of wind prediction are usually not able to guarantee such high accuracy, especially within high mountainous terrain like in the Khuzestan and Kohgylooyeh Boyer Ahmad provinces. However, it should be taken into account that plausible final results are not available before completion of the 12-month wind measurement.

After completion of the calculation process for the complete windmap, a more detailed windmap for the Kohgylooyeh Boyer Ahmad province was done.

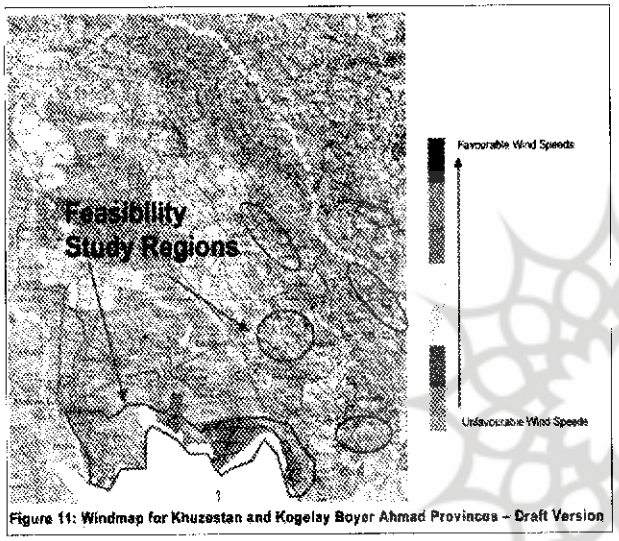


Figure 11: Windmap for Khuzestan and Kogelay Boyer Ahmad Provinces – Draft Version

5. Wind Information System

To simplify processing of the measurement data a so called wind information system (WIS) will be established for the KWPA supply region. The wind information system includes a database for wind measurement data storage and evaluation as well as a digital version of the wind potential map. A special feature enables an update of the wind map in the case more wind measurement data or stations are available and the calculation of the energy yield for a chosen wind turbine type at anyone site.

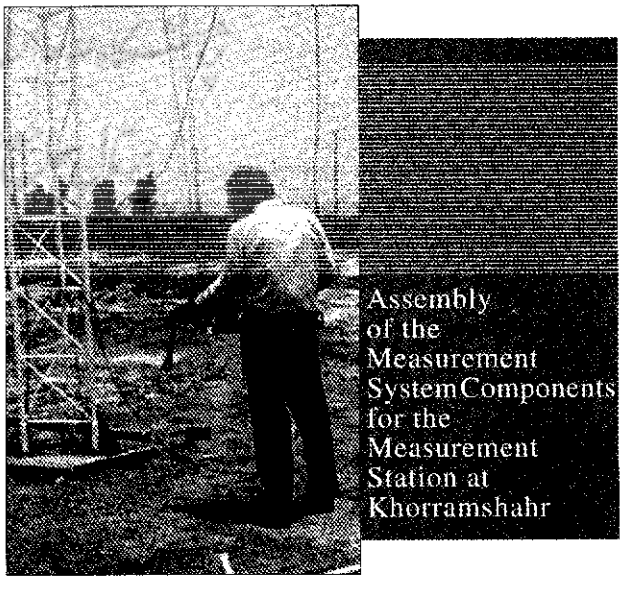
Up to now, the wind information system includes a data base of approximately 20 wind turbine types, ranging from a few hundred kW up to the 2.5 MW class. In the future, the data base will include the 50 most common wind turbines.

6. Opportunities for wind energy applications

On basis of the intermediate results, several sites with favourable conditions for wind energy applications have been identified:

- One location which is suitable for a wind farm is the coastal region near the cities Abadan and Khorramshahr. In this area wind velocities above 6 m/s in average have been measured since June 2003. Here it is possible to install a pilot wind park with a capacity of approximately 30 MW, which is corresponding to a number of approximately 15-20 turbines, depending on the capacity of a single wind turbine.
- A second site with favourable wind conditions was identified near the construction site of Marun Dam, which will be operated by KWPA. The available land area enables the installation of approximately 30 wind turbines, with 60 MW of a total capacity. In addition, the combination with hydropower is possible at this site and would result in additional benefits and cost reduction.

The next project steps will be the preparation of a feasibility concept in the first half 2004 for the above mentioned wind farm sites. Based on the results of the feasibility concept the implementation of the wind farms may be possible in 2005.


