Executive Summary

1.0 Introduction

In 2008, cumulative installed wind power capacity increased nearly 29% (1) worldwide and nearly 23% (2) in the member countries of the IEA Wind Implementing Agreement. In the IEA Wind member countries, 17,000 MW was added in 2008 for a total of close to 92 GW of generating capacity. Even more encouraging, electrical production from wind increased more than 25% in IEA Wind countries to about 194 TWh (Table 1). This electrical production from wind met 2% of the total electrical demand in the reporting IEA Wind member countries—up from 1.6% in 2007. The percentage contribution from wind is growing steadily even in this time of economic slowdown. Electrical output from wind in the world was enough to cover the electricity consumption of Australia.

At the close of 2008, three-quarters of the nearly 121 GW (Table 2) of the world's wind generating capacity was operating in the IEA Wind member countries. Located in Europe, North America, Asia, and the Pacific Region, the member countries are sharing information and research efforts to increase the contribution of wind energy to their electrical generation mix. They are also reaching out to other countries to join this co-operation.

2.0 Progress Toward National Objectives

2.1 Wind generation capacity

The dramatic increase in electrical generation capacity and output from wind in the IEA Wind member countries as a whole can be seen in Figure 1. Capacity has increased from less than 5 GW in 1995 to nearly 92 GW in 2008. In 2008, the member countries added more than 17 GW of new wind generating capacity, and much more is being planned for 2009 and beyond. Thirteen countries added more than 100 MW of new capacity, and four countries added more than a gigawatt of new capacity: the United States (8,558 MW), Spain (1,609 MW), Germany (1,665 MW), and Italy (1,010 MW) (Table 3). In addition, Australia, Canada, Japan, the Netherlands, and Portugal added 300 MW or more. The Netherlands reached an all-time record of 490 MW of new installed wind capacity in 2008. Australia, Italy, and the United States also broke their national records due to favorable changes in domestic programs. Increases in capacity were less than hoped for in other countries such as Austria, Denmark, Finland, Korea, Mexico, Norway, and Switzerland because of uncertainty about government programs or very low competing energy prices. Total

Table 1 Key Statistics of IEA Wind Member Countries 2008

	2007	2008
Total installed capacity	74.84 GW	91.77 GW
Total offshore wind capacity	1,125 MW	1,431 MW
Total new wind capacity installed	13,315 MW	17,000 MW
Annual increase in capacity from previous year	21%	23%
Total annual output from wind	155 TWh/yr	194 TWh/yr
Wind generation as % of national electric demand	1.6%	2.3%

Table 2 Worldwide Installed Capacity for 2008			
IEA Wind Members		Rest of World (2)	
Country	MW	Country	MW
United States	25,369	China	12,200
Germany	23,902	India	9,645
Spain	16,740	France	3,387
Italy	3,736	New Zealand	468
United Kingdom	3,331	Poland	405
Denmark	3,163	Belgium	384
Portugal	2,819	Turkey	383
Canada	2,369	Egypt	365
Netherlands	2,214	Brazil	336
Japan	1,880	Taiwan	224
Australia	1,306	Bulgaria	158
Sweden	1,047	Morocco	134
Ireland	1,002	Czech Republic	133
Austria	995	Hungary	127
Greece	990	Ukraine	90
Norway	430	Costa Rica	92
Republic of Korea	236	Estonia	78
Finland	143	Iran	67
Mexico	85	Caribbean	57
Switzerland	14	Tunisia	54
Total	91,771	Lithuania	52
		Luxembourg	35
		Philippines	33
		Argentina	30
		Latvia	27
		Pacific Islands	24
		Colombia	20
		Chile	20
		Uruguay	18
		Croatia	17
		Russia	11
		Romania	10
		Reunion (France)	10
		Others (<10 MW)	38
		Total	29,132
		World Total	120,903

generating capacities of each country varied greatly, from the United States with 25,369 MW to Switzerland with about 14 MW.

