Chapter 9
Greece

9.1 INTRODUCTION

Greece is making profound institutional, regulatory, engineering, and funding efforts in order to meet the indicative target set by *Directive 2001/77/EC*. This is difficult because of the yet fluid state of liberalization of the utility market that was dominated for more than a half century by the single utility company in the nation. One of the aims of the Greek government is to substitute expensive imported fuel, currently used for electricity production in a large part of the Greek territory, by exploiting the country's wind potential. Government support for wind energy exploitation is part of its policy concerning renewable energy sources.

9.2 NATIONAL POLICY

Strategy

In Greece, *Law 2773/99, Liberalization of the Electricity Market – Regulation of Energy Policy Issues and other Provisions*, constitutes the basic legal background. Also, according to this law, two companies – the Regulatory Authority of Energy (RAE) and the Hellenic Transmission System Operator (HTSO S.A. or "the Operator") – have been created. These two companies are the basic factors of the free electricity market.

RAE is an independent, public authority that manages, suggests, and promotes the existence of equal opportunities and fair competition. It gives operation licenses to producers, providers, and all others related to the market.

In addition, RAE formulates suggestions to the Minister of Development with regard to the issue of power generation authorizations. Thereafter, RAE monitors the implementation progress of the renewable energy sources (RES) projects through quarterly reports and recommends which investors to remove from the sector due to unjustifiable slowness. RAE also recommends legislative measures for further deregulation of the electricity market within which critical RES issues can be addressed (as is the case of hybrid plants). On a more long-term basis, RAE considers the introduction of green certificates and the establishment of a network of large-scale, dispersed energy production.

HTSO is the company that handles the Hellenic Transmission System of Electric Energy. HTSO S.A. has a double role. The first role is the one being played by Public Power Corporation in respect to the transmission system: it always looks for a balance between production and consumption, and it ensures that quality electric energy is provided reliably and safe.

The second role of HTSO is to settle the market – in other words, to act like an energy "stock market" that arranges on a daily basis who owes to whom, according to *Law 3175/2003*. HTSO does not provide electric energy, and whatever basic exchanging relations exist are bilateral ones between producers/providers and their customers.

Prior to 1 February 2003, RAE approved a number of applications for power production from wind energy – 304 wind turbines with a total installed capacity of 3,533.9 MW. More specifically, 2,967.25

MW (from 195 turbines) have been approved for the interconnecting system of the mainland, 166.7 MW (from 31 turbines) have been approved for Crete Island, 229.36 MW (from 70 turbines) have been approved for the islands of the Aegean Sea, and 70.6 MW (from 8 turbines) have been approved for the islands of the Ionian Sea.

An optimistic estimation of wind-energy penetration up to the year 2010 is 2,170 MW. This estimate takes into account the 30% restriction on penetration of wind energy into the electric network. More specifically, 700 MW for Evia (Andros, Tinos islands); 350 MW for Thraki; 280 MW for Lakonia, East Arkadia; 240 MW for Crete, Rhodes, and other non-interconnected islands; and 600 MW for the rest of the country.

According to *Law 2773/99*, HTSO uses wind energy as first priority during generation unit dispatching. The price paid to the producer is a percentage of the tariff paid by the medium- and low-voltage consumers, the same power use as defined by the older *Law 2244/94* until *Law 2773/99* came in effect. The difference is that the Minister of Development is allowed to ask the producers from renewable sources for a discount on price.

Progress Towards National Targets

In 2003, the installed capacity of wind turbines reached 424.4 MW (from 772 wind turbines). The current national target for wind energy is now 2,000 MW for the year 2010, following EU directives.

The new *Law 2773/99*, introducing electricity market liberalization, maintains energy support from renewable sources in the framework of the competitive market, yet the effect of liberalization on the development of wind energy is not obvious.

Figure 9.1 Mavromihali, Evia, 11.4-MW wind park
Source: ROKAS AIOLIKI EVIA

Figure 9.2 Tsilikoka, Evia, 10.2-MW wind park
Source: TERNA ENERGY SA

9.3 COMMERCIAL IMPLEMENTATION

Installed Capacity

In 18 separate projects, a total of 100 wind energy conversion systems with an installed capacity of approximately 75.5 MW, were connected to the electricity supply network during 2003. This brings the total installed wind energy capacity to 424.4 MW (772 machines).