Assembly of the Measurement System Components for the Measurement Station at Khorramshahr

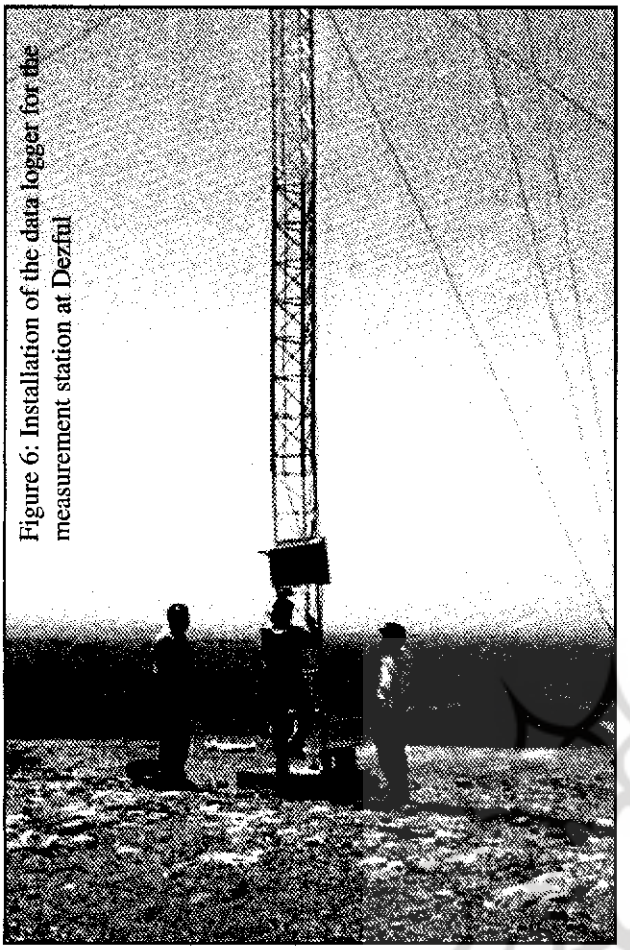


Figure 6: Installation of the data logger for the measurement station at Dezful

The following table summaries the intermediate results of the measured wind speeds.

Site	Start of Measurement	Average Wind Speed at 30m a.g.
Korramshar	03.06.2003, 18:00	6.4 m/s
Dezfull	04.06.2003 14:40	3.9 m/s
Masjed -e- Soleyman	07.06.2003 18:10	3.1 m/s
Behbahan	17.07.2003 12:20	3.5 m/s
Margoon	11.12.2003 12:40	3.1 m/s

An analysis of the wind direction indicates, that the wind flow at two of five stations (Khorramshahr and Masjed -e- Soleyman) is driven by the upper air wind conditions, whereas the wind speeds for the stations at Dezfull and Behbahan are mainly influenced by the local terrain. The following pictures show the wind direction distribution for the measurement station and the average wind speed per sector.

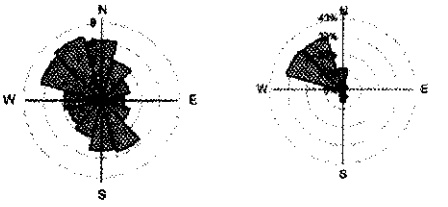


Figure 7: Average Wind Speed Distribution in [m/s] (left) and wind direction distribution (right) for Korramsharr

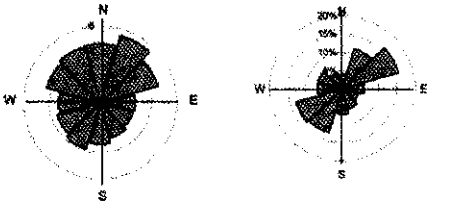


Figure 8: Average Wind Speed Distribution in [m/s] (left) and wind direction distribution (right) for Dezfull

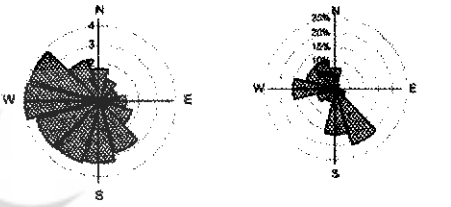


Figure 9: Average Wind Speed Distribution in [m/s] (left) and wind direction distribution (right) for Masjed -e- Soleyman

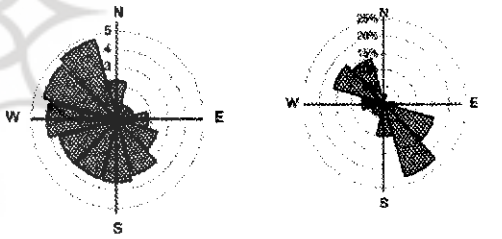


Figure 10: Average Wind Speed Distribution in [m/s] (left) and wind direction distribution (right) for Behbahan

4. Results of the calculation

The following picture shows a draft version of the calculated wind speeds in an elevation of 80m above ground.