The growth rate in many countries far exceeded the respectable average of 23% (Table 4). In the United States, wind energy capacity grew more than 50% in 2008 and accounted for 42% of that nation's new electrical generation for the year. Australia had the highest growth rate at 58%, while 11 countries had growth rates exceeding 23% for the year. Looking regionally, in Europe wind power installations alone made up almost 36% of new power installations and grew more than any other power generating technology there.

Many countries report significant amounts of capacity in the planning stages, including planning applications submitted, successful acquisition of land leases, projects under construction, and projects awaiting final connection to the grid. The capacity of projects planned or under construction is more than three times the capacity added in 2008 (Table 5). Mexico has 330 MW of capacity under construction, nearly four times the capacity operating at the close of 2008. In the United States, more than 4,000 MW were under construction at the beginning of 2009, more than half the capacity added in 2008. In the United Kingdom, more than 7,000 MW had received planning approval and 1,665 were under construction. And Australia is poised to repeat its 2008 record year with another 6,359 MW planned or under construction.

Offshore generating capacity was added in the Netherlands and in the United Kingdom. The UK is now the world leader in offshore wind energy, with 598 MW installed capacity. Much more offshore capacity is in the planning stages and could be connected as early as 2009: Denmark (28 MW), Germany (512 MW), Sweden (30 MW), and the UK (90 MW). Significant offshore resources to be exploited in the near future have been identified in Finland, Ireland, Italy, the Netherlands, Norway, and Spain.

Another trend in wind capacity increases is repowering—the replacement of older, smaller turbines with fewer, larger turbines representing the state of the art in power production. Especially for countries that have been installing wind turbines for a decade or more, repowering onshore is expected to increase in years ahead. In 2008, the Netherlands decommissioned 37 turbines (total capacity 14.6 MW) and replaced them with 53 turbines (total capacity 126 MW). The net repowering effect was an increase of about 112 MW. In Denmark, 164 turbines were removed and 51 new turbines were installed for a net addition of 39 MW, and the new incentive structure will encourage more repowering.

Increased interest in small wind systems (less than 40 kW) was reported in several countries (Canada, Ireland, Italy, Japan, Portugal, Spain, the United Kingdom, and the United States). In the United States, the small wind turbine industry (turbines rated at less than 100 kW) grew by almost 78% in 2008. The industry added 17.3 MW of new capacity, bringing the total small wind capacity to more than 80 MW. In Portugal, an active research program has developed and is testing a small vertical-axis turbine for urban applications.

2.2 Contribution to electrical demand

Total electrical production from wind energy in the IEA Wind member countries has increased from less than 10 TWh in 1995 to nearly 194 TWh in 2008 (Figure 1 and Table 3). The contribution from wind energy to the combined electricity demand has increased from under 0.2% overall in 1995 to well over 2% in 2008. In 2008, electrical generation from wind increased even as national electrical demand decreased or remained nearly constant in several countries (Denmark, Finland, Germany, Greece, Ireland, Italy, Portugal, Spain, Sweden, Switzerland, United Kingdom, and the United States). As a result of these two factors, the contribution of wind energy to electrical demand increased significantly in 2008. Wind's contribution to national electrical demand varied from under 1% in several countries to nearly 20% in Denmark. In five countries, the wind energy contribution to national electrical demand exceeded 5%, and in 14 countries it met or exceeded the 1% mark (Table 3). Portugal and Spain both got more than 11% of electricity demand from wind energy. In Ireland, nearly 9% of electricity demand was satisfied by wind energy in 2008. In the United States, as a result of record growth the past three years, wind energy for the first time supplied close to 2% of that country's electrical demand.

In Europe overall, total wind power capacity operating at the end of 2008 produced 142 TWh, or 4.2% of EU power demand in an average wind year, and avoided emissions of about 108 million tons of CO_2 annually. In 2000, less than 0.9% of EU electricity demand was met by wind power.

Wind energy is becoming a significant source to meet peak demand. In Spain, wind energy covered more than 40% of hourly demand on several occasions in 2008, and for several days it supplied more than 30% of daily electricity demand.