Rates and Trends in Deployment

The development of wind energy within the last ten years is shown in Figure 9.3, which depicts the total installed capacity per year.

Contribution to National Energy Demand

The energy produced from wind turbines during 2003 was approximately 850 GWh, while the energy produced in 2002, 2001, 2000, 1999, 1998, and 1997 was 650 GWh, 756 GWh, 460 GWh, 160 GWh, 71 GWh, and 38 GWh, respectively. The total energy consumption in the country is on the order of 50 TWh, so the energy produced from wind turbines accounts for about 1.5 % of the energy demand.

Figure 9.4 shows the electricity produced from wind turbines for the last ten years and the corresponding capacity factor. For the year 2010, the total energy consumption in the country is expected to reach 72 TWh.

9.4 MARKET DEVELOPMENT AND STIMULATION

Main Support Initiatives and Market Stimulation Incentives

The Operational Program Competitiveness (OPC) supports the development of wind energy projects. OPC raises resources from

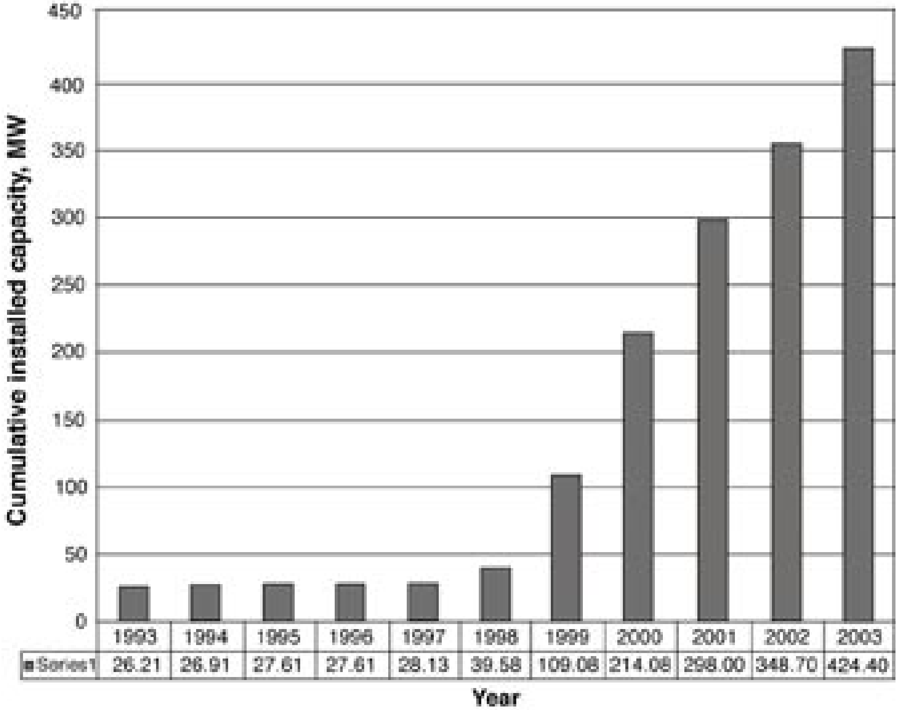

Figure 9.3 Cumulative installed wind capacity in Greece

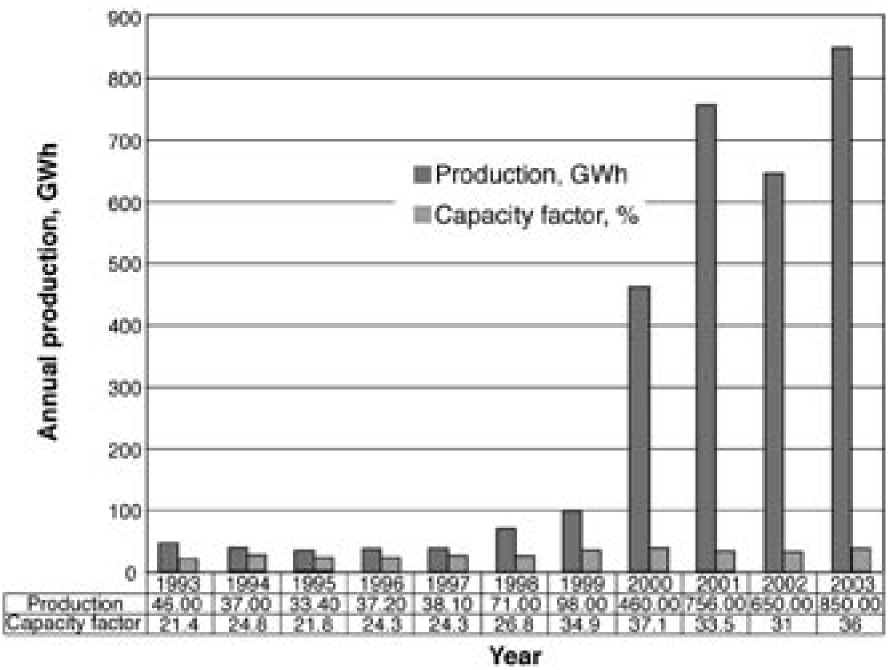

Figure 9.4 Electricity produced and capacity factor for wind turbines in Greece

the 3rd Community Support Framework, which provides public aid to RES and energy-saving, substitution, and other energy-related actions as high as 1.02 billion euro. The public aid accounts for 30% of the eligible cost of the projects and goes up to 50% in the case of transmission lines that will be constructed for the connection of RES plant with grids.