It is obvious that the best wind conditions can be expected near the shore line and on top of some mountain hills in the eastern part of the Khuzestan province as well as in the province Kohgylooyeh Boyer Ahmad.

A first comparison of the intermediate results of the wind measurement campaign and the simulated wind velocities resulted in a deviation of less than 10 %. Other methods

conditions.

During the numerical calculation boundary conditions are kept fixed, while the threedimensional flow pattern – after a certain iteration time – adapts itself within the complex terrain. The numerical iteration is proceeded until the wind speed alterations within one incremental time step under-runs a given limit value. The three-dimensional flow adjustments result in the occurrence of the characteristic flow patterns, such as channelling along valleys, speed-ups while traversing mountain ridges, weakening at the lee side of mountains as well as over forest areas and the large-scale passing of the major topographic structures.

For the preparation of the wind map the following working steps have been performed subsequently:

- Data collection and pre-processing of input data for the KLIMM model.
- Performance of the flow simulations with the KLIMM model for totally 16 individual meteorological situations (8 wind sectors x 2 temperature profiles).
- Superposition of single results according to their individual frequency to give the complete long-term representative annual wind pattern.
- Fine-adjustment of the long-term annual wind speeds through correlation with wind measurement data at according to totally 4 locations within the investigation Korramshar, Dezfull, Masjed -e- Soleyman and Behbahan with measuring heights of 30 m)
- Terrain following extraction of wind speeds for a fixed height above ground (80 m) and preparation of wind map.

2.5 Model Area

The provinces Khuzestan and Kohgylooyeh Boyer Ahmad measure approx. 128,000 km2, and are located between 30°00' and 33°30' Latitude North and 48° and 51°30' Longitude East. The landscape in these provinces is dominated by a rocky tableland, ranging between sea level and approximately 4,000 m above see level in the Kohgylooyeh Boyer Ahmad province. Major mountain ranges, the Zagros Mountains, appear all over the northern and eastern part of the provinces. The southern part is dominated by a large flat plain, which starts from the Persian Gulf and stretches towards the mountainous area at the northeast.

The model area comprises a horizontal extension of 356 km x 328 km, covering an area of 116,768 km² with a grid resolution of between and 1,000 m.

3. Wind Measurements

To improve the accuracy of the wind potential map calculation, five wind measurement stations have been installed in mid 2003 in the Khuzestan and Kohgylooyeh Boyer Ahmad provinces by KWAP and Lahmeyer International and will be operated for a period of 12 months. All measurement stations are equipped with two sensors, installed at 10 and 30 m above ground to mete the wind speed and a wind vane for the wind direction. All stations take wind data in ten-minute steps. Monthly data transfer and station maintenance is performed by KWPA staff. Four measurement stations were installed in June 2003 a further station in the province Kohgylooyeh Boyer Ahmad in December 2003.

The following two pictures give an impression of the installation process of the measurement systems.

2.3.1 Topography File *.TOP

The topography data are stored in the KLIMM topography file: *.TOP, usually named by the name of investigation area.

This file contains the KLIMM topography matrix (altitudes) with NX columns and NY rows.

Additionally there is a header consisting of three parameter lines:

- The first line contains the number of grid cells in x-, y- and z-direction.
- The second line contains the z-levels of the vertical layers
- The third line contains the horizontal grid spacing and the topography minimum value

The following picture shows a 3D-simulation of the topography data.

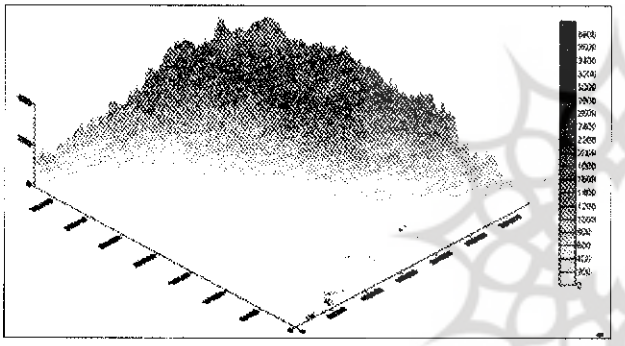


Figure 4: Digital elevation model (DEM) of the Khuzestan and Kohgylooyeh Boyer Ahmad Provinces

2.3.2 Land-use File *.BOD

This file consists of an ASCII matrix of integer values. The size of the matrix corresponds directly to the horizontal dimensions of the grid. Each value represents a land-use type for the corresponding grid cell. The following land-use types are actually parameterised in KLIMM:

