ALPINE WINDHARVEST

Development of information base regarding potentials and the necessary technical, legal and socio-economic conditions for expanding wind energy in the Alpine Space*

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Work Package 03

Technological Aspects

Energiewerkstatt Verein

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Alpine Windharvest Homepage: http://www.sbg.ac.at/pol/windharvest

ALPINE WINDHARVEST

… is an interdisciplinary research project funded by the EU Interreg IIIB "Alpine Space Programme" (Project No. A/I-2/3.1/5) and by national and regional co-financing bodies of the project partners. The project started in May 2002 and will end at the end of April 2005.

Background of the project:

Wind power became a leading renewable energy technology in flat terrain, especially near shore. While the alpine space also promises some excellent wind locations, much of the knowledge and experience accumulated about wind power so far cannot simply be transferred to the alpine setting.

The lack of experience concerns all levels of government confronted with problems of siting, spatial planning, nature protection/environmental impact analyses, road and electric grid requirements, appropriate tariff regulation etc. The project aims at remedying these deficiencies.

This lack of experience also regards entrepreneurs, investors and even producers of equipment given the special climatic and geological conditions. This increases economic risks, inhibits site exploration and planning activities even for attractive locations. The small number of existing projects in the alpine space impedes standard procedures.

Lack of experience also affects the acceptance of wind power by nature protection organisations and local residents. There is much need for additional knowledge and information; standard models for the resolution/mediation of conflicts will be useful.

For this reason, it is essential to pool the limited experience with wind power in the alpine space for synergy effects, cross-fertilisation and greater efficiency in developing data sets, methods, approaches and solutions for public and private actors, particularly since many of the underlying phenomena are trans-national while most research so far was primarily national (e.g. meteorology).

A common approach will facilitate a harmonised European approach to the problems under consideration, particularly with regard to government policy.

Main activities:

Develop knowledge basis for deploying wind energy:

a) Methods and instruments for identifying wind energy potential in complex terrain more efficiently (meteorologists, geographers, digital relief analyses and actual wind measurements; includes pilot measurements on specific locations).

b) Deal with problems peculiar to wind turbines in alpine conditions (blade icing; access - need for special mounting equipment); standardise technologies, estimates of access requirements (roads and grid). Common approaches for entire alpine space will create bigger market for improvements and induce responses from equipment manufacturers.

c) Analyse ecological impact of turbines in different alpine settings on fauna and flora according to altitude, soil/rock and meteorological conditions; establish check list of factors for whole alpine space. Develop strategies to minimise impact. Improve information for local/ regional authorities.

d) Analyse and compare legal, social, political and economic framework conditions for deployment of wind power in alpine space and their impact on its competitiveness. Formulate regulatory proposals.

e) Prepare methods of resolving conflicts between wind power and other interests (environmental organisations, local residents, hunting). Improve visualisations (more difficult in alpine terrain), standardise participation in administrative procedures and mediation. Facilitate work of local and regional authorities.

f) Measure potential contribution of this energy source to regional development, particularly when joined with hydro storage and electricity generation from biomass.

Alpine Windharvest Report Series:

The Alpine Windharvest Report Series is published by the Alpine Windharvest partnership network in order to disseminate the results of the project to the interested public and to experts in the field. Reports are edited by the responsible project partner(s) who commissioned and approved the report according to our internal division of labour. Reports can be downloaded from our homepage. Printed versions can be directly ordered from the project coordinator by e-mail: dieter.pesendorfer@sbg.ac.at.

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WP-03 Technological Aspects

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Abstract

At the end of 2004 there was an installed capacity of 41,000 megawatt of wind energy worldwide. With an installed capacity of 34,000 MW, the 15 EC states meanwhile cover about 3% of their electricity demand with wind power. For central European countries without their own coastal area the use of exposed locations in the Alps provides a possibility to intensify the deployment of wind energy. The technical challenges posed by complex terrain and extreme climatic conditions were examined in the AWH project.

Currently there are 39 wind energy plants operating at alpine sites in Austria, Italy, France, Slovenia and Switzerland. The 34.2 MW installed capacity of these plants corresponds to only 1.5% of the total wind energy capacity in the region of the Alps that was surveyed. There are however now 126 MW under construction or in the process of planning permission at alpine sites and approximately 380 MW in the phase of design planning.

So far it has not been possible to gain sufficient experience in the construction and operation of wind energy plants in alpine locations and there is a need for research and development into the necessary modifications in turbine technology to comply with the conditions prevailing in the Alps. A survey involving the operators of existing wind energy turbines in the Alps was intended to support the evaluation of problems to be faced in the field of transport, erection, cable installation and operation of the turbines under extreme climatic conditions. The standard turbines currently available are suitable for use at alpine sites only to a certain extent. The turbines can be modified for transport and erection in exposed locations at a justifiable cost and the corresponding know-how already exists. On the other hand there is a need for action with regard to the operation of the turbines at very low temperatures and the problem of ice build-up on the turbines, the rotor blades and the control sensors has not yet been completely solved. In practice hardly any measures are taken to prevent the danger from falling ice and hardly any attempts have been undertaken to solve the issues of heating the rotor blades and developing reliable sensors to control the turbines.

The figures collected concerning future development and the experiences of the operators of existing turbines in the Alps basically confirm the need for action in the field of research and development. At the same time it should be taken into account that the solutions called for would also be applicable to large areas of Northern and Eastern Europe and can present a vast additional potential for wind energy worldwide.

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1. Introduction

At the end of 2004 41,000 megawatt of wind energy had been installed worldwide, about three-quarters of this in Europe. With an installed capacity of 34,000 MW the 15 EC states meanwhile derive approximately 3% of their energy requirement with wind energy. The targets for further development of wind energy deployment in Europe are mainly concentrated around offshore areas. Wind turbines with up to 5 MW installed capacity and 126 m rotor diameter are already at prototype stage and in the coming years 15,000 MW wind energy farms are to be constructed in coastal waters.

Countries without a coastal area of their own can potentially make use of exposed and windy locations at altitudes of over 1,200 m in order to best exploit wind energy. The technical challenges this poses with respect to complex terrain and extreme climatic conditions require a different approach than solutions for offshore operation. The turbine manufacturers address this subject only hesitantly mainly because for the most part they are still treading on new ground.

The examination of the economic and technical prerequisites for exploitation of wind energy in alpine regions detailed in this report is based on the survey and analysis of experience already gained and it gives an estimate of the short and long term developments that are to be expected and the potential for development in the corresponding regions.

The area surveyed is defined with the appropriate alpine sub-areas of the regions and countries shown below: Rhône-Alpes region in France, Trentino-Alto-Adige region in Italy, the federal states of Styria, Salzburg, Tyrol, Vorarlberg in Austria, Slovenia and Switzerland.

Fig.1: Map showing the participating regions and the installed wind energy capacity of the countries (end of 2004)

2. A survey of the installed wind energy capacity in the Alps

The survey of installed wind energy capacity was limited to the alpine regions of the countries participating in the Alpine Windharvest project. Although at the end of 2004 the total wind energy capacity installed in France, Switzerland, Italy, Austria and Slovenia was 2,126 MW, only 1.5 % of this was in operation in the alpine regions of these countries. In the area examined a total of 39 wind energy installations with a turbine capacity of between 20 and 1,750 kW and a total capacity of 34.2 MW were recorded.

Region/Country	Number	Installed capacity [kW]	Annual output [MWh]
Austria (Styria, Salzburg, Vorarlberg, Tyrol)	15	24,100	54,600
Switzerland	22	8,635	10,036
Slovenia	0	0	0
Italy (South Tyrol)	2	1,500	1,900
France (Rhône-Alpes)	0	0	0
Total	**39**	**34,235**	**66,536**

Table 1: The number and capacity of wind farms in the alpine sections of the regions and countries surveyed

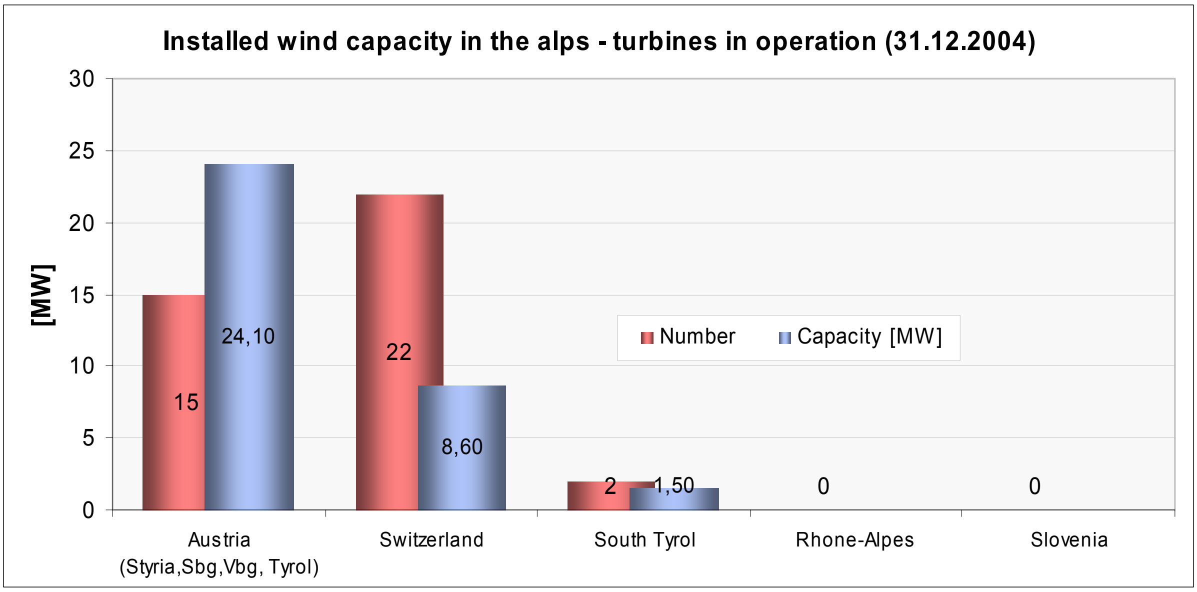

Fig. 2: The number and capacity of wind turbines in the Alps

2.1 Austria (Styria, Salzburg, Tyrol and Vorarlberg)

The Austrian provinces of Vorarlberg, Tyrol, Salzburg and Styria are participating in the project 'Alpine Windharvest'. In these regions a total of 15 wind energy farms with an installed capacity of 24.1 MW and an annual generating capacity of 54.6 GWh are in operation. The general map displayed shows that all plants examined in the survey are situated in Styria whereas in the western provinces of Vorarlberg, Tyrol or Salzburg no plants are in operation.

The main reason for this development in the Austrian alpine region is that the province Styria has been very active in the development of wind energy, undertaking extensive planning activities. Styria was the first of the alpine provinces to commission an investigation into the deployment wind energy.

Fig. 3: Tauern Wind Park Oberzeiring (A) at an altitude of 1,900 m

The plants operating in Styria prove that excellent output can be achieved in alpine locations when reliable turbine technology is used and consistent care and maintenance are exercised. The specific power output of more than 1,000 kWh/m²/year achieved here is comparable with that harvested on the North Sea coast.

The positive experience gained through operation of the highest wind farm in the world at Oberzeiring confirms that alpine locations can be profitably used and at the same time provide information on the enormous effort required for operation and maintenance of the plants in wintertime. The planning and erection of the wind farm was co-financed as a research project under the 5th program of the European Commission and the Austrian Kommunalkredit AG. Experience gained from the construction and operation of the turbines is documented in research reports and can be accessed via the homepage of the operator (www.tauernwind.com).