The Center for Renewable Energy Sources (CRES) acts as an intermediate agent in charge of the administration and management of projects included in Measure 2.1, Action 2.1.3 of the OPC. More specifically, CRES is the thematic intermediate agent responsible for the administration and management of all wind energy projects in the mainland and those with nominal capacity greater than 5 MW on the islands of Greece.

The relevant budget is up to 650 million euro. An installation permit is necessary in order to finance a project. The eligible cost for financing a wind farm is up to 900.00 euro/kW, without including the cost for electrical grid connection.

Unit Cost Reduction

No data available.

9.5 DEPLOYMENT AND CONSTRAINTS

Wind Turbines Deployed

The average capacity of the wind turbines installed in 2003 was 755 kW, while the average capacity of all the wind turbines operating in the country is 549 kW. The market share per manufacturer is depicted in Figures 9.5 and Figure 9.6.

Operational Experience

Due to relative short operation periods of most wind-energy projects, limited malfunctions have been reported since their commissioning. However, CRES has developed, and continuously updates, a database with related information for the operation and performance of all the wind parks around Greece.

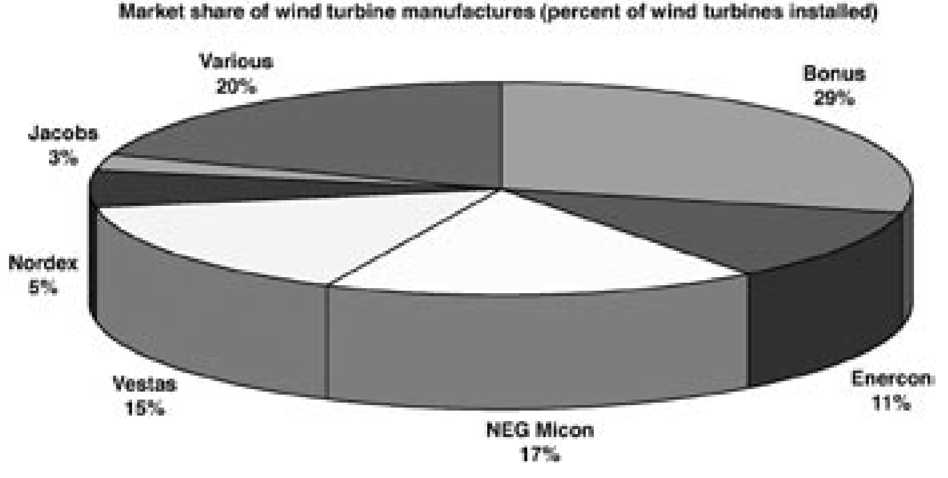

Figure 9.5 Market share of wind turbine manufacturers (percent of turbines installed)