2.3 Environmental benefits

Wind power's contribution to providing for the world's electrical demand reduces the amount of conventional fuel burned to generate electricity. Many countries evaluate their generation mix and calculate the effects of using wind power. For example, the total U.S. wind generation capacity at the end of 2008 produced enough electricity to power approximately seven million U.S. households. Generation from these projects over their lifetime will displace nearly 44 million tons of carbon emissions—the equivalent of taking more than seven million cars off the road. In Ireland, a nation that is more than 90% dependent on imported energy supplies, wind power displaced almost 1.28 million metric tonnes of CO_2 emissions and primary energy imports of 215,000 metric tonnes of oil equivalent.

Table 3 National Statistics of the IEA Wind Member Countries for 2008

Country	Total installed wind capacity (MW)	Offshore installed wind capacity (MW)	Annual net increase in capacity (MW)	Total No. of Turbines	Average new turbine capacity (kW)	Wind generated electricity (GWh/yr)	National electricity demand (TWh/yr)	% of national electricity demand from wind*
Australia	1,306	0	482	756	2,000	***3,462***	***267.0***	1.3%
Austria	995	0	14	618	2,000	2,050	70.7	2.9%
Canada	2,369	0	523	1,681	1,863	5,800	***575.0***	1.0%
Denmark	3,163	423	39	5,101	2,000	6,975	36.2	19.3%
Finland	143	13	33	118	3,000	260	87.0	0.3%
Germany	23,902	0	1,665	19,568	1,667	40,400	***615.1***	6.5%
Greece	990	0	115	1,190	1,650	2,300	51.0	3.7%
Ireland	1,002	25	207.7	834	1,696	***2,298***	***26.2***	***8.8%***
Italy	3,736	0	1,010	3,588	1,566	***6,637***	337.6	1.9%
Japan	1,880	11	342	1,508	1,247	2,856	913.2	0.3%
RP of Korea	236	0	43	152	1,579	421	422.0	0.1%
Mexico	85	0	0	104		254	209.7	0.1%
Netherlands	2,214	228	490	2,053	2,219	4,259	119.3	3.6%
Norway	430	0	45	200	2,531	921	128.6	0.7%
Portugal	2,819	0	694	1,500	1,900	5,737	50.6	11.3%
Spain	16,740	0	1,609	>16,000	1,600	31,100	266.5	11.7%
Sweden	1,047	133	216	1,151	1,700	1,974	145.9	1.4%
Switzerland	14	0	2.3	28	2,000	19	57.4	0.03%
United Kingdom	3,331	598	912	1,952	2,060	5,274	406.0	1.3%
United States	25,369	0	8,558	>15,000	1,670	71,000	3,736.8	1.9%
Totals	91,771	1,431	17,000	58,102	1,886	193,997	8,521	2.28%

*% of national electricity demand from wind= (wind generated electricity/national electricity demand)*100

Bold italic= estimated vale

Table 4 Wind Energy Capacity Increases		
Country	Capacity added in 2008	Percent wind capacity increase
United States	8,558	51%
Germany	1,665	7%
Spain	1,609	11%
Italy	1,010	37%
United Kingdom	912	38%
Portugal	694	33%
Canada	523	28%
Netherlands	490	28%
Australia	482	58%
Japan	342	22%
Sweden	216	27%
Ireland	208	26%
Greece	115	13%
Norway	45	12%
Korea	43	22%
Denmark	39	1.0%
Finland	33	30%
Austria	14	1%
Switzerland	2.3	19%
Mexico	0	0%
Average rate		23%

The environmental benefit of wind power production in Finland is about 0.2 million tons of carbon dioxide savings per year. In Austria, 162 wind parks with 618 wind turbines generated 2.1 TWh of electricity, enough to power 570,000 households. This generation displaced 1.3 million tonnes of CO_2 for the year. In Spain, the use of wind power lowered CO_2 emissions by about 18 million tons just during 2008. Furthermore, wind generation saved up to 6 million tons of conventional fuels and supplied the electrical consumption of more than 10 million households.