Fig. 4: Austrian wind energy sites

	Location	Altitude [m]	Manufacturer	Number	Capacity [kW]	Annual output [MWh]	Start up
01	Oberzeiring I	1.950	Vestas	11	19.250	44.000	2002
	Oberzeiring II	1.950	Vestas	2	3.500	8.000	2004
02	Präbichl	1.250	Enercon	1	600	1.200	2001
03	Plankogel	1.430	NEG Micon	1	750	1.400	1999
	Total			**15**	**24.100**	**54.600**	

Table 2: Austrian wind energy farms in the Alps

2.2 Switzerland

At the end of 2004 a total of 22 wind power olants with an installed capacity of 8.6 MW were operating in Switzerland. These were almost exclusively individual turbines. The only wind energy farm in Switzerland is located on Mt. Crosin at an altitude of 1,250 m and consists of 8 turbines

Fig. 5: The highest large-scale wind power plant in the world on the Gütsch near Andermatt (CH) at an altitude of 2,330 m

The majority of wind energy plants in Switzerland are situated in the Alps and the Jura at altitudes of over 1,200 m. Table 3 indicating the classification of plants shows, remarkably, that the majority of installations are of low capacity. The reason for this development could be that in many cases the plants are older installations, erected more than 10 years ago. In some cases the size of the plant was also dictated by problems related to access to the location for transport and construction vehicles.

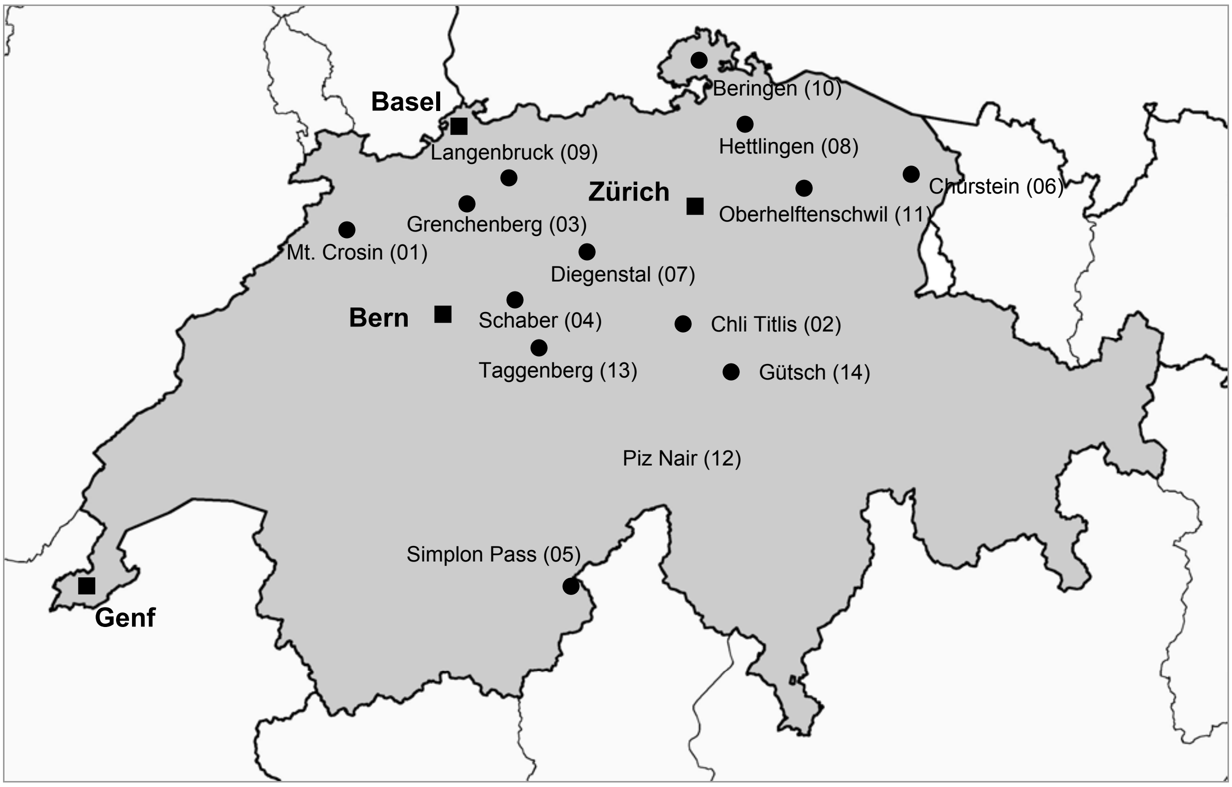

Fig. 6: Swiss wind energy sites

	Location	Altitude [m]	Manufacturer	Number	Capacity [kW]	Annual output [MWh]	Start up
01	Mt. Crosin I	1,250	VESTAS	3	1,800	1,440	1996
	Mt. Crosin II	1,250	VESTAS	1	660	800	1998
	Mt. Crosin III	1,250	VESTAS	2	1,700	2,200	2001
	Mt. Crosin IIII	1,250	VESTAS	2	3,500	4,560	2004
02	Chli Titlis	3,000	HWS 30	1	30	12	1997
03	Grenchenberg	1,200	BONUS	1	150	124	1994
04	Schaber Emmental	951	Südwind	1	15	5	1993
05	Simplon Pass	2,000	HSW 30	1	30	30	1990
06	Chürstein	1,148	Lagerwey	1	90	45	1995
07	Diegenstal	810	Eigenbau	1	5	2	1993
08	Hettlingen	420	SW-60	1	2	1	1994
09	Langenbruck	1,000	HSW	1	25	15	1986
10	Beringen	440	BTP AG	1	3	3	1996
11	Oberhelftenschwil	900	Aventa	1	6	5	
12	St.Moritz, Piz Nair	2,650	Aventa	1	6	9	2002
13	Taggenberg		Aventa	2	13	12	2003
14	Gütsch	2,330	ENERCON	1	600	800	2004
	Total			**22**	**8,635**	**10,036**	

Table 3: Swiss wind energy farms

2.3 Slovenia

There is currently no large-scale grid-connected wind energy plant in operation in Slovenia. A single wind energy turbine is in operation, not however connected to the grid, located at the Krederica mountain hut below the Triglav at 2554 meters above sea level. This provides the first experience in this country in the operation of wind energy turbines in complex terrain and under extreme climatic conditions.

2.4 Italy (South Tyrol)

Although 1,025 MW of wind energy was installed on Italian territory at the end of 2004, in the Northern Province of South Tyrol (Trentino-Alto Adige) only two grid-connected wind farms with a total installed capacity of 1.5 MW were registered.

The larger of the two plants is located on heathland, the Malser Heide, in the Vinschgau region at an altitude of 1,450m and has a rated output of 1,200 kW. The ski lift manufacturer Leitner located in South Tyrol intends to launch its activities in the field of wind technology with this plant. Leitner AG's experience in the construction of gearless drive systems for ski lifts has been employed in wind power technology. The plant has a multi-pole permanent magnet synchronous generator and was erected by Leitner for a 2 year period as a prototype for the purpose of carrying out technical tests. Plans exist to extend this site on the Malser Heide by further turbines.

Fig. 7: The Leitner prototype plant on the Malser Heide in Vinschgau (I)

The second wind energy facility is situated in the community of Sand in Taufers, about 15 km north of Brunico. The plant has a rotor diameter of 30 m and a rated output of 300 kW. It was erected in autumn 2004 and has replaced a wind energy plant in the same location that was in operation for 8 years.

In addition to these two plants there is a series of smaller facilities that are not grid-connected operating in the alpine region and supplying mountain huts or farms.

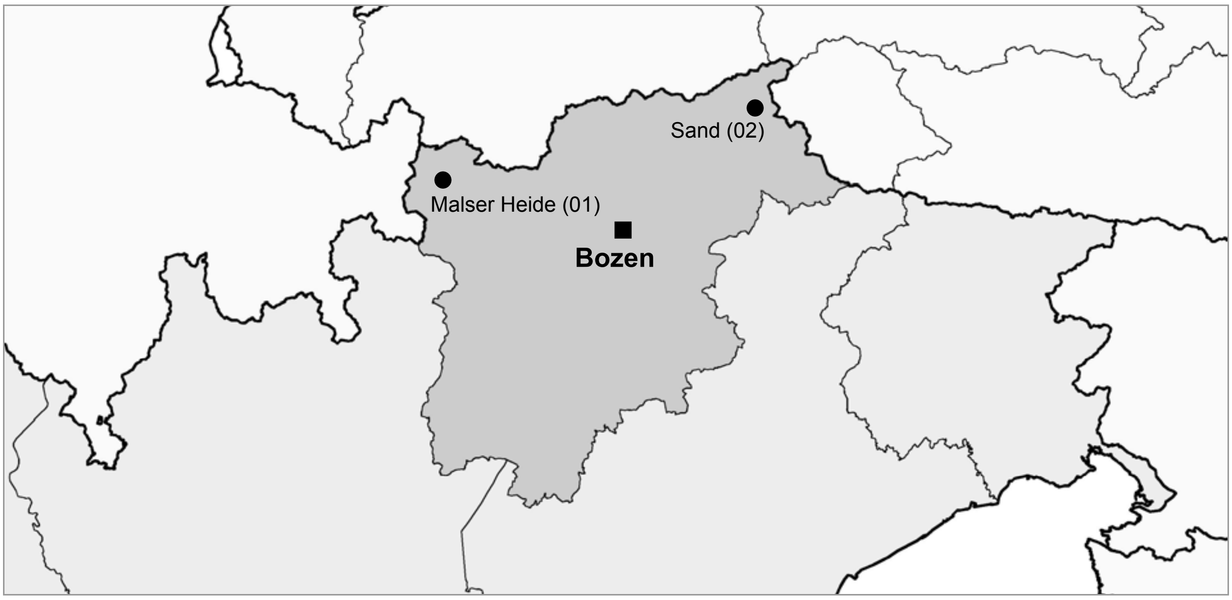

Fig. 8: South Tyrol wind energy sites

	Location	Altitude [m]	Manufacturer	Number	Installed capacity [kW]	Annual output [MWh]	Start up
01	Malser Heide	1,400	LEITWIND	1	1,200	1,500	2003
02	Sand in Taufers	1,600	BONUS	1	300	400	2004
	Total			**2**	**1,500**	**1,900**	

Table 4: South Tyrol wind energy farms

2.5 France (Rhône-Alpes)

In 2004 France experienced an increase of 138 MW in installed wind energy capacity and currently has an available capacity of over 386 MW. The sharp increase in installed wind energy capacity in the last two years was due to a new law governing feeding power into the grid that offers planners and investors sufficient security for their investments. The region Rhône-Alpes, a participant in the Alpine Wind Harvest project, also recorded a considerable increase: at the end of 2004 37 turbines with a capacity of 27.65 MW had been installed. However, at present not a single wind energy plant has been erected in the French Alps.

3. Plant projects in the alpine region

3.1 A survey of operators and planners

In order to estimate the development of wind energy deployment until the year 2010 in the Alps (Rhône-Alpes in France, Trentino-Alto Adige in Italy, Slovenia, Switzerland, also Styria, Salzburg, Vorarlberg and Tyrol in Austria) a survey was carried out of planners and operators. The respective companies and individuals were questioned about the location of the projects planned, the altitude, the number of plants intended and the proposed installed capacity.

The projects currently in the planning stage were divided according to progress into:

- **Phase I:** Planning permission (the project is already approved or currently undergoing authorization procedure)
- **Phase II:** Design planning (the project concept and wind measurement are concluded)
- **Phase III:** Project concept (preliminary design phase, wind measurement and yield calculations are still outstanding)

Projects in Phase **I 'Planning Permission'** were defined as already authorized or currently undergoing authorization procedure. They are either under construction or will in all probability be underway by the end of 2007.