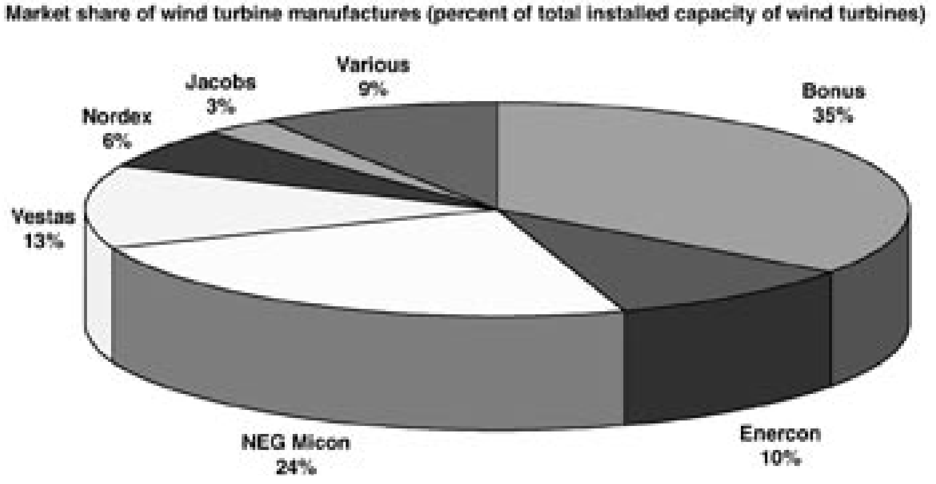

Figure 9.6 Market share of wind turbine manufacturers (percent of installed capacity)

Main Constraints on Market Development

The two main constraints for the installation of new wind farms remain (1) the complicated procedures for the acquisition of generation authorization, and (2) the inadequate electrical network to absorb the energy produced.

9.6 ECONOMICS

Trends in Investment

The total cost of wind power projects depends on wind turbine type, size, and accessibility. This cost varies between 970.00 euro/kW and 1,170.00 euro/kW. The generated wind-power cost could be assumed to be between 0.026 euro/kWh and 0.047 euro/kWh, depending on the site and project cost. The typical interest rate for financing wind energy projects is on the order of 7% to 8%.

Trends in Unit Costs of Generation

The power generation system in Greece is divided into two categories: the so-called interconnected system of the mainland and the autonomous power plants of the islands. In the liberalized electricity market, as well as before, a single charging price exists in both systems, depending on the identity of the consumer and the voltage class.

This price list concerns the tariffs of electricity purchased since 1 September 2003 by HTSO according to *Law 2244/94*; the decision of the Minister of Industry, Energy, and Technology numbered Δ6Φ1/ OIK.8295/19.4.95 (ΦΕΚ 385/10.5.95); and *Law 2773/99*. This electricity is either produced by independent producers or is the surplus of auto-producers and comes from either RES or cogeneration of heat and power (CHP). There is no capacity charge on purchases from producers in non-interconnected islands.

9.7 INDUSTRY

Manufacturing

There have not been any significant manufacturing developments in 2003 except for a couple of small wind turbine manufacturers in a typical range of 1 kW to 5 kW. However, an important involvement

Connection voltage	Magnitude with tariffs	Independent production a) From RES b) From CHP through RES	Auto-producers surplus a) From RES b) From CHP through RES
High	Energy	0.06449	Peak 0.03275
			Interim Load 0.02269
			Low Load 0.01684
	Capacity	1.65565	-
Medium	Energy	0.06449	0.05016
	Capacity	1.65565	-
Low	Energy	-	0.06201
	Capacity	-	-

Table 9.1 Interconnected systems and interconnected islands (in euro/kWh and euro/kW)

Connection voltage	Magnitude with tariffs	Independent production	Auto-producers surplus
		a) From RES b) From CHP through RES	a) From RES b) From CHP through RES
ALL	Energy	0.07973	0.06201

Table 9.2 Islands non-interconnected (in euro/kWh)

in the manufacturing of tubular towers by the Greek steel industry has been considered. One Greek company that has been involved in blade manufacturing has not yet managed to commercialize its products.

Certification

Greece requires installation permission for a wind turbine with more than 20 kW of capacity. With the new Law, *Procedures for the Installation and Production Permits*, a type approval certificate and a power quality certificate are required for each wind park. CRES is, by law, the certifying authority for wind turbines in Greece and is responsible for issuing the certificates.

CRES accepts type certificates and reports of power quality measurements issued by authorized institutions – such as Germanischer Lloyds, TUV and DNV, or any other organization accredited according to EN45011 for certifying wind turbines – according to the following standards and criteria:

- Germanischer Lloyds Regulations
- Danish standards and criteria
- Dutch standards and criteria
- International Electrotechnical Commission (IEC) 61400-1 standard

Additionally, CRES's Wind Energy Department participates in the standardization work carried out by the Hellenic Organization for Standardisation (ELOT), in the framework of European and international organizations working on certification procedures and standards to be followed nationwide, taking into account the climatic characteristics of Greece.