2: loosely built-up area, uncongested
3: densely built-up area, congested
4: water
5: grassland
6: farmland
7: deciduous forest
8: coniferous forest
9: mixed forest
10: permanent crop
11: sand, dunes
12: moor land
13: special usage (e.g. surface mining)
14: medium congested built-up area
15: general ambient average type

2.3.3 Vertical Temperature Profile *.TEM

This file describes the thermal stratification of the atmosphere to be modelled by KLIMM. It contains temperature values in [°C] for the individual vertical layers as a result of the application of the tool MAKETEM. Since in the course of the wind flow calculations the temperature profile is used as a fixed boundary condition, the KLIMM reacts rather sensitive on these input data, especially if they are faulty, i.e. unrealistic. Using the MAKETEM ensures more or less smooth vertical temperature profiles. Only the vertical temperature gradients (in [K/100 m]) have to be defined.

2.3.4 KLIMM Control Files *.INP

These files control the KLIMM runs for the individual wind directions and temperature profiles. The structure of the files is as follows:

1	new run (=0 for continuation run)
500	number of time steps
1	for control of output (binary, ascii, logging)
9.0	geostrophic wind speed in [m/s]
45.	geostrophic wind direction in ° against North
sar	prefix of input file names in "EIN" directory
sar45	prefix of output file names in "AUS" directory

2.4 Calculation runs

With topography, land use, geostrophic wind distribution and the temperature stratification of the atmosphere the numerical model for the KLIMM flow simulations is well defined. For the defined model area the KLIMM runs are performed for totally 16 individual meteorological situations (8 wind sectors x 2 temperature profiles). Each individual flow simulation is carried out with the respective characteristic meteorological boundary

sectors are decisive for the highest wind velocities.

2.2 Temperature Profiles

For the assessment of the wind characteristics in the investigation area, apart from the upper air wind statistics, also information on the atmospheric temperature stratification is required.

The temperature stratification describes the strong influence of atmospheric stability on the local flow pattern. For instance, in a stable stratification of the atmosphere (represented by cold air near ground covered by warmer air in the upper layers) the vertical mixing of air masses – and the transportation of upper air wind speeds towards the ground – is very much suppressed compared to an atmosphere with unstable stratification (represented by air near ground warmer than above), which facilitates vertical mixing. As a consequence, wind speeds at a certain location near ground can differ with atmospheric temperature stratification although the upper air wind speed is the same.

For the provinces Khuzestan and Kohgylooyeh Boyer Ahmad, two different temperature stratifications were taken into account for the calculation:

Table 1: Upper air wind distribution in approximately 5,900 m above ground

Wind direction sector	Mean wind speed [m/s]	Frequency share
0° = North	8.47	3.4 %
45°	4.99	2.8 %
90° = East	4.02	3.8 %
135°	4.45	2.6 %
180° = South	6.81	4.3 %
225°	15.00	17.9 %
270° = West	16.37	49.2 %
315°	13.09	15.7 %
Total	14.01	100 %

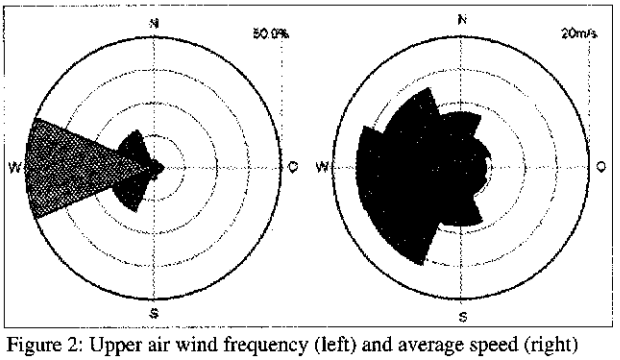
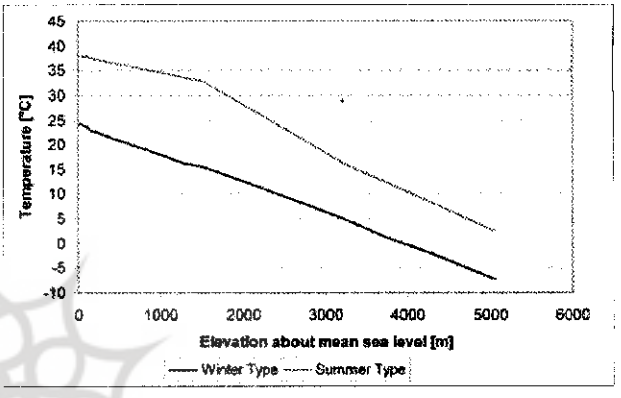


Figure 2: Upper air wind frequency (left) and average speed (right)

1. A "winter type" profile for the seasons January-June and October-December. These months are characterised by high wind velocities from western direction.