A prerequisite for projects in Phase **II 'Design Planning'** was that contracts for sites have already been concluded and a realistic concept for the project with calculations of energy yield and calculation of costs has been submitted. In many cases these projects are already currently undergoing regional planning procedure.

Most of the projects in Phase **III 'Project Concept'** have not yet been presented to or discussed in public. Only a project idea exists and the preparatory stages, such as wind measurement, conclusion of site contracts and the preliminary layout and size of the facility are still under preparation.

Since a number of locations are situated beyond the curve of the Alps in low-lying mountain regions in Switzerland (Jura), in France (Ardèche) and in Slovenia (high altitude karst land), these mountain sites were also taken into consideration in the list of projects planned. The survey shows that in the Alps and in the defined lower-lying regions around **126 MW** of wind energy capacity are currently in the phase of obtaining planning permission and approximately **380 MW** in the design and/or pre-design phase.

The results of the survey show that mainly operators of existing plants are involved in the development of new projects in the alpine region. Either sites on which plants already exist are being extended or, based on experienced gained from existing plants, new sites developed.

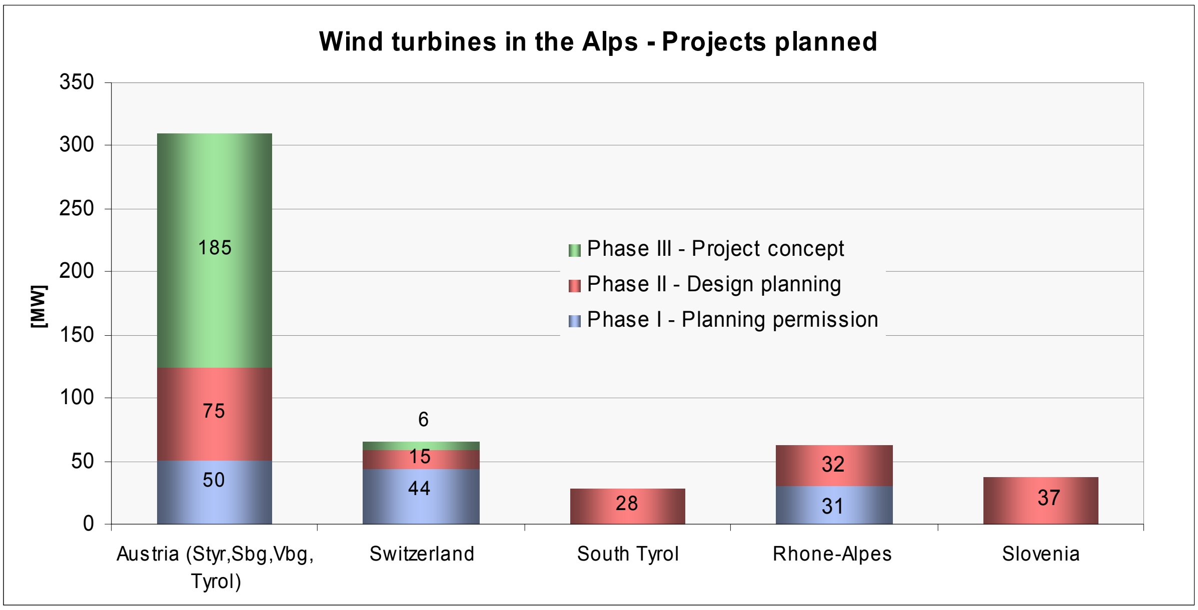

Fig. 9: Projects planned in the alpine zones of the region surveyed

Region/Country	Phase I [MW]	Phase II [MW]	Phase III [MW]
Austria (Styria, Salzburg, Vorarlberg, Tyrol)	50	75	185
Switzerland	44	15	6
Slovenia	0	37	0
Italy (South Tyrol)	0	28	0
France (Rhône-Alpes)	31	32	0
Total	**126**	**187**	**191**

Table 5: Projects planned in the alpine zones of the regions surveyed

3.2 Future development and problems specific to individual countries

In the guidelines for the deployment of renewable energy sources issued by the European Commission, an increase is planned in the proportion of renewable sources for power generation in the 15 EU states from 13.9% in 1997 to 22.1 % in the year 2010. National targets are set for the individual states and it is left to the member states to put in place the corresponding measures in order to achieve these goals.

The varying development of wind energy expansion in the individual member states therefore reflects the seriousness of the efforts to realize these aims in the country itself. Those in which clear and economically sound conditions were set were able to develop considerable potential within a short time and achieve profitable results whereas the development in countries with less well thought out economic guidelines stagnated.

3.2.1 Austria

The introduction of the eco-electricity law on 1st January 2003, guaranteeing a fixed feed price for wind power of 7.8 ct/kWh for 13 years, was the first step in Austria towards establishing sound economic guidelines for the erection and operation of wind energy plants. As a result of this newly created situation, an increase of 468 MW was recorded in the years 2003 and 2004 and within this period the installed capacity was almost quadrupled.

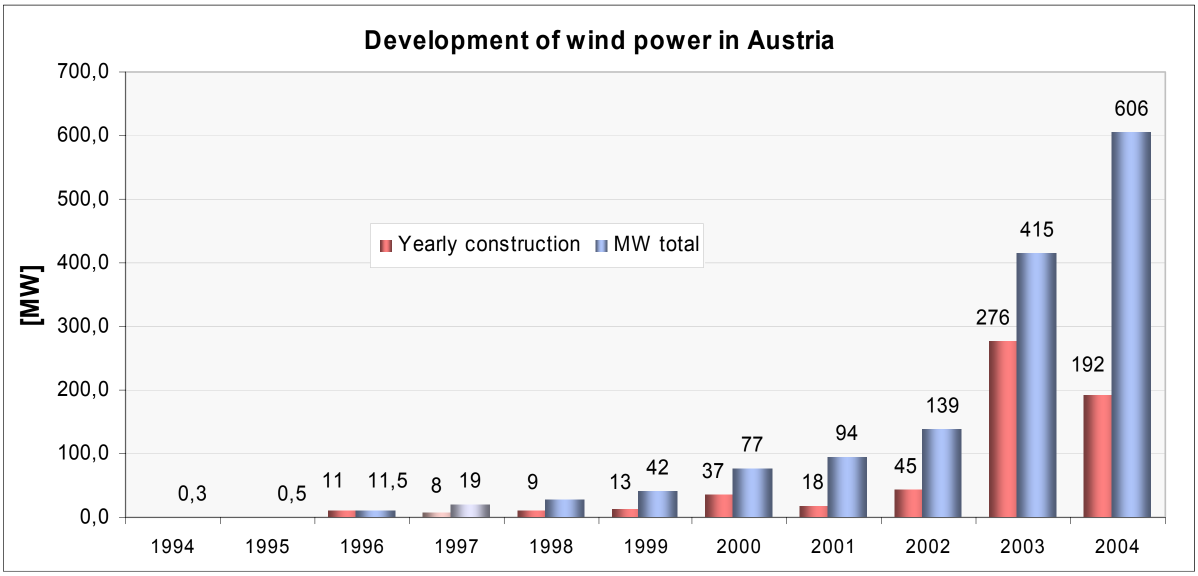

Fig. 10: Development of wind energy deployment in Austria

Due to the feed regulation time limit of 2 years it was however only possible to realize those projects that were granted approval within these two years and/or had previously been granted building permission. As a result of the extra time required to develop sites in the Alps many projects that were in the design phase did not manage to achieve approval before 31.12.2004. The current uncertain situation regarding the economic conditions and the cut in feed prices with a simultaneous stop to development funds for eco-power as already announced is a further obstacle to the ongoing development in alpine regions.

With regard to the legal conditions for authorization, varying requirements are applicable in the individual provinces:

In **Styria** work began very early to establish the eco-political and legal requirements for project authorization. In the year 2000 a planning guide for wind energy was compiled on behalf of Landesenergievereins Steiermark and in 2003 a feasibility study with a detailed examination of possible locations for potential wind energy farms was completed. The Styrian provincial government played a decisive supporting role in its positive development by providing funding for wind measurements at potential sites and through targeted public relations. The action taken by the Styrian provincial government probably contributed to the fact that at the time the eco-electricity law was introduced, projects already existed that were ready for realization.

In the province of **Salzburg** two factors have an inhibiting effect on the development of wind energy. Firstly, the sites in the area covered by the northern limestone mountains are considerably more difficult to exploit than locations in the southern limestone mountains due to the steep and rugged terrain. Secondly, the scope to generate energy from wind in a landscape interrupted by steep valleys is significantly lower than in other regions of the Alps. A further reason for the long delay in development of the few wind sites in the Province of Salzburg is the lack of support for wind energy deployment from politicians and authorities.

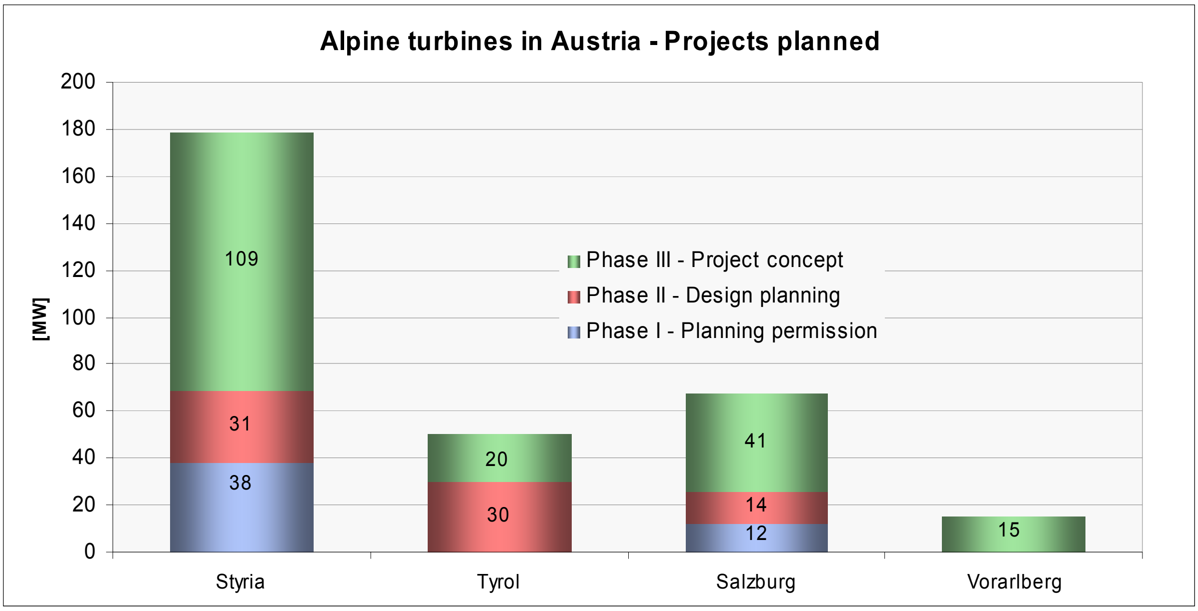

Fig. 11: Wind energy projects planned in Austria

Very favourable conditions for the establishment of wind energy projects present themselves in **Tyrol** with the East-West stretch of the main ridge of the Alps in pass and saddle locations. At the same time these sites that are situated close to the border between Austria and Italy have the advantage of military access roads that were built decades ago and can be used for the transportation of wind energy plants. There are, however, in Tyrol similar political and official obstacles to those in the Province of Salzburg that are responsible for the slow progress in the development of wind power installations.

