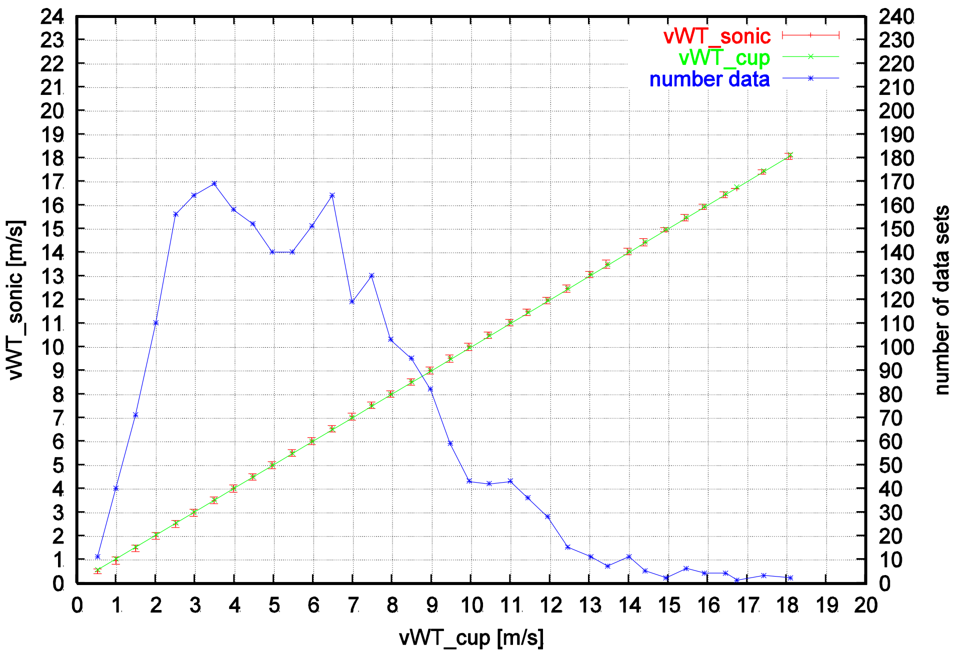

Fig. 22: Calculated wind speeds for the future WT position by means of the cup and sonic anemometer. Only datasets in the planned measurement sector (0 degrees to 50 degrees) are plotted.

A linear least square fit has been performed for the binned wind speed datasets presented below:

$$v_{\mathrm{WTsonic}} \approx (0.999 \pm 0.001) \cdot v_{WTcup} + (0.014 \pm 0.011)\frac{m}{s}$$

vWTsonic=wind speed at the future WT position; calculated by means of the sonic anemometers
vWTcup =wind speed at the future WT position; calculated by means of the cup anemometers

The relative error of the slope of the performed linear regression amounts to 0.1 % while the relative error of the intercept amounts to 78 %. Anyway the results show a surprisingly good agreement for the wind speeds calculated by means of both measurement principles.

Beside of these results, key numbers as the vertical inflow angle and wind shear on the future WT-18 position have been calculated and presented in the deliverable D-12.2.

Regarding to the deliverable of a high quality database it has to be mentioned that the quality of the data for the first site calibration (WT-27) is limited due to damaged sensors (see above) and voltage problems on both masts. Also the missing sonic anemometer and frequently changing logger configurations on the reference mast in the beginning of the measuring period have to be noted as problematic. Nevertheless all data have been conditioned and have been made available as deliverable D-12.1. The total time period of data is about seven month. The associated report is deliverable D-12.2, in which the data conditioning and measurement system is described.

3.12.4 Power Performance Measurements

Turbines are currently not installed at the site in Rudine, Croatia; in fact the planned turbine type has still not been confirmed. Due to this, DEWI could not perform a power performance measurement until now.

4. Achievements of the Project to the state-of-the-art

4.1. Wind measurements

The wind measurements have been carried out according to the state of the art. Yet several issues are still matter of investigations within the scientific community, like the shape and weight of the anemometer cups. It has been found out that especially for turbulent locations (as for the sites in Rudine, Podvelz and Vlasina) the classic anemometers show significantly higher wind speeds than most recent sensors with updated anemometry. Since the wind speed has to be taken into consideration at its cube when it comes to the calculation of the energy yield, this lead to rather huge mistakes in the results. More modern anemometer cups are less disposed to consider vertical wind speeds and turbulences and hence represent the relevant wind speed at a very precise level. These evaluations have been part in other projects in more detail. Some consolidated findings are already discussed and included in the new 2013 revised IEC 61400-12.
Additionally no state of the art technology is available for wind measurements under icing conditions at locations without grid connection. At those locations external power supply systems need to be used. However those systems are still in its fledgling stages and cannot provide enough power security to enable wind data recording throughout the winter season. During the last 6 years further development was done related to heated Ultrasonic Anemometers and remote power supplies with fuel cells. But still additional research work and practical filed experience is quite necessary in this context.