2.4 National targets

All IEA Wind member countries recognize that renewable energy in general and wind and solar energy in particular offer great potential to reduce overall carbon emissions of the power industry. In addition, reducing the cost of electricity and decreasing reliance on imported fuels are justifications for several national targets

Table 5 Potential Increases to Capacity After 2008				
Country	Planning application* (MW)	Planning approval** (MW)	Under construction*** (MW)	Total planned and/or under construction (MW)
Australia	2,767	3,057	535	6,359
Austria	150	30	0	180
Canada				5,834
Denmark		200	200	500
Finland	80	30	3	113
Germany				
Greece				
Ireland	11,000	1,400	580	12,980
Italy				2,885
Japan		134		134
Korea			420	420
Mexico	2,500	2,000	330	4,830
Netherlands				200
Norway	4,535	2,095	0	2,095
Portugal	3,880	971	739	5,590
Spain				
Sweden	1,140		125	1,265
Switzerland	50	26	4	80
United Kingdom		7,093	1,665	8,758
United States			4,451	4,451
Totals	26,102	17,036	9,052	56,674
	*Means all paperwork has been submitted to official planning bodies	**Means all relevant planning bodies have approved the projects	***Means all approvals are received and physical work has begun on the projects	

for renewable energy. In 2008, success in meeting targets for renewable energy contribution to electricity demand prompted several countries to propose or adopt more aggressive targets. In Australia, the renewables target set for 2010 was met, so the Australian federal government proposed a new target of 20% by 2020.

Along with new targets, some countries are also changing the incentive structures. In Finland, the new target is 2,000 MW of wind power in 2020. This would be about 6% of the total electricity consumption in Finland. A new subsidy system is proposed to start in 2010. Projects that are planned, are under feasibility studies, or have just been proposed equal 1,100 MW onshore and 5,700 MW offshore. Ireland could reach its 2010 target if 60% to 70% of contracted wind farms are connected by 2010. This seems likely, so Ireland increased its target from 33% renewables by 2020 to 40%, and this target is now described as a minimum. In Germany, the EU target for renewables was exceeded in 2007, so the German government set a new target that at least 25% of electricity consumption should come from renewable sources. This translates to a strategic goal for offshore wind development of 1,500 MW by 2011 and 25,000 MW by 2030. This effort may be facilitated by the Infrastructure Acceleration Act, which requires transmission system operators to pay for and install the grid connection from the onshore grid access point to the offshore wind farm.

An important goal has been set for the European market for wind energy technology by EU framework legislation combined with legislation at the national level aimed at reducing barriers to the development of wind energy and other renewables. The EU has issued a new Renewable Energy Directive for a binding 20% renewable energy target by 2020. The EU's overall 20% renewable energy target for 2020 has been divided into legally binding targets for the 27 member states, averaging out at 20%. These targets must be implemented at the national level.

Studies of wind energy potential are also driving policy and planning. In the United States, a report published in 2008 examined the potential for wind energy to provide 20% of U.S. electricity by 2030. Wind capacity contributing 20% would support 500,000 jobs, reduce greenhouse gas emissions equivalent to taking 140 million vehicles off the road, and save 4 trillion gallons of water. The report concluded that reaching such capacity will require