In **Vorarlberg** on the other hand there is a very obvious political intent to increase the development of renewable energy sources, and this applies also to the use of wind energy. A study of wind potentional drawn up by the Central Institute for Meterology and Geodynamics on behalf of the Provincial Government of Vorarlberg was completed in 2002 and before the introduction of the nationwide eco-electricty decree, in Vorarlberg a pricing structure was set out for energy supplied to the grid. It should be added that the Province of Vorarlberg has very few locations that are suitable for the installation of wind energy.

3.2.2 Switzerland

Switzerland has been attempting for some years to increase the use of wind energy and at a very early stage the essential economic conditions for the operation of wind energy plants were agreed. In the past however, the general right of appeal in favour of nature conservation has proved a great barrier to the realization of wind energy projects. There is a great likelihood that appeals will be filed and a lot of time is lost until these proceedings are settled.

To improve the coordination in the sequence of planning, a consensus between the representative bodies of the Federal Government, the cantons, the energy industry and environmental associations for wind energy was compiled in 'Konzept Wind-Energie Schweiz' (Concept Wind Energy Switzerland) and the general criteria for the selection of a location were laid down. Subsequently 110 potential wind energy sites were identified by means of GIS modelling that met these conditions.

The government has now declared that its target is to produce an additional 500 GWh of power from new renewable energy sources by the year 2010 under the program 'EnergieSchweiz’ (Energy Switzerland). With a choice of 12 ‘priority sites’ approximately 50 to 100 GWh of electricity are to be produced from wind energy by the year 2010. The priority sites named were basically suitable for the erection of 70 wind energy plants with about 100 MW of installed capacity, however it is assumed that building permission will not be granted for all these sites.

The areas of Switzerland suitable for the deployment of wind energy are found in the Jura and where passes have been built through the Alps. There are currently nine projects in the planning stage, three of which are in the Alps and six in the Jura Mountains. Given the risks of objections being raised when planning data is published, only very limited information is available on projects that are in the design phase. It is estimated that the number of projects in the preliminary stage of planning is actually much higher than stated in the surveys.

3.2.3 France

Due to newly created economic incentives France is currently undergoing an acceleration in the development of wind energy installations and there are a number of projects now in the planning stage. In the entire Rhône-Alpes region there are presently 45 officially approved turbines with an installed capacity of 80 MW and further 69 turbines with an installed capacity of 132 MW are now in the planning permission stage. Only one of the projects planned is situated in the Alps near Grenoble (2 x 1.5 MW), authorization procedure however has come to a standstill due to an appeal filed by rural conservationists.

When taking into consideration non-alpine sites in mountain regions at altitudes of over 1,000 m (the Ardèche region, west of the Rhône Valley), 20 authorized turbines with a capacity of 31.2 MW and further 16 turbines with a capacity of 32 MW capacity were identified as being in the planning stage.

3.2.4 Slovenia

Slovenia plans the erection of wind energy plants with a total capacity of 150 MW by the year 2010 within the guidelines of its National Energy Program. The current wind measurements show that the greatest wind potential lies in Southern Slovenia in the karst mountains. Two projects are presently at the planning stage. A wind farm with 11 turbines each of 2 MW is to be erected in the region Primorska-Litoral near the coast and a further park with 44 turbines, each rated at 850 kW, close to Ilirska Bistrica in South East Slovenia. Both projects are in the course of planning procedures and were included on the list of projects planned since the orography has characteristic alpine features.

Currently we have no information on projects planned in the Slovenian Alps. At two sites surveyed under the Alpine Wind Harvest Project, whilst ideal for the development of wind projects, no steps in the way of planning have yet been undertaken (Menina Planina and Rogla).

3.2.5 Italy

In Italy the return on feeding eco-electricity into the grid is divided into a basic price that is determined annually and depends on the market price for electricity, and an allowance for trade with green certificates. The basic price depends on various tariff times and is currently on average approximately 4.5 ct./kWh. The income from the sale of certificates depends on the relevant market price and the length of the contract entered into. At the present time a price of about 9 ct./kWh can be agreed on conclusion of a short-term contract (2 years). The maximum possible length of contract is 8 years.

Concerning the future development of wind energy deployment in Italy, although in some regions targets have been defined, in South Tyrol there are no such commitments. For the time being, the government in Bolzano has commissioned a wind measurement program to find out which areas are suitable for the exploitation of wind energy in order to subsequently set out a development plan for wind energy. Currently some individual projects are at the planning stage but their realization depends on specialized and political discussions that are still pending.

The areas best suited for the exploitation of wind energy are probably at high altitudes above 2,000 m near the border to Austria. An existing network of military roads could be used to develop this area.

4. Experience with the operation of wind energy plants in alpine locations

There is still not sufficient experience in the operation of wind energy plants in alpine locations having complex terrain and extreme climatic conditions. Operators and planners have to develop projects partly with inadequate information and insufficient basis for planning and even the authorities often face issues that have not been solved during authorization procedure.

There are then obvious reasons for questioning the operators of the few existing wind energy constructions in the Alps on their experiences in order to obtain a basis for the appreciation of unsettled questions and problems. The survey for operators was carried out in the form of a questionnaire. This form consisted of 31 questions in total and was sent to all known wind energy plant operators in the Alps. The compilation and interpretation of data and information was supported by accompanying phone calls.

The form was divided into the following subject areas:

- Transport
- Grid connection

- Modifications of construction technology
- Experience with operation
- Visions for the future

The questions were practice-orientated and easily to understand. Altogether 23 questionnaires were sent to operators of wind energy plans in the Alps. The feedback with13 questionnaires filled in was 57%. In all, it was possible to analyse the operations of 32 wind energy installations with a capacity of 33.4 MW. In the results of the survey, the plant on the Plöcken Pass in Carinthia (1 x 500 kW ENERCON) was also taken into account although Carinthia does not come under the area to be examined in the ‘Alpine Wind Harvest' project.

	Project	Country	Number of plants	Capacity [kW]
01	Oberzeiring	A	11	22,750
03	Plankogel	A	1	750
03	Präbichl	A	1	600
04	Plöckenpass	A	1	500
05	Mt Crosin	CH	8	7,660
06	Chli Titlis	CH	1	30
07	Oberer Grenchenberg	CH	1	150
08	Chürstein (Gäbris)	CH	1	80
09	Sool	CH	1	2
10	Beringen	CH	1	3
11	Pitz Nair	CH	1	6
12	Gütsch	CH	1	600
13	Sand in Taufers	I	1	300
	Total		**32**	**33,431**

Table 5: Operator Survey – evaluated questionnaires

4.1 Results of the operator survey

As most experience gained in the operation of wind energy installations in the Alps is with sites in Austria and Switzerland it was from there that the most well-founded information about problems with the erection and operation of wind energy installations in complex terrain and under the influence of extreme climatic conditions was obtained. The projects of the Austrian operators can be regarded as rather more representative for current issues than those of Swiss operators since due to the late development, more progressive technology was applied than in Switzerland. Many of the smaller installations in Switzerland are based on specifications for alpine sites that, compared with today’s technology, are outdated.

Of the 32 wind energy installations situated on the 13 sites and in operation, 3 plants have a capacity of less than 10 kW, 2 plants of between 11 and 100 kW and 27 have a capacity of more than 100 kW. The average size per turbine is 1,045 kW.

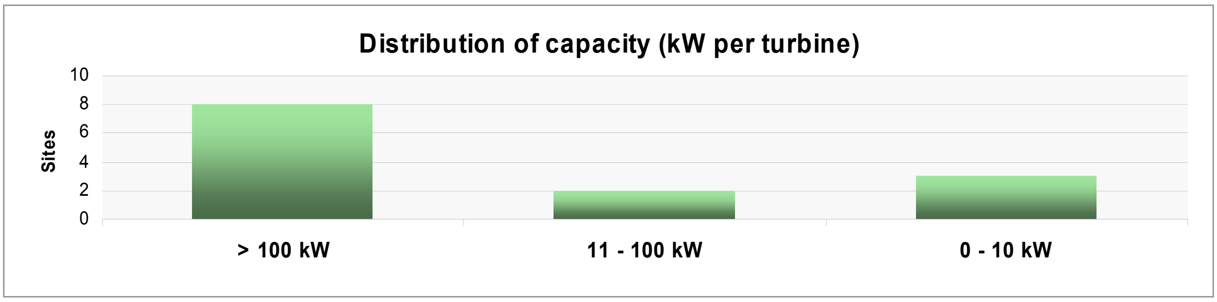

Fig. 12: Operator Survey – Distribution of capacity

4.1.1 Transport and construction of the installations

- **Access roads**

The chief criterion in the selection of a site for wind energy is basically its prospects of wind. In alpine regions the suitability of the site is however equally dependent on whether access to the site and the grid connection can be established at an economic cost. Therefore, when selecting a site, planners and operators of wind energy projects in the Alps endeavour to ensure that an access road exists at the intended location, that it can be used and if necessary developed.

The access road must be suitable to allow transportation of heavy-weight construction parts (nacelle and tower segments) and long sections (rotor blades). Defined criteria with regard to the maximum gradient and minimum bend radius must be met. A well prepared access road with the possibility for snow clearance in winter is also of decisive importance for servicing and repair work.

At all 13 sites covered by the survey access roads already existed although some of these partly required extension and improvement. The stretch requiring improvement was only longer than 0.5 km per MW capacity in three cases and for most projects it was below 0.1 km/MW.

Fig.13: Widening a bend In Oberzeiring (A)

Fig. 14: Reinforcement of a bridge in Oberzeiring

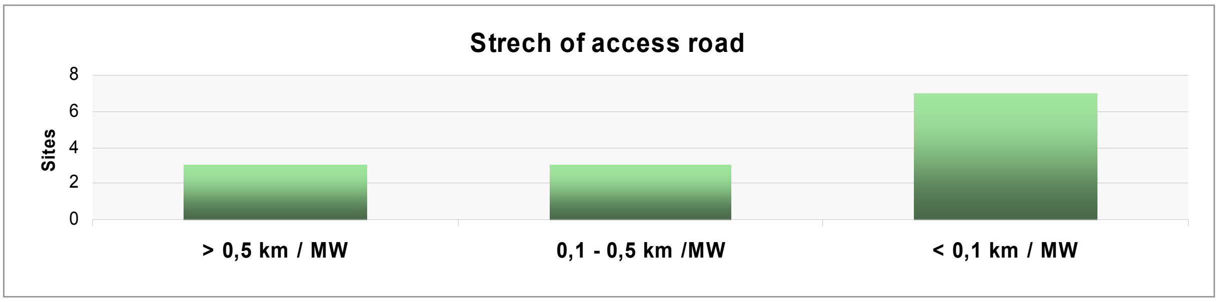

Fig. 15: Operator Survey – Stretch of access road in need of improvement

The maximum gradient that had to be overcome was over 18% in only three projects and in most cases it was below 12 %.