In 2003, active involvement in the activities of IEC TC-88, CLC/BTTF83-2, and their working groups continued.

9.8 GOVERNMENT-SPONSORED R,D&D

Priorities

The Ministry for Development promotes all R&D activities in the country, including applied and basic R&D as well as demonstration projects.

Key areas of R&D in the field of wind energy in the country are: wind assessment and characterization, standards and certification, wind turbine development, aerodynamics, structural loads, blade testing, noise, power quality, wind desalination, and autonomous power system integration. There is limited activity in Greece concerning megawatt-size wind turbines or offshore deployment.

CRES is the national organization for the promotion of renewable energy in Greece mainly involved in applied R&D in the fields of aerodynamics, structural loads, noise, power quality, variable speed, wind desalination, standards and certification, wind assessment, and integration. CRES developed and operates its Laboratory for Wind Turbine Testing, which has been accredited under the terms of ISO/IEC 17025:2000.

CRES, in co-operation with a Greek company, designed and developed a pilot autonomous hybrid (wind turbine/photovoltaic) reverse osmosis system for seawater desalination, within the National Programme PAVET, of the Greek Ministry for Development, for further research on technologies coupling. The system has been installed at the CRES Wind Park at Lavrio, Attiki.

New R,D&D Developments

Several research projects were running at CRES during 2003, co-funded by the European Commission and the Greek Secretariat for Research and Technology. These research projects had the following goals:

1. Characterizing the main features of complex or mountainous sites (most sites favorable for wind energy development are of such topography) and identifying the crucial parameters affecting both the power performance and the loading of different types of wind turbines operating at such environments (new techniques are under development for power-curve measurement of wind turbines operating in complex terrain)
2. Developing wind turbines for installation in hostile environments
3. Improving the damping characteristics of wind turbine blades
4. Developing new techniques for power-quality measurement and assessment
5. Increasing understanding of wind turbine standardization procedures
6. Developing blade-testing techniques within the in-house experimental facility
7. Understanding generic aerodynamic performance of wind turbine blades through computational fluid dynamics (CFD) techniques
8. Developing cost-effective, micro-siting techniques for complex terrain topographies

Basic R&D on wind energy is mainly performed at the country's technical universities. The National Technical University of Athens (NTUA) is actively involved in two research areas concerning wind energy: (1) rotor aerodynamics and (2) wind-energy integration in the electrical grid.

The fluids section of the Mechanical Engineering Department of NTUA is active in wind modeling, rotor aerodynamics, load calculation, fatigue analysis, noise, and wind farm design. Work conducted during 2003 included applied research on rotor aerodynamics for wind turbines.

More specifically, in terms of prediction/ design codes, NTUA participated in a European Community (EC)-funded benchmark exercise concerning the verification of design tools for wind turbines. Within this activity, NTUA upgraded the free-wake model, GENUVP, developed in-house into a complete aeroelastic tool. In particular, a new hybrid wake model was implemented that allows the simulation of complete, ten-minute time series with turbulent wind inflow. The code was successfully validated against measured data.

The new viscous-inviscid interaction model for airfoils, FOIL2W, was validated against wind tunnel measurements in cases of light as well as deep stall for pitching airfoils.

In terms of design, NTUA further developed the computational procedures concerning the optimum design of airfoil sections and complete blades for stall-regulated machines. The family of airfoils designed has improved polars, especially in regard to roughness sensitivity and stall behavior. Application of this procedure was carried out for megawatt-scale machines within a EU-funded project. Extension of the optimization procedure to the case of pitch and variable-speed machines has been initiated, aiming at an improved design for new, large, offshore machines.

The Electrical Engineering Department of NTUA has been actively involved in the field of wind energy since the beginning of the 1980s, participating in R&D projects sponsored by the EU and other institutions and co-operating with universities and research centers from many European countries.

In 2003, the Electric Power Division of NTUA continued its research activities on issues related to the technical constraints and problems in the integration of wind power into the electrical grids, the management and control of isolated power systems with increased wind power penetration, power quality of wind turbines and wind parks, and the design of electrical components for variable-speed machines.