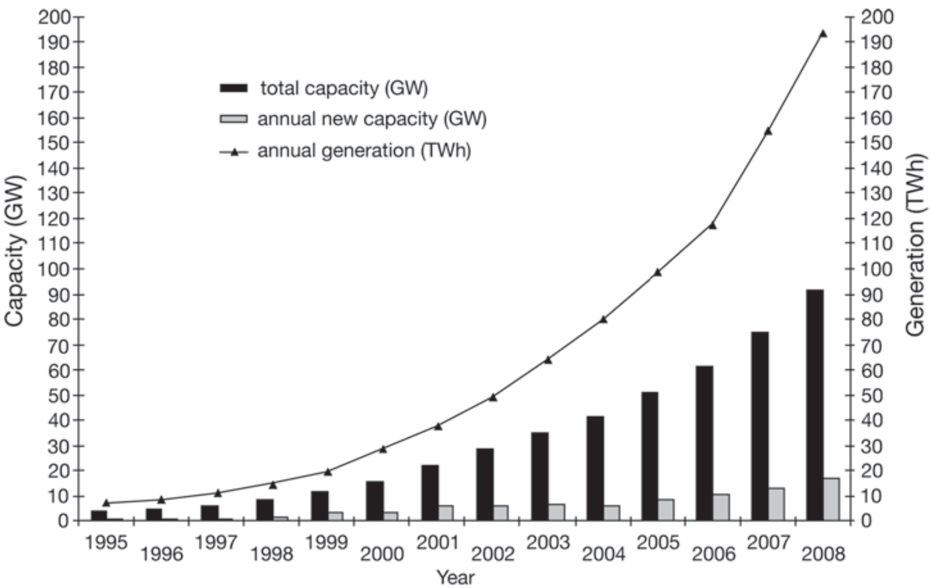

Figure 1 Annual installed capacity, cumulative installed capacity, and annual generation as reported by IEA Wind member countries, 1995–2008.

an increase from the current 25.3 GW to more than 300 GW. To achieve this increase by 2030, annual increases in wind capacity will need to exceed 16 GW after an initial 10-year ramp-up period. The 8.5-GW increase in 2008 is a significant step toward meeting this goal. In Italy, the maximum wind potential is considered to be 12,000 MW by 2020 according to the 2007 Renewable Energy Position Paper of the Italian government. Offshore installations should contribute 2,000 MW to this target, corresponding to a total annual production of 22.6 TWh. (See Table 1 of the each country chapters for specific national targets.)

2.5 Issues affecting growth

IEA Wind member countries report several key issues affecting increased deployment of wind energy. Work in the countries and co-operative research tasks (annexes) within the IEA Wind Implementing Agreement are under way to address some of these issues. (See also Section 5.0, R, D&D Activities, of each country chapter.) Countries experiencing rapid growth attributed the growth to favorable financial incentives and regulatory environments that allowed for efficient approval and construction of projects. Slower growth was often attributed to uncertainty about the future of incentives, lack of sufficient incentives, or difficult regulatory issues that prevented timely approval of projects.

2.5.1 The world economy

The economic situation referred to as a credit crisis, economic slowdown, or economic crisis began to affect wind energy development in the second half of 2008 in some countries. All countries mentioned this issue when discussing prospects for 2009.

2.5.2 Grid capacity, integration, and transmission

Today's grids are mostly the result of previous planning and are adapted to the needs of an electricity system made up of centralized, large-scale power plants. The move toward smaller and more decentralized generation plants thus requires adaptation of the grid.

Integrating wind energy and hydropower renewable resources for the benefit of consumers and the electrical generation system is appealing, and its technical and economic issues have been explored by IEA Wind Task 24, Integration of Wind and Hydropower Systems. Expected outcomes of this work, to be published in 2009, include the identification of practical wind/hydro system configurations and an understanding of the costs, benefits, barriers, and opportunities when integrating wind and hydropower systems.

System operation impacts from wind power are a concern of transmission system operators. Responding to the need to explore this issue, IEA Wind Task 25, Power Systems with Large Amounts of Wind Power, began work in 2005. The final report of the first phase of 2006–2008 shows the error of claims that wind power requires large amounts of reserve power and that integration costs erode the benefits of wind power. The report finds that a substantial tolerance to variations is already built in to our power network. This is why the influence of wind power fluctuations can be further balanced through a variety of relatively easy and inexpensive measures for reasonably large penetrations (10% to 20%). The impact of a large share of wind power can be controlled by appropriate grid connection requirements, extension and reinforcement of transmission networks, and integration of wind power production and production forecasts into system and market operation.

Forecasting the output of wind plants can increase the value of wind generated electricity and make system impacts more manageable. IEA Wind Task 11 Base Technology Information Exchange held a Joint Action Symposium that gathered experts on wind forecasting techniques. The value of the wind forecasts depends on several factors like the characteristics of the system, the way the system is operated, regulations, climatic conditions, and so on. To continue the exchange between modelers and users of information, IEA Wind may sponsor additional meetings on this topic. In Australia, the variability of wind generation prompted implementation of the Australian Wind Energy Forecasting System (AWEFS), a sophisticated forecasting model that predicts wind generation for use with the National Electricity Market management systems.