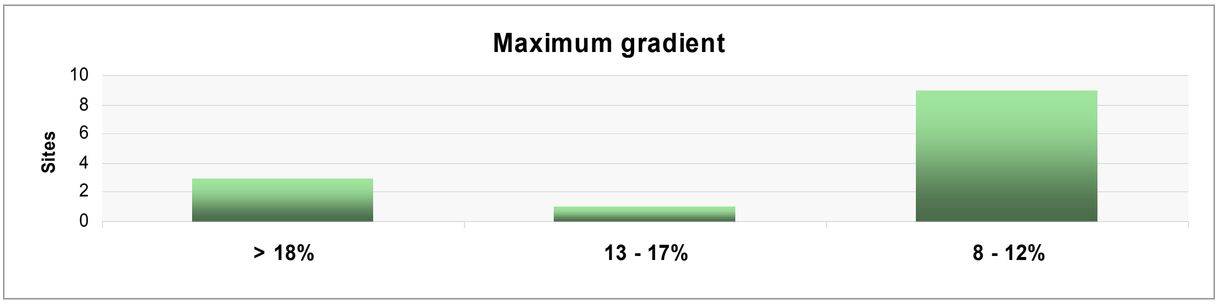

Fig. 16: Operator Survey – Maximum gradient of access roads

Fig.17: Transport of a tower segment up to the Gütsch (CH)

Fig. 18: Transport of a nacelle on a gradient of 18 % in Oberzeiring (A)

- **Use of special vehicles for the transport of plant components**

To optimise the required measures to improve access roads, it can be advantageous to use special vehicles that are able to cope with small radius curves or steep gradients. As a rule, when using special vehicles it is necessary to transfer the load in the valley as the lengthy road journey from the factory has to be carried out on normal transporters.

Around half of the projects examined required a considerable amount of extra time for special transportation means. Particularly in Oberzeiring a transport scheme was planned in detail to optimize the costs for road building and save time during transport of the components by using special vehicles and put into action. For example a reinforced re-loading area was constructed in the valley for temporary storage of the components that were delivered. Transportation of tower sections and nacelles on to the mountain was carried out on special low loaders, and a semi-trailer with a rotary swivel bearing block was built for this purpose. Part of the transport of rotor blades was carried out by helicopter to save time and money.

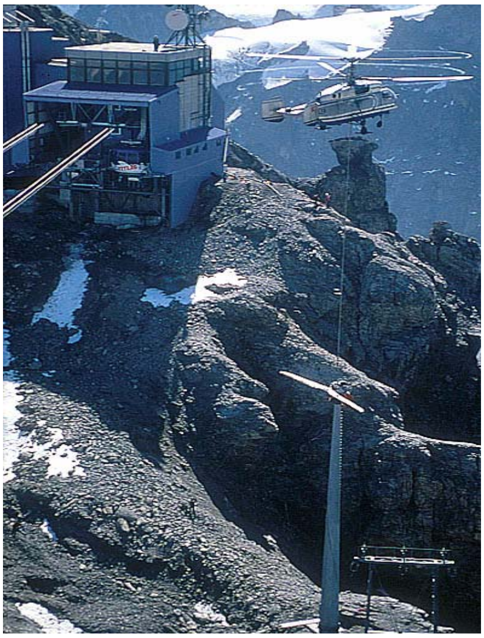

Fig. 19: Transport of a wind energy plant with nacelle and rotor to the Chli Titlis (CH) site at an altitude of 3,000 m

Transport up to the 2,330 m high Gütsch site in Switzerland proved to be as difficult as in Oberzeiring. At the other locations in Austria and Switzerland where large machines are installed no special measures were required. The smaller plants in Switzerland were transported partly by helicopter but the experienced that was gained cannot be applied to the current technology with capacity of over 500 kW.

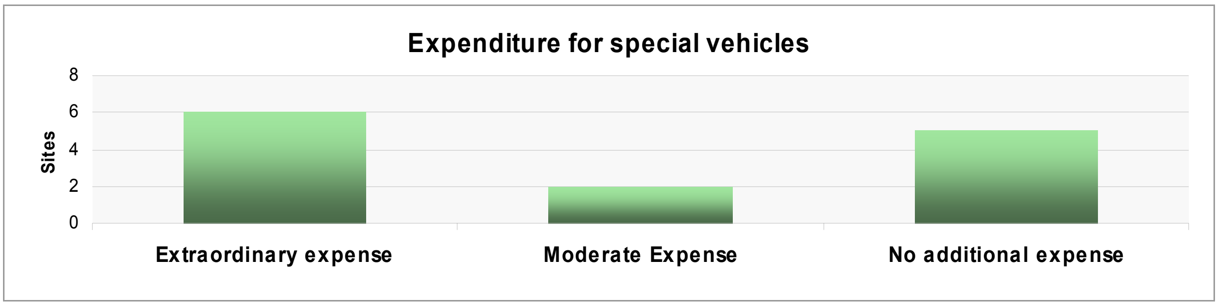

Fig. 20: Operator Survey – Expenditure for special vehicles

Fig. 21: Rotor blade transport on trailer in Oberzeiring (A)

Fig. 22 Transport of rotor blades by helicopter in Oberzeiring (A)

- **Special erecting technique and equipment**

Due to the fact that the size of the installations is continually increasing there is practically no choice in the selection of techniques for their erection. The rules are set by the necessity to use a crane and so there are practically no differences in techniques compared to conventional erection on sites inland. In some cases it was not possible to pre-assemble the rotor on the ground due to steep or wooded terrain. Single-blade mounting, as was necessary in these cases, caused only slight additional expenditure.

The results of the survey show that the main difficulties occur at the time of transportation of the plant components and that the access roads inevitably require adaptation for transportation of the machine parts. The cranes required for erecting the equipment can generally use the improved access roads without encountering major problems.

The only unconventional mounting technique was used on the Chli Titlis in Switzerland at an altitude of 3000 m where helicopters were used to erect the entire plant. As the HSW 30 is a small plant with a capacity of 30 kW the experience gained here is not applicable for current plant techniques since the lifting capacity of helicopters is limited to a maximum of 4 to 6 tons and the construction elements of wind energy plants with a capacity of over 500 kW are many times this weight.

- **Additional costs for transport and erection in the Alps**

In the survey only two operators indicated extra expenditure for improvement work on access roads, for construction of areas for cranes and re-loading, for actual re-loading, mountain transport and complicated erection. Four operators described this extra expenditure as moderate.

As the additional costs were not specified by the operators in figures, no exact statement on the level of these costs can be made. The telephone interviews with operators and planners (projects at Oberzeiring and Gütsch) showed that the extra expenditure on measures required for road improvement and transport and erection of can amount to around 3 to 5% of the total project cost.

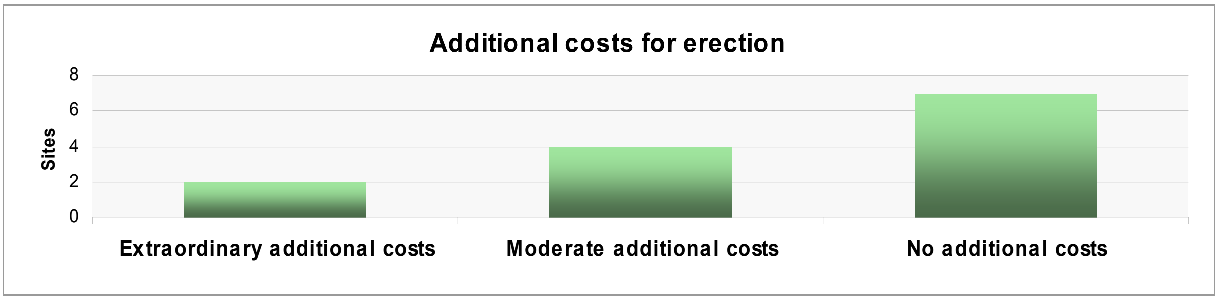

Fig. 23 Operator Survey - Additional cost for erection

4.1.2 Grid connection

Similar to the opening-up of roads to wind sites in the Alps, the development of grid connections also incurs increased expenditure. As a rule both operators and planners will always attempt to make use of existing grid lines in the vicinity of areas used by skiers or tourists. As is common in the wind energy technology, underground cable systems are only used in the Alps as new overhead lines that are subject to technical approval are no longer considered suitable. The additional expenditure arises mainly from the length of cable required and the higher costs for excavation on steep, rocky terrain.

Since the survey of existing installations in the Alps is limited to grid-connected facilities, no stand-alone systems were studied. In one single case the energy is used primarily for personal needs and only the residual energy is fed into the grid. All other installations are solely for the supply of electricity to the grid.

- **Voltage level**

The supply to the grid from the installations surveyed is mostly small capacity at low voltage level (0.4 to 1 kV) but for facilities with over 30 kilowatt at a high voltage level (1 kV to 30 kV). When the facilities are listed according to size, the proportion of installations examined is 45% low voltage and 55% high voltage.

- **Transformer stations**

In cases where the generated electricity is fed into the grid at high voltage level it becomes necessary to use transformers. Weather conditions and site conditions should be taken into consideration when selecting transformers and station buildings. The location of the station must be safe from avalanches and accessible even in extreme snow conditions. The vent holes must be protected against snow drifts and the designed capacity of the transformer selected must take into consideration the site altitude (air density and temperature).

At the Tauern Wind Park in Oberzeiring the transformers of all 13 wind turbines are accommodated in the nacelle of the turbines. A building was erected only for the switching station. On the Gütsch the transformer is housed in the cellar of a foundation that can be accessed from above when there is deep snow. At the wind energy facility on the Plöcken Pass (in Carinthia) the transformer had to be accommodated in a building that was erected at a distance of about 30 m from the turbine pylon in a spot protected from avalanches.

It can be generally said that every effort was made in many of the projects to house the transformer close to the turbines and protected from the elements. In some cases the transformer was housed in the turbine to avoid spoiling the beauty of the landscape.

- **Grid connections**

Grid lines play an important role in the planning and construction of wind energy facilities in the Alps. The problems are caused, in comparison with sites on flat country, not so much by the length of the lines but far more by the shape of the terrain and the earth. The plough method, most commonly used for installation of underground cables on flat land, can only be used in isolated cases in the Alps as work must be carried out on steep and rocky ground with open trenches. The additional costs for excavation requiring expenditure for cutting and blasting on rocky terrain are estimated by the installation companies at 20 to 50% of the total installation cost for the lines.

In the survey only two projects were found with a sufficiently high capacity to necessitate providing a new grid line. (Oberzeiring and Mt.Crosin). All other projects were single plants for which the existing grid capacities were sufficient.

In Oberzeiring for example, for the wind farm's total capacity of 22.75 MW an electric line of 22 km was installed. A 30 kV duplex cable system with 2 x 240 mm² was used and it was possible to plough about 1/3 of the trench. The specific length of the electric cable with its approximately 1 km per MW wind farm capacity is not considerably greater than the normal lengths for cables on flat land with 0.5 – 1.0 km/MW. There was however considerably higher expenditure for excavation work on this project.

Fig. 24: Installation of cables in Oberzeiring using ploughs

Fig. 25: Installation of underground cables in awkward and steep terrain in Oberzeiring

4.1.3 Modification of plant equipment

Wind energy plants require at least partial modification if they are to be erected and operate safely in alpine locations. The adaptation of equipment to meet the demands of a site consists mainly in making it more suitable for transportation and taking measures to ensure that the equipment will operate under extreme climatic (ice, deep temperatures, gusty winds and severe fluctuations in air density).

- **Modification of plant structure**

The most common modifications to the structure of the turbines are the use of shorter tower segments to improve their suitability for transportation and the reinforcement of load-bearing machine components to withstand higher wind and ice loads. In this respect the question arises particularly during the planning phase as to how the conditions at that particular location can be assessed. It is often necessary to make predictions years in advance concerning maximum gusts of wind, turbulence, ice-loads and temperature conditions that are to be expected without having adequate data available as a basis. It is also only possible to obtain approximate predictions about probable loads from wind, snow and ice at high alpine altitudes based on standards and records.