2. A "summer type" profile for the months July-September. During these three months, lower wind speeds occur from eastern and southern directions.

The following figure demonstrates the differences in the temperature profiles.



2.3 The KLIMM Program System

The KLIMM simulation is based on a division into Cartesian cells. The investigation area is divided in grid cells with a horizontal resolution depending on the topography and a vertical resolution depending on the height of the wind turbine.

The KLIMM Program System consists of several routines which can be changed individually for each application. It contains the following programs:

Table 2: The KLIMM Program System

Program File	Working Step	Purpose of Application
KLIMM	main routine	calculation of wind velocity and direction
PARAM.TKE	parameter file	
TOPOG	topographical data	calculation and evaluation of the topographical data
SMOOTHER	smoothing the topographical data	SMOOTHER is directly applied to the topography file in KLIMM input files directory "EIN". It changes the original KLIMM topography file *.TOP. After the SMOOTHER has been applied TOPOG has to re-run according to the changed topography
TOPTOSU	Visualisation	the topography file *.TOP is re-formatted into a general (x,y,z) column format using the tool TOPTOSU
MAKETEM	thermal stratification	calculation of thermal stratification
MESOPOL	Output file transfer	MESOPOL reads the KLIMM binary files and produces a new corresponding ASCII file For given reference points MESOPOL will provide the vertical wind profiles
MELTASC	Results for generation of wind maps	MELTASC provides a statistical mixing of individual wind directions and temperature stratifications for generation of wind maps

Articles

Wind Potential Analysis for Khuzestan Province

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1 Introduction

Due to the promising wind conditions in the Khuzestan and Kohgylooyeh Boyer Ahmad provinces, especially in the coastal area and on the mountain ridges, KWPA decided to carry out an analysis of the regional wind conditions with the objective to implement several wind energy projects in both provinces.

One method to achieve reliable information of the regional wind conditions without implementation of long-term wind measurements is the calculation of a so called wind potential map. The main objective of this region-wide wind potential map is to show favourable areas for the upcoming development of wind energy projects.

2 Calculation Method

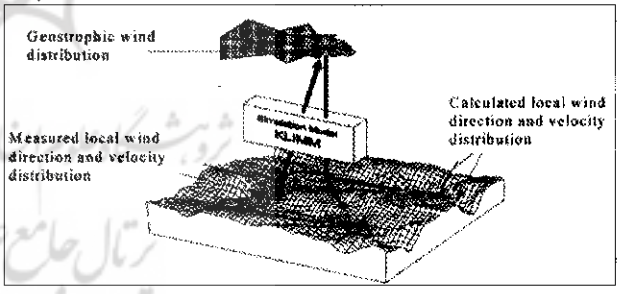
The calculation of the wind potential map has been done by using the KLIMM model, originally developed by the University of Mainz and Lahmeyer International, Germany, being a three dimensional numerical mesoscale model of the atmosphere which allows to simulate wind situations at any point in the atmosphere. From this, an analysis of typical weather situations and locally measured wind resource data, the long-term annual wind speed for any location can be calculated. KLIMM has been already applied successfully in various wind mapping projects like in Panama, Eritrea and Greece for example.

For the desired results the KLIMM model only requires the following input data:

- Geodetic height data (satellite data or digitised from topographic maps),
- Information of the land-use (water surface, forest, agriculture, city,...),
- Measured geostrophic wind rose and air temperature stratification at one location,
- Measured wind velocities at a few numbers of wind monitoring stations (meteorological office, airports or additional wind monitoring stations.

The following figure shows the general simulation approach of KLIMM. As can be seen it is a "top-to-bottom" approach. Starting from the distribution of the upper air geostrophic wind, the model calculates for each grid cell within the three-dimensional terrain the wind direction and the wind velocity.

In order to get an overview on the KLIMM program system, the following sections describe the various data pre-processing and post-processing tools, developed as Fortran programs.



2.1 Upper Air Wind distribution

With regard to the wind direction and wind speed distributions to be expected in the investigation area, the measured upper air wind directions and wind speeds for three different locations at an elevation 5,900 m above mean sea level, have been used for the calculation.

The averaged long-term representative upper air flow characteristics are shown in the following table. The most frequent flow directions are represented by winds coming from western directions. The same direction