Limited capacity of the transmission system has prompted rationing of capacity and construction of expanded systems. In Ireland, the electricity regulator directed system operators as to how they should control the connection of wind applicants in the coming years. Those wishing to connect to the grid join an applicant queue once their application is "deemed complete." The options considered for accepting applicants included a date-order approach, a mixed date-order/optimization approach, or a Grid Development Strategy, which will result in the issuance of offers to selected applicants in the connection queue when the application process closes. To gain full advantage of its abundant wind resource, Ireland should have a 500-MW East-West Interconnector with the mainland by 2012. Another 350-MW high-voltage direct-current interconnector between Ireland and Britain is planned by Imera Power, a private asset-investment company that will build and operate the interconnector on a merchant basis.

The Mexican government awarded a 209-million-USD contract in August 2008 for the construction of a 300-km electrical transmission line for wind energy projects. The new line will be rated at 2,000 MW and will be shared by wind project developers who will also pay for the line over the long term. The transmission line will be commissioned by the end of 2010.

In the United States, a study by an investor-owned utility and the trade association concluded that a transmission superhighway will be needed for the United States to obtain 20% of its electricity from wind. More than 19,000 miles of new 765-kV (high-efficiency) transmission lines are proposed, costing 60 billion USD. To improve grid access, planning and construction of multistate, extra-high-voltage transmission lines is under way.

2.5.3 Planning issues and public resistance

Planning issues were mentioned as both benefiting wind development (when planning proceeded smoothly) or obstructing projects. Complex requirements in plans can obstruct wind development. In Japan, a building code that became effective in June 2007 classified wind turbines over 60 m high (highest point of blade tip) as a kind of building. Under this code, the installation of wind turbines requires the minister's sanction, and the application procedure for planning permission is very complicated, time consuming, and expensive. Only in July 2008 was the first project approved under this new code. After that, the permission process became more standardized, and many other projects are being authorized.

In Korea, wind farm development has been slow for several reasons, including the complex system for approval of developments caused by conflict among existing laws, public acceptance issues, and difficulty getting permits for grid connection. Also, onshore sites are limited because of mountainous terrain.

Some countries have improved the permitting process in recent years. In the United Kingdom, the approval rate for new wind energy projects in 2007 was 70.1%. This was significantly greater than the rates of 54.7% in 2006 and 59.6% in 2005. In 2008, the approval rate dropped to 61%. Although this rate was lower than the 2007 rate, significantly more capacity was approved in 2008 (almost 4 GW) than in 2007 (2,300 MW).

In response to growing concerns about public acceptance of wind energy development, IEA Wind Task 28 Social Acceptance of Wind Energy Projects was approved in 2008. The work will collect case studies of successful community and market engagement and will publicize successful strategies for developing wind power.

In Denmark, public resistance is being addressed by government regulation. Beginning in 2009, the owners of new turbines to be installed will pay neighbors for resulting loss of property value. The compensation will be based on an individual evaluation of the loss of property value.

3.0 Benefits to National Economy

3.1 Market characteristics

The economic impact of wind energy development is estimated in various ways by the IEA Wind member countries (Table 6). Monetary values in this report are calculated using the exchange rates effective on December 31, 2008 (Appendix C Currency Conversion Rates). One measure of benefit, sometimes referred to as economic turnover or contribution to gross domestic product, is the value of all economic activity related to such development. It includes payments to labor, cost of materials for manufacture and installation, transportation, sales for export, and value of electricity generated. Other values reported include industrial activity, construction, and value of exports. Many countries are estimating the number of jobs created by wind energy manufacturing, development, and operation. According to the EWEA, 15.1 jobs are created in the EU for every megawatt installed. In addition, 0.4 jobs are created per megawatt of cumulative capacity in operations, maintenance, and other activities. About half of these jobs are associated with wind turbine and component manufacturing. For offshore, the numbers are higher.