As illustrated by Oberzeiring, alternative expert opinions and methods of calculation were used to determine the maximum loads. Modifications to the equipment here were concentrated firstly on the transport issue by manufacturing shorter tower segments. Secondly special attention was paid to operation at extremely low temperatures and to ice build-up. All switch and control cabinets were made to be heated and the nacelle to be completely isolated from outside environment during periods of low temperature via a special ventilation and heating system that can be temperature controlled. As part of an accompanying research project the influence of various load conditions on the service behaviour of the turbines was examined in the first year of operation. In particular the influence of extreme gusts of wind on the bending moment of the tower and blade were measured and analysed as well as the effect of ice and turbulence on the performance parameters.

The results of the survey show that modifications to the equipment were carried out for only three projects. Although some operators are aware that modifications would be required, due to the costs involved it is usually almost impossible for turbine manufacturers to supply non-standard equipment. Due to the number of turbines involved in Oberzeiring, an extensive modification of the standard turbine was carried out in this particular case to suit conditions in alpine locations.

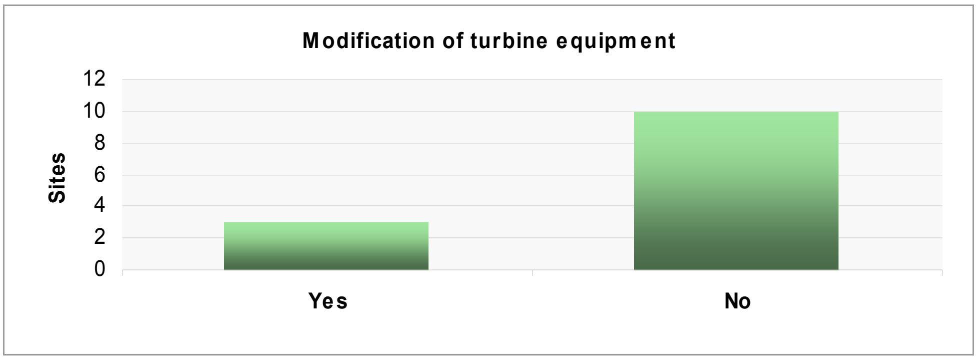

Fig. 26: Operator Survey – Modification of turbine equipment

- **Special foundation constructions**

The construction of foundations on alpine sites differs from those on flat terrain mainly with regard to the higher expenditure for transportation of construction and excavated material. In particular excavation work on rocky ground can cause considerable extra expenditure. Difficulties also occur when carrying out the earth-bonding of foundations as the required resistance is difficult to achieve in dry and rocky ground. The dimensioning of the foundations usually requires less additional expenditure as foundation designs for extreme wind zones are available for most standard turbines.

One possible means to save materials and consequently expenditure for transport would be to use rock anchors. At the moment there is almost no record of experience with this foundation technique nor was there a single foundation with a rock anchor base listed in the evaluated results of the survey. However, the results of the survey show that special foundations were used in five cases. These were mainly specially built due to the unusual position of the turbines. The plant on the Plöcken Pass in Carinthia was, for example, erected in a zone where there is risk of avalanches and it therefore had to be built with a raised concrete base. A similar construction was used on the Gütsch. The plant in Chli Titlis is the only one with a foundation in the permafrost zone but this is rather the exception to future practice.

It is worth mentioning the additional expenditure at Oberzeiring for the earthfill and restoration of the vegetation over the surface of the foundation. For reasons related to nature conservation it was necessary to carefully raise the grass sods when starting excavation work and to store these under moist conditions. After the foundation had been concreted the grass sods were carefully replaced. Had the grass been destroyed it would not have recovered at this altitude of 2,000 m for 50 to 70 years.

Fig. 27: Foundations in Oberzeiring (A) replanted with grass

Fig. 28: Foundations with incorporated transformer station on the Gütsch (CH)

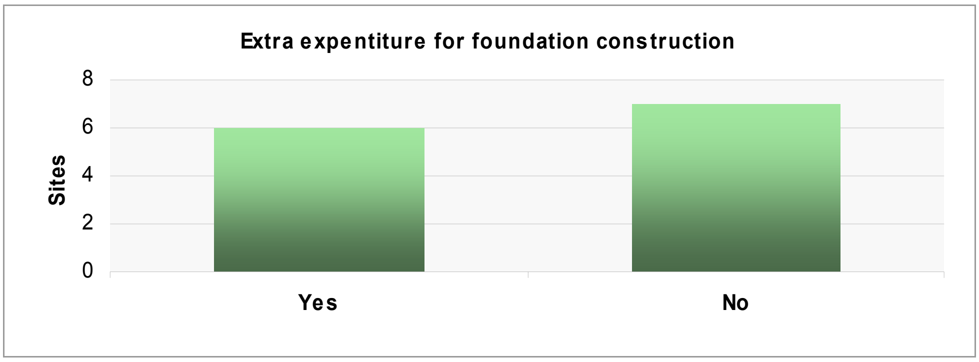

Fig. 29: Operator Survey – Extra expenditure for foundation construction

- **Measures to maintain equipment in working order**

The operating range of wind energy turbines from mass production usually lies within a wind speed range between 4 m/s and 25 m/s. The turbines start power generation at a wind speed of about 4 m/s and switch off automatically at 25 m/s. This operating range also corresponds to the demands of sites in exposed positions and provided the turbines are certified to operate in such conditions, no special precautions are called for.

In the case of temperature-dependent operating range, there are however higher demands in alpine locations. Whereas the temperature range of mass-produced turbines for sites inland and on the coast is normally between +40 and -20 °C, there are frequently temperatures of below -20 °C at sites in the Alps. To avoid shutdown periods due to outside temperatures that are too low, it is recommended to heat switch boxes, drives or the entire interior of the nacelles at locations in the Alps.

The majority of the wind energy installations surveyed are equipped only with standard equipment for conventionally designed turbines. Although temperature control is installed, there is no heating for the machine parts.

However, unlike other installations, turbines in Oberzeiring and two turbines at the Mt. Crosin wind farm are equipped with a comprehensive heating system. At both sites these are VESTAS V66 / 1,750 kW turbines. On this type the air grille closes automatically at a defined temperature level and the interior is warmed by electric fan heaters. In this way the machines can be kept ready for operation even at very low temperatures. This system has proved successful in the first years in operation and has the additional advantage that the interior is also protected from drifting snow.

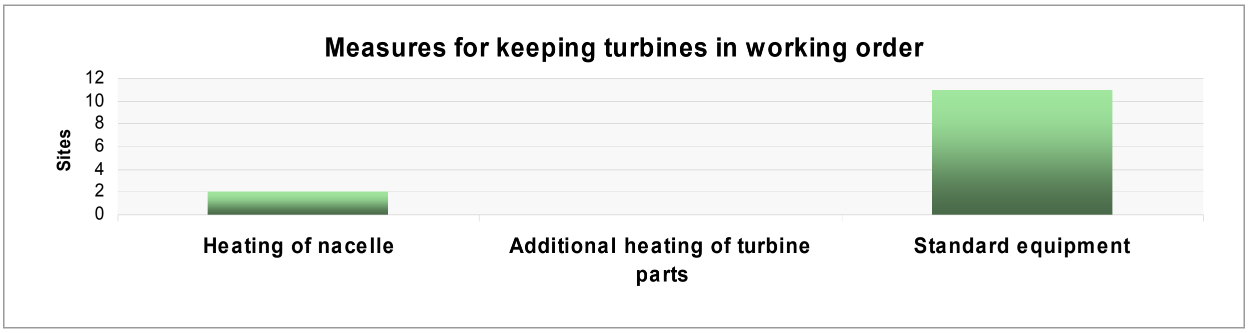

Fig. 30: Operator Survey – Measures to keep equipment in working order

- **Special sensors for control**

The operational safety and efficiency of a wind energy turbine depends to a great extent on its ability to react quickly and reliably to changing external conditions such as wind speed, wind direction, temperature and eventual ice build-up on the machine components. At sites with extreme climatic conditions it is essential to use heated wind sensors and ice detectors for heater control. Heated anemometers and tail vanes usually rate as standard equipment for wind turbines as ice or hoarfrost can also form on the anemometers at normal inland locations. In comparison, less frequently used are ice sensors that provide additional safety in shutting down the wind turbines when ice builds up.

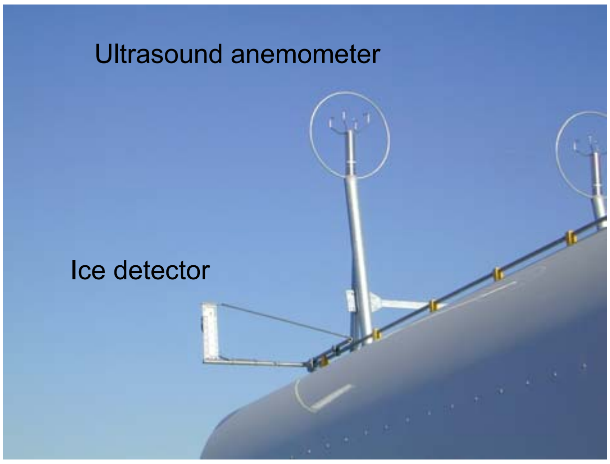

Fig. 31 Nacelle in Oberzeiring with ice detector and ultrasound anemometer

Fig. 32 Heated ultrasound anemometer with iced over lightning protector in Oberzeiring

Heated wind sensors were used in around two thirds of the installations surveyed. Ice detectors are used only at the Tauern wind farm in Oberzeiring. The use of ice detectors should ensure reliable shutdown if there is danger of ice being thrown off the rotor and their use is mandatory. In the first year of operation at the Tauern Wind Park, web cams were introduced in addition to check the reliability of the turbine controls. Generally speaking, the question of the use of sensors to detect ice still needs more attention and at present there is still no reliable system on the market.

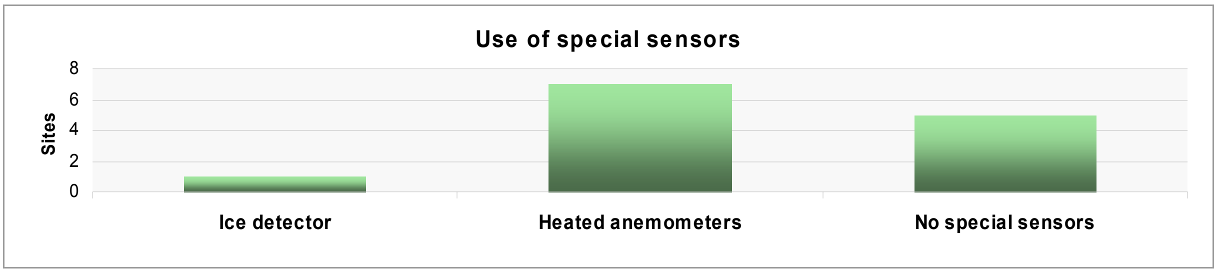

Fig. 33: Operator Survey – Use of special sensors

- **Measures to avoid ice**

When ice or hoarfrost builds up on the surface of the rotor blades this has an effect on the aerodynamics and consequently a reduction in the performance of the wind turbine. This decrease in capacity and the shutdown of a turbine that becomes necessary if there is ice build-up affects the energy yield and thus the economic efficiency of a project. A further problem connected with ice build-up on the rotors is the danger caused by ice that is thrown off.

By heating and de-icing the rotor blades the yield can be increased, while at the same time the risk of ice falling from the rotors can be avoided. The additional yield achieved by taking these measures should however be compared with the increased investment and operating costs of the heating of the de-icing system. The use of a de-icing system is only practical and profitable on sites where severe ice build-up can be expected.