The technical constraints and problems with integration of wind power into electrical grids have been investigated in various regions of Greece where the transmission system is weak and there is high interest in related wind projects due to favorable wind conditions. Steady-state voltages, voltage variations, and power quality issues have been investigated. Besides work on the interconnected system, emphasis has been placed on the secure integration of increased shares of wind energy in island systems.

Work has continued on MORE CARE, the advanced control system comprising load and wind-power forecasting, unit commitment, economic dispatch, and online dynamic security assessment modules integrated within a friendly person-machine interface. The advanced control system has been installed on Crete and is currently under evaluation with promising preliminary results. In addition, various control systems of variable-speed wind turbines have been studied. A specialized code has been developed for simulation of the effect of most common wind turbine types on the steady-state and dynamic performance of weak grids. This tool allows the convenient study of relevant power quality problems.

Dispersed renewable generation is gaining considerable attention, and research in this area has continued, focusing mostly on technical issues related to the integration and control of such units, their impact on distributed grid operation, and distribution network planning in areas with high dispersed generation potential. Particular emphasis is placed on the development of microgrids, which are comprised of low-voltage grids with increased dispersed generation.

Work continues on the control of variable-speed (large- and small-scale) wind turbines, in order to reduce the mechanical stresses and achieve a more "grid-friendly" operation (i.e., improved power quality and a controlled power factor for voltage support of weak grids).

Design of electrical generators and converters for wind turbine applications is in progress, including permanent magnet synchronous generators with state-of-the-art electronic converters suitable for small wind turbines.

Integration of wind turbines in small, stand-alone systems is being researched, with specific application in water desalination for remote areas.

Power quality issues related to the grid-connected operation of wind turbines (e.g., slow- and fast-voltage variations, flicker, and harmonics) are a central research area, and a great deal of work has been performed on the elaboration of connection guidelines.

Increasing wind power penetration in isolated island systems, with proper application of pumped storage via reversible hydropower stations, is also an important research topic and crucial for the exploitation of wind potential in many non-interconnected Greek islands. Another ongoing research area is the development of advanced control centers for the management of conventional and renewable generation in isolated island systems of this type. Within this framework, algorithms and techniques are elaborated for short-term wind forecasting for operational planning.

The applied mechanics section of the Department of Mechanical Engineering and Aeronautics, University of Patras (UP), has focused on educational and R&D activities involving composite materials and structures since 1990. Emphasis is placed on wind turbine anisotropic material property characterization, structural design, and dynamics of composite rotor blades. Participation in several national and EC-funded research projects has provided experience in these areas.

During 2003, UP contributed to the following three EC-funded research projects:

1. Wind Turbine Rotor Blades for Enhanced Aeroelastic Stability and Fatigue Life Using Passively Damped Composites (DAMPBLADE)
2. Development of a Megawatt-Scale Wind Turbine for High Wind Complex Terrain Sites (MEGAWIND)
3. Reliable Optimal Use of Materials for Wind Turbine Rotor Blades (OPTIMAT BLADES)

In the DAMPBLADE project, UP is contributing with experimental characterization of anisotropic damping properties; development of a dedicated FEM code for efficient damping modeling of composite structures; and design of a 20-m GRP rotor blade, optimally damped.

In the MEGAWIND project, UP has accomplished the structural design of a modular (split) 30-m blade, which will be verified by full-scale testing at CRES. A prototype is under development by Geobiologiki SA.

In the OPTIMAT BLADES project, UP is a task group leader investigating blade material behavior under complex stress states in which the effect of multi-axial static and cyclic loading on strength and life of composite laminates is to be assessed. Results will be available in the form of design guidelines for rotor blade manufacturers.

Other research activities of applied mechanics at UP include the following:

1. Finite element formulations and dedicated code accounting development for selective non-linear lamina behavior (e.g., in shear and in the laminate, as well as modeling of property degradation due to damage accumulation so as to predict life of large rotor blades under spectrum loading)
2. Probabilistic methods in the design of composite structures
3. Residual strength and fatigue damage characterization of composite materials using wave propagation techniques
4. Smart composites and structures
5. Structural damping and passive and active vibration control

No new demonstration projects were initiated in 2003. Performance results on the previously reported demonstration project titled, CRES 3.1 Megawatt Wind Farm in Complex Terrain can be found at http://www.cres.gr/windfarm. The monitoring software has the ability to periodically update the contents of the Internet site, presenting the latest operational data of the wind farm.

Offshore Siting

Does not apply.

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