4.2. SODAR / LIDAR measurements

The SEEWIND research activities have confirmed well-known shortcomings of SODAR in comparison to LIDAR devices like low data availability of heights beyond 150 m.a.s.l and impracticality of absolute measurement values. These are the main reasons why LIDAR measurements - despite the much higher costs - tend to replace more and more SODAR measurements. In this context it is necessary to point out that in the meantime (the SEEWIND measurement campaigns took place in 2007 and 2008), the technology of SODAR devices has been improved significantly and several project developers and consultants nowadays return to the utilisation of those up-to-date SODAR devices.
Another aspect that is currently under discussion is the necessary post-processing of SODAR and LIDAR measurement data in complex terrain. Due to the fact that those remote sensing devices measure a volume flow within a cone, especially in complex terrain the results may vary from data of anemometer measurements. Currently data processing solutions are offered from the producers of the measurement devices as well as from providers of CFD models. The performance of those solutions needs to be confirmed through independent studies.

4.3. Wind Forecast Tool

The wind forecast tool which has been set up within the SEEWIND project is very innovative especially for complex terrain and of high value for the operators. As more and more wind farms drop out from the feed-in tariff system and need to sell the generated electricity on the day-ahead market, wind forecast models will get more and more interesting to wind farm operators.

4.4. Wind maps based on numerical weather models

The main aim of WP6 was to calculate a long term wind map for SE Europe, which describes the wind potential in that area and at the same time, provides long term information on the wind potential at the three project sites. Whereas the 2nd aim could be somehow fulfilled, especially as not reliable long-term data of met stations is available in many parts of SE Europe, the 1st aim only lead to partially usable results. The wind map is neither usable for the investigation of appropriate wind farm conditions nor can the results be used for long-term assessment of sites other than the three project locations. However, it has to be said that no better tools regarding that issue are yet available on the market. The best option regarding long-term assessment of the wind potential is still the use of data of met stations, yet not always available.

4.5. CFD models for Micro-scale simulations

Although CFD models have significantly improved recently, their accuracy especially in complex terrain is still limited. Investigations within SEEWIND regarding a comparison of different CFD models revealed that the comparison of the overall values of the energy yield calculation showed a moderate agreement. Nevertheless, the comparison for certain turbine locations showed high deviations in the calculated wind potential. The SEEWIND Consortium recommends further investigations in this matter.

4.6. Standards and Certifications

Although several projects are being developed in Croatia, Serbia and Bosnia, in Serbia and Bosnia still no multi-megawatt turbine has started to operate. This is mainly due to a lack of knowledge regarding approval procedure, which results in high uncertainties and risk for the project developer. It is estimated that the published results give a boost to WF development in those countries. One major recommendation of the SEEWIND Consortium is to establish a 'One-Stop-Shop', where all relevant information regarding the facts and requirements of approval procedure can be obtained.

4.7. Power Curve Measurements

Up to now power curve measurements have been performed following a short-term site calibration process. The duration for this site calibration usually has been only 8 weeks. This seems enough for locations in flat terrain, where this period can be extrapolated easily to an entire year. However, for complex terrain this is not possible, as the vertical wind profile may change significantly during different seasons. Hence the site calibration that is performed within Project SEEWIND for duration of 8 months is a great novelty and of great interest to the scientific community, not only regarding power curve measurements, but about behaviour of wind in complex terrain in general.

5. Degree to which the objectives have been reached

Objective	**Deliverables to achieve Objective**	**Achievement of Targets**
To gain experience with innovative measurement and simulation techniques in complex terrain and under specific local wind systems in SEE.	• Documentation of each SODAR and LIDAR measurement campaign • Results of each SODAR and LIDAR measurement campaign • Comparison of SODAR and LIDAR profiles • Rating of the suitability of LIDAR for measuring vertical profile of wind speed in complex terrain • Summary of the WP's main conclusions and their relevance to wind energy utilisation	100%
To improve the accuracy of energy yield prediction in complex terrain.	• Description of mean wind, turbulence, wind shear, flow inclination and extreme wind conditions at project sites • Energy yield assessment • Flow model comparison and verification results	100%
To gain knowledge about energy yield prediction at sites with specific local wind systems in SEE especially concerning extreme wind conditions and with regard to long-term behaviour of wind potential.	• Yearly reports (3 years) of long term measurements for each pilot site. • Reports on short term measurement campaign for each pilot site.	100%
To test a MW-scale wind turbine under extreme wind conditions at three different sites in West Balkans (Rudine II, Podvelez, Vlasina).	• Optimized wind farm outline for each pilot site • Reports on environmental impact statement for pilot sites • Reports on results of approval procedures • Investment cost for each pilot site based on tendering • Evidence of economic efficiency and financing plan for each pilot site • Documentation of construction works for each pilot site • Three pilot wind turbines at three project locations	80%