Fig. 34: Ice that has fallen from rotors

Fig. 35: Impact in snow from falling ice

At present two different systems are used to heat the rotor blades. One is available as a standard system and works on the principle of introducing warm air into the cavities of the rotor blades. This type of heating has the disadvantage that heating must be carried out from inside for a long time until ice melts on the blade surface. Therefore the entire mass of the rotor blade needs to be brought to the required temperature level. For this reason heating procedure is carried out when the blades are stationary in order to minimize cooling through the rotating rotor. According to the operators, this method functions only with outside temperatures of down to minus 5 degrees.

This method of blade heating is used by three of the projects examined. (Plöcken Pass in Carinthia, Präbichl in Styria and Gütsch in Switzerland). Comments made by the operators regarding the operational reliability of this system underline the main disadvantages as, above all, the length of time required for heating and the ineffectiveness of the process at very low temperatures. It also causes high personnel costs due to the visual checks and the manual switch-on and off it requires. Nevertheless, considering that there are no alternatives available, the operators emphasize that this system is in effect only partly operationally reliable.

Another system of blade heating has been developed in Finland where it has already been tested on several prototype plants. This system heats parts of the rotor blade surface (blade nose and front third of the surface) by means of electrically heated foil or carbon fabric. The advantage of this system is that it requires very little heating to produce a release between the ice and the blade surface at the interface between the rotor blade and the ice. Due to the optimised use of heating energy, this system can also be operated when the rotor is in motion and can also prevent ice build-up instead of thawing after build-up has taken place.

This system of heating is not currently in use at any of the projects surveyed in the Alps and very little experience has been gained in Finland where no plants using the system have been installed in the last few years. It is intended to use this form of surface heating at the Steinriegel wind farm in Styria (13 x BONUS 1.3 MW) that is currently under construction.

Another method by which to avoid ice build-up could be the application of very smooth and repellent coatings. This theoretical approach has been tested on two of the projects examined. Such a coating was applied to the rotor blades of the small wind energy plant on the Pitz Nair in Switzerland, at an altitude of 2,650 m, and in Oberzeiring a surface coating based on Teflon was applied to the surfaces of one turbine rotor for test purposes. No experience has been recorded from either project. However, since this approach has not been further pursued, it can be assumed that this method did not meet expectations.

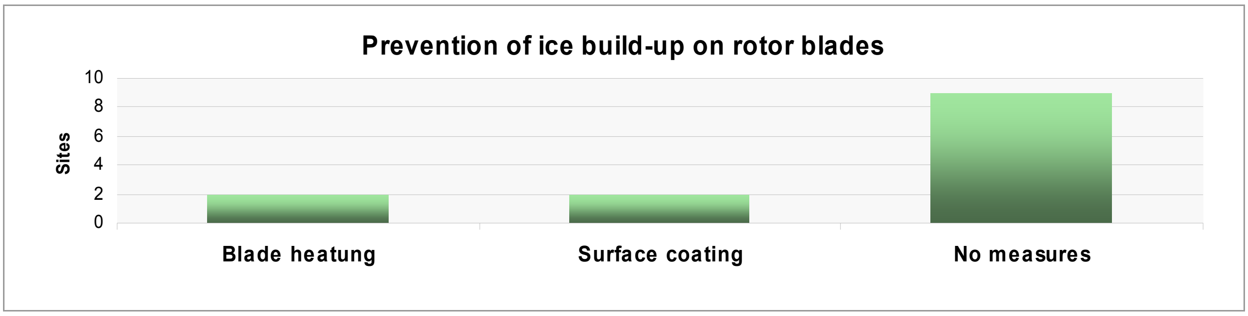

Fig. 36: Operator Survey – Prevention of ice build-up on rotors

4.1.4 Operation, service and maintenance

Operation of wind energy plants in alpine regions pose a number of additional risk factors compared with sites inland. Environmental conditions such as gusts of wind, wind shear, ice, temperatures, fluctuation in air density or lightning strikes can have a considerable influence on plant availability and, as a result, on the yield. Difficult access to the sites during wintertime also limits the possibility of carrying out maintenance and repair work quickly.

- **Access in winter**

The accessibility of a site plays an important role especially in winter since experience has shown that two thirds of the annual production in alpine locations occurs during the wintertime and that breakdowns happen more frequently in periods of adverse weather conditions. Some of the sites examined are not accessible for several months in the year when using normal road and transport vehicles. In order to guarantee smooth operation and fast repairs in the event of a breakdown, the operators use special vehicles to ensure access to their sites even in deep snow. Furthermore, the health and safety risks to staff involved in repairs must be given due consideration. The erection of clearly signposted emergency shelters for protection during snowstorms is equally as important as access roads that are protected from avalanches and the use of vehicles that provide protection from the elements.

Fig. 37: Container shelter for maintenance work in Oberzeiring

Fig. 38: Maintenance staff at work (Oberzeiring, A)

In most of the projects analysed, access can be ensured by clearing snow from the roads. Depending on the size and location of the site, it is sometimes sufficient in emergencies to combine the use of 4x4 vehicles with fast methods of snow clearance. In one of the cases under review, even a major road is used as service road. Not even a 4x4 vehicle is needed there. In three cases special vehicles are used in addition as it is not possible to carry out snow clearance throughout the route. In Oberzeiring two snowmobiles are in action for three to four months a year and on the Gütsch the site is accessed either by snowcat or chair-lift. In another case where a small plant is concerned, maintenance workers access the site in winter by chair-lift.

Fig. 40: Rotary snow plough in Oberzeiring

Fig. 41: 4x4 vehicle after snow clearance in Obezeiring

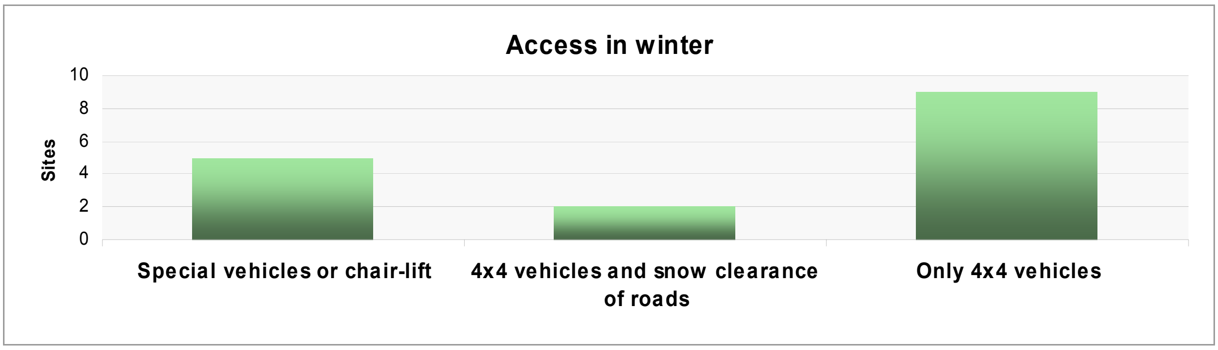

Fig. 39: Operator Survey – Access in winter

Fig. 42: Unsuccessful trip by snowmobile

Fig. 43: Snowmobile in a snowstorm

- **Plant shutdown**

Due to the extreme climatic conditions in alpine locations it is a basic assumption that the number and length of shutdowns caused by breakdown and weather conditions is higher than at sites inland.

The plant operators stated when questioned that shutdown for the reasons mentioned is on average for periods of 3 to 4 days. Based on this data there is no considerable difference compared to plants in normal inland locations. At only two sites were periods of 10 days indicated by the persons questioned, which would correspond to an operational availability of over 97 %.

In this case previous experience with operation of the Tauern wind farm in Oberzeiring should be mentioned. At this site operational data is carefully recorded and can be viewed at their website (www.tauernwind.com). After initial problems had been solved, operational availability of almost 98% was achieved in the first two years of operation. This value is surprisingly good and its roots can certainly be found in the well thought-out plant technology and professional management.

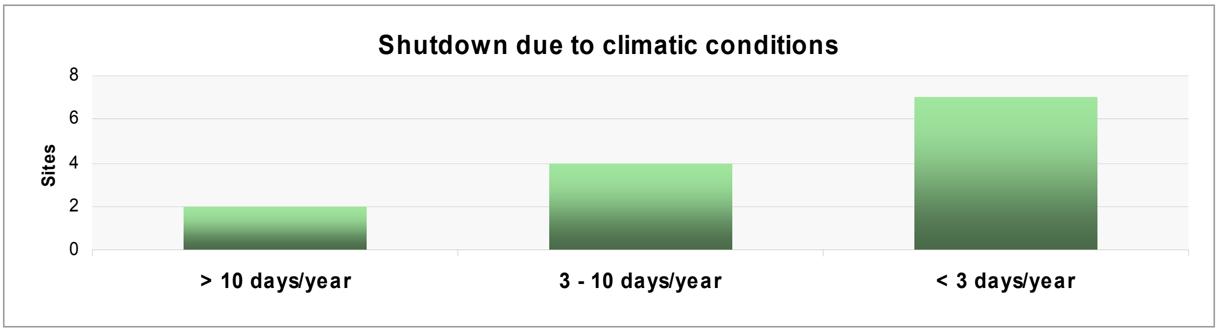

Fig. 44: Operator Survey – Shutdown due to climatic conditions

- **Loss of output due to ice build-up**

Wind energy plants work with reduced capacity when there is ice or hoarfrost build-up on the rotor blades or if shutdown becomes necessary due to imbalance or the danger of ice being thrown off. An estimate of loss of output due to these circumstances is however very difficult. In the absence of basic data the operators usually have to depend on their subjective perception, thus the quality of information on this issue varies greatly. The estimated loss of output resulting from ice and hoarfrost build-up lies between 1 and 25 percent. The wide variation in the information quoted probably does not reflect the actual shutdown periods or operation during ice and hoarfrost build-up but is more likely a subjective view influenced by a specific incident.

Fig. 43: Iced up wind turbine in Oberzeiring

During the planning phase in Oberzeiring loss in yield due to climatic conditions was calculated at between 5 and 7% but in fact the loss probably lies between 3 and 5%. Having said that, even at this site no detailed statement can be made as information could only be obtained by comparing the yield achieved in practice with the theoretically calculated yield. To achieve this, a specific monitoring program would need to be carried out with measurements running parallel.

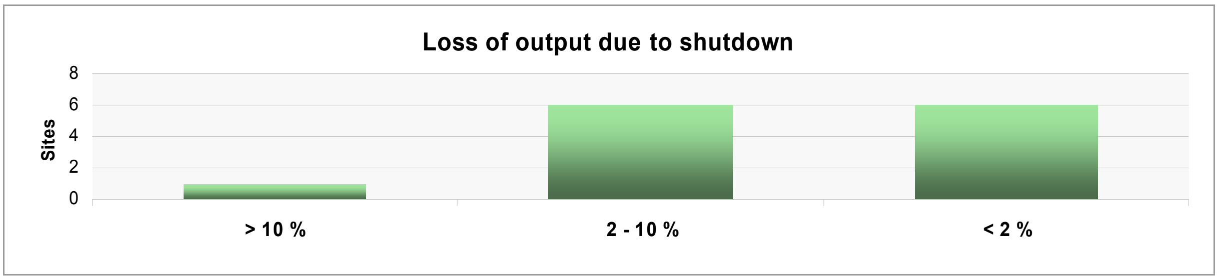

Fig. 45: Operator Survey - Loss of output due to shutdown

- **Damage due to meteorological effects**

Damage at alpine sites can be caused due to meteorological conditions such as lightning, hail, ice build-up and exceptional weather conditions with wind shear or extreme turbulence.