To generate knowledge about design parameters and power performance of operating wind turbines at sites in complex terrain and under the influence of extreme local wind conditions in SEE.	• Providing a high quality, high resolution data base for research purposes including report • Report on site calibration results with emphasis on the 3D information from the sonic and comparison with the calculated results • Report on power curve measurements with emphasis on nacelle anemometer based methods	66%
To increase efficiency and reliability of operating MW scale wind turbines at sites in complex terrain.	• Report on operational experience for each pilot site • Recalculation of economic efficiency for each pilot site • Costs for generating electricity from wind in SEE	0%
To standardize and harmonize building codes and related standards for wind turbine construction in West Balkans.	• Certification report on the assessment of site specific load assumptions for the wind turbines • Site Specific Certificate for the wind turbines • Compilation of the national building codes in a technical report	50%
To gain more detailed knowledge about possible wind potential in SEE	• Report with description of local wind systems and case study results • Long term 10-minute time series of wind data from Mostar met station • Website with 24 h wind forecast for pilot project areas • Report on the development and configuration of the meso-scale modelling system. • Validation of meso-scale simulation and assessment of the short term correlation • Meso-scale simulation of long term wind conditions over South East Europe	100%
To provide an impulse to wind energy exploitation in SEE.	• Web-site, webcam and folders for each pilot site • Information board and guided visitor tours at the pilot sites • Brochures about costs of wind energy generation and wind potential in SEE • Two conferences on wind energy in complex terrain • Wind workshop for companies • Socio-economic studies at the project sites	80%

Tab: 4 Overview table regarding the Degree to which the objectives have been reached

6. Publishable Results

6.1. Operation of numerical weather models in complex terrain

Forecasting wind and, thus, the power output of wind farms in the next hours or days contributes to an improved operation of a wind farm. Wind farm operators need forecasts to participate in a day-head electricity market or to plan maintenance of wind farms. MET-SW tested, operated and validated a numerical weather model at the pilot project sites. Validation was partly carried out in cooperation with project partner DEWI. Based on this knowledge and also the reference from the project, wind forecasts can be offered to wind farm operators anywhere in the world. Knowledge is protected as company secret.

6.2. Use of LIDAR and SODAR under harsh climatic conditions

Knowledge of the shape of the vertical wind profile is an important issue particularly for site assessments and energy yield calculations. Strong efforts in the remote sensing technology yielded to state of the art wind measuring instruments like SODARs (SOund Detecting And Ranging) and LIDARs (LIght Detecting And Ranging). MET-SW carried out several SODAR and LIDAR measurement campaigns at the pilot project sites in collaboration with project partner EWS. Validation was done partly in cooperation with project partner DEWI. Based on this knowledge and also the reference from the project, remote sensing wind measurements can be offered to wind farm planners anywhere in the world. Furthermore, a close collaboration with the manufacturers of these instruments could be established. Knowledge is protected as company secret.

6.3. Overview on local wind systems in South East Europe

Wind conditions of the Balkan Peninsula are influenced by large-scale weather patterns but also by complex orography and land-sea contrasts. Knowledge about these local wind systems and their special characteristics are of utmost importance for the planning, the installation and the operation of wind turbines on the Balkan Peninsula. MET-SW set up a report on the typical local wind systems in South East Europe in collaboration with all SEEWIND partners. The report will be freely available and thus contribute as a whole to the further development of wind energy in South East Europe.

6.4. Determination of the wind potential of Bosnia-Herzegovina, Croatia and Serbia

DEWI calculated large scale wind potential maps for 50m, 70m and 100m above ground level covering Bosnia-Herzegovina, Croatia and Serbia, with an underlying modeling resolution of 3x3km. These maps have been made available via the SEEWIND web page www.seewind.org. It is one of the few public atlases for these regions, and probably the most current one. In this way it is a good help for finding regions with general good wind potential, which is both helpful for developers and politics.

To perform wind potential calculations, the MM5 model was optimized and configured regarding physics, resolution and number of vertical layers for the use in wind energy. These results are presented the deliverable D-6-1, also available publically via www.seewind.org.

6.5. Site & Energy Assessments for pilot wind farms

DEWI performed the site and energy assessments for four pilot sites: Pag (Croatia), which was changed to the new site Rudine, the site Vlasina (Serbia) and the site Podvelez in Bosnia-Herzegovina. At the site Vlasina a Sodar device was used in parallel to the measurement masts, at the site Rudine Sodar and Lidar devices have been used in parallel with measurement masts.

All site assessments provide a solid basis for further project development on these sites, although the short measurement periods and large data gaps in combination with low mast heights reduced the possibilities to draw general reliable conclusions from these measurements.

6.6. Overview of national building codes in Bosnia, Serbia and Croatia

Contacts with the many public authorities, institutions and persons in Bosnia, Serbia and Croatia have been established for assist for the investigation of approval procedures. Overview of national building codes in Bosnia, Serbia and Croatia in form of the technical report was done and it will be freely available to the further development of wind energy projects in South East Europe. It has to do to improve legal procedure in Bosnia, Serbia and Croatia in next period.

6.7. Re-evaluation of old paper wind charts to get valuable 10-minute values

During the project special way of getting 10-minutes wind data from old paper charts from widely represented (at this region) mechanical anemographs has been developed. Usage of digitizer has been applied, and by that means 10-minutes values has been very precisely determined.

List of Tables

List of figures