The results of the survey show that very little damage is caused as a result of ice or low temperatures. Only one operator listed damage that had been caused by the rotor blades colliding with falling ice. Damage caused by hail was however listed by many of the operators. According to the comments of operators, special attention should be paid to damage caused by hail. The problems result from the fact that hailstorms usually occur in combination with high wind, which means the rotor blades are hit with considerable energy and this effect is in turn increased by the high blade tip speed of turbine rotors. The danger of lightning strikes, which is considerably higher than at sites inland, is often cited by the operators as a cause of damage, although this usually causes no serious effects. The reason is probably found in the highly developed lightning protection systems installed at modern sites that ensure safe conduction of lightning strikes that result in only minor damage. Such incidents rarely require shutdown since such damage can usually be repaired in the course of routine maintenance work on the rotor blades.

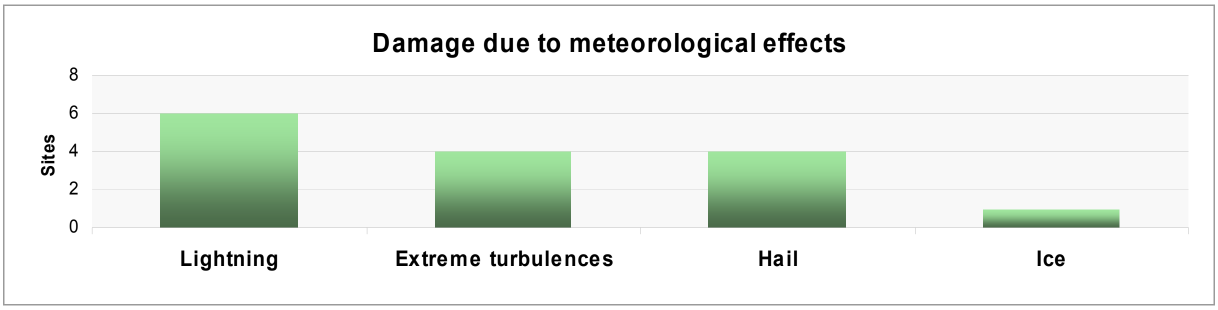

Fig. 46: Operator Survey – Damage due to meteorological effects

- **Special service fluids**

Low temperatures may interfere with the effectiveness of necessary service fluids such as transmission oil and lubricants. If a wind turbine is to be suitable for operation at very low temperatures, either the individual machine components and/or the service fluids they contain must be kept at a moderate temperature, or special purpose fluids must be used that retain their effectiveness at the given operational conditions.

The question of which fluids are used also confirmed the fact that at the sites reviewed almost no measures have been introduced to take into account the exceptional meteorological conditions. Only one site stated that transmission oil suitable for low temperatures was used. For the projects Oberzeiring and Mt Crosin (two VESTAS V 66 plants) this measure is not necessary as the entire nacelle is kept at a constant temperature of at least 10° C and therefore the service fluids are not subjected to temperature extremes.

- **Precautions for personal safety**

At sites with a great likelihood of ice and hoarfrost build-up on the rotor blades, there is also the danger that fragments of ice may be thrown from the rotors. This results in danger for persons who are in the vicinity of wind turbines and also poses the threat of material damage to buildings or vehicles. It is therefore essential that measures are taken on such sites to prevent potential damage.

This problem should be taken into account during the planning stage by observing safety distances between buildings and routes used by the public. It is possible to make a precise calculation of the trajectory of ice that is thrown off depending on the direction and speed of the wind and recommendations already exist on the observation of minimum distances to features and property that are at risk.

Even when these minimum distances to public places and features are observed, there still remains a risk for persons who are in the vicinity of the wind turbines. This is the case particularly in alpine regions where one must assume that hikers or skiers can approach the installations. For this reason it is necessary to take precautions against injury to persons in addition to observing the minimum distances to public places. It is necessary to differentiate between two possible measures:

- Passive measures that promote personal safety such as e.g. warning signs, fences or barriers that are intended to point out the existing danger to people.
- Active measures as e.g. shutdown of plants or reduction of the rotor speed.

The survey shows that danger posed by falling off was taken into consideration in very few of the projects and particularly at the older plants. Only three of the 13 operators questioned replied that they use signs in winter to warn people against falling ice. Active measures are in-place only at Oberzeiring where the turbines are switched off by ice detectors when there is ice build-up. In addition, there are barriers on the routes leading to the wind farm and at each turbine there is a flashing light to warn that there is danger of ice being thrown off.

Fortunately none of the 13 locations under review has reported damage to persons caused by falling ice.

Fig. 47: Road barrier when there is danger of falling ice

Fig. 48: Warning sign showing danger from falling ice

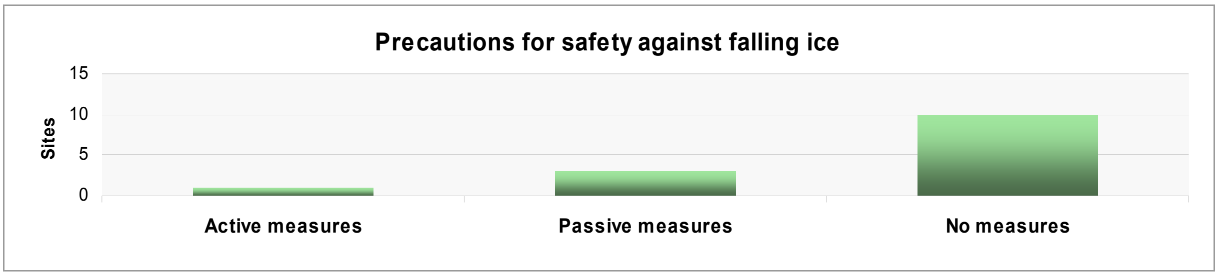

Fig. 49: Operator Survey – Precautions for personal safety against falling ice

4.1.5 Visions of the future

The operators of the existing wind energy installations are confronted first hand with the immediate problems of operating wind energy plants in alpine locations, this experience providing the basis for the potential development of knowledge and technology. Neither planners nor manufacturers are closer to the source of this experience than are the operators.

Even if only few plants are in operation in the Alps at the present time and of these only a part can be considered as representative of current issues and future developments, an important factor in the future construction of wind energy projects in comparable locations lies in the access to the experiences of these operators.

- **Evaluation of available technology**

This question was intended to provide information on the extent to which operators can propose new ideas for improvements on the basis of their experience.

Study of the answers leads to contradiction with the answers to the question about experience gained through operation. The majority of operators indicated in the previous questions that the technology they employ meets the requirements quite well. At the same time, 80% of the operators state that improvements are needed for the future. In their opinion, the technology currently available on the market cannot fulfil the demands made on the operation of wind energy turbines under extreme climatic conditions.

- **A call for action**

From the operators' point of view, action is needed in the following areas:

Proposal	Rating
Keeping rotor free from ice	4
De-icing during operation	1
Coating of rotor blades	1
Use of heated sensors	3
Improvement of turbine controls	1
General reduction in the susceptibility to breakdown	1
Improvement of aerodynamics	2
Better reaction to wind gusting	1
Protection of cooling unit against hail	1
Improvement of transportability to exposed locations	1
Improved means of winter access	1
Better selection of sites – no construction of cover-up plants	1
More precise wind measurement as basis for planning	1
Improved turbine maintenance	1
Positioning of transformers close to or inside the installation	1
No proposal for improvement	3
No information	1

Table 6: Call for action from the operators' point of view

The most frequently called for actions are the de-icing of the rotors and the development of reliable sensors for operation of the turbines (heated wind sensors and ice detectors). It is surprising that in this connection not a single operator lists improved personal safety where there is risk of ice being thrown off as a problem requiring a solution.

Apart from two rather more general calls for the improvement of rotor aerodynamics, the remaining priorities are concerned with operational problems operators have with their plant. Three operators see no necessity to improve plant technology and no answer at all was received from one operator.

The replies offered little insight into the issue of what action should be taken in future, suggesting that the question was somewhat too far-reaching for the operators to address, either due to lack of time or for technical reasons. To gain a deeper insight into the range of experience the operators have accumulated, a further study would need to take place including a targeted investigation on site, combined with the evaluation of the operating performance and details of failures.

4.1.6 Summary of the results of the survey

Only about 1.5% of the turbine capacity installed in Austria, Italy, France, Slovenia and Switzerland is situated in locations in the Alps. A total of 35 wind energy installations are operating at 23 sites in the alpine regions of the countries listed. By means of a questionnaire, experience with the operation of these installations has been gathered. Operators of wind energy plants in 13 locations made their experience available, making it possible to draw on a comprehensive range of experience as the survey is representative of installations of varying age and capacity.

In summary it may be said that transportation and erection of wind energy plants at locations in the Alps, whilst placing huge demands on planners, manufacturers and operators, can in fact be achieved using the vehicles and equipment that are available nowadays. In most cases the improvement to bends and embankments and the use of special vehicles for mountain transport is necessary. The costs required for these measures can be estimated at 3 to 5% of the total project expenditure, depending on the length of the access route. For storage and re-loading of the construction components from road vehicles to vehicles suitable for mountain transport, provision must be made in larger projects for the construction or rental of reinforced storage areas in valley locations. A reduction in the improvement measures required on access roads can be achieved by adapting the turbine components to suit local conditions by e.g. using shorter tower segments or delivering the machine cabins in single parts.

Electricity lines do not pose an insurmountable hurdle either when compared with locations on flat land. The extra costs are incurred not so much by the length of cables needed, but more particularly by the more difficult task of excavation in steep and rocky terrain.

A far greater problem is the adaptation of system technology to the specific climatic requirements in alpine locations. The currently available standard turbines are only suitable for use in alpine regions up to a point and so far mostly slightly modified standard inland turbines have been used.

Regarding the design of wind energy turbines with respect to the wind, ice and snow loads anticipated, there is no need for action as all manufacturers include in their equipment range wind energy turbines for high wind zones (IEC Class I or DIBT Zone 3), such turbines being suitable for sites in the Alps.

The two significant subject areas in which action is needed are operation at very low temperatures and the possibility of ice build-up on the rotor blades. Standard turbines are currently equipped for operation at – 20° C and at lower temperatures the turbines have to be switched off. In alpine locations such operating conditions frequently occur, making heating of the individual machine components (e.g. gears or hydraulics), or of the entire nacelle, a necessity. At the existing plants this problem was, however, hardly an issue and measures to heat the nacelle have been undertaken only on one turbine type (VESTAS V 66)

The problem of ice build-up on the turbine, the rotor blades and the control sensors is an important issue for the operators. In most projects heated wind sensors for turbine control are already in use, although ice detectors to switch off the wind turbine when ice builds up on the rotor blades are used at only one project site. Rotor blade heating is carried out at three locations, however using a heating system that is not suitable for automatic operation and can only be used at temperatures down to - 5° C. At two locations tests have been carried out using a special coating on the rotor blades to prevent ice build-up. No results of these tests have been made available and since the idea has not been pursued, it is to be assumed that expectations were not met.

More operators are not aware of the dangers in operating wind energy turbines with ice build-up on the rotor blades. Hardly any measures are undertaken to warn against dangers from ice that is thrown off and only one operator switches off the turbines for safety reasons. The manufacturers have until now not made a sufficient contribution either to the question of operational safety of the turbines or the risk of falling ice. There are almost no ideas to resolve heating for the rotor blades and the sensors required for control of the turbines do not yet function reliably. On the other hand the authorities are exerting pressure with regard to safe and reliable operation where there is risk of ice being thrown off.

Service and maintenance of the turbines in winter proves very difficult and great demands are made on the operators' staff. On this point most operators have introduced various ideas and solutions.