The rapid growth of Canada's wind energy industry has resulted in a growing number of firms entering the market, resulting in increased activity in a variety of areas including resource assessment, project development, manufacturing, construction, and operations. In fact, the Canadian Wind Energy Association's (CanWEA) corporate membership has grown from 86 members to about 400 members over the past five years.

In Italy, the economic turnover of the wind sector in the past two years rose to more than 1 billion €, including turbines and components delivered to foreign countries. At the end of 2008, 18,309 employees were involved in the wind sector, of which 5,353 are directly employed. The total personnel involved is subdivided as follows: feasibility studies, 2,240; manufacturing of turbines and related industry, 3,033; development and civil works, 5,246; installation, 1,421; and management O&M, 6,369. A study estimated that by 2020, assuming full exploitation of an Italian wind potential of 16,200 MW and energy production of 27.2 TWh, some 66,000 people would be employed (including indirect employment). This development is taking place in rural areas needing employment. Another positive aspect ensuing from the rising wind power capacity is increased investment in upgrading electrical grid infrastructures.

Total investment in wind energy installations in the Netherlands for 2008 can be estimated at 850 million €, assuming an average investment cost of 1,250 €/kW for the 370 MW installed onshore and an investment cost for the Q7 Offshore Wind Farm of 3,192 €/kW for the 120 MW installed. The total investment in wind energy installations from 1989 to 2008, not corrected for inflation, is estimated at some 3 billion €. For the 490 MW installed in 2008, an estimated 4,000 jobs were involved in the Netherlands. Further, for the 2,214 MW of total installed capacity, about 1,000 jobs are created permanently in operations, maintenance, and other activities.

In Spain, investment in wind energy was more than 2,250 million € in 2008. About 50% of Spanish wind energy equipment production is exported. According to a study, the number of jobs related to wind power reached more than 40,000 in 2008. Of this total, the number of direct jobs in operation and maintenance of wind farms, manufacturing, assembly, research, and development is estimated at more than 21,800. The number of indirect jobs (linked mainly to components) is estimated to be more than 17,000.

In the United Kingdom, it is estimated that companies working in the renewables sector currently sustain about 16,000 domestic jobs. If the UK meets its proposed 2020 RE target, 122,000 to 133,000 jobs will be involved, although not all of these will necessarily be in the UK.

In the United States, the new wind generating capacity installed in 2008 represents an investment of about 17 billion USD (12.2 billion €). About 85,000 people were employed in the wind industry, up from 50,000 in 2007. The share of components for wind systems made domestically has increased from less than one-third in 2005 to about half in 2008. In 2007 and 2008, manufacturers of turbines and components announced additions to or expansions of 70 facilities, which created an estimated 8,400 new jobs in 2008 alone.

Even countries with small increases in domestic wind capacity are benefiting from the industrial activity of the wind industry. The Austrian component suppliers specialize in wind turbine control systems, blade materials, generators, and wind turbine design. Last year the turnover of these companies rose by 25% to about 300 million €. About 35,000 MW of wind capacity worldwide is equipped with the control systems of the Austrian company Bachmann electronic. The sale of wind turbines from Denmark in 2008 is estimated to be about 7 GW. Nearly all turbines manufactured were exported.

3.2 Industrial development and operational experience

3.2.1 Turbines

The average rated capacity of new turbines installed in 2008 increased slightly to 1,872 MW. The increase is mainly thanks to a large contribution provided by 2-MW turbines and a number of other machines ranging from 1.35 MW to 3 MW. For example, in the Netherlands the average generation capacity per installed turbine increased to 2.2 MW in 2008. This was mainly due to the large number of 3-MW turbines. Of the 221 turbines installed, 97 had a capacity of 3 MW. The average hub-height has risen to nearly 80 m, and 91 turbines installed in 2008 have a hub-height of 100 m. The swept area per unit of power decreased from 2.5 m^2/kW in 2007 to about 2.1 m^2/kW, because of the 64 turbines with 82-m-diameter rotors and 3-MW generators installed in 2008.

The IEA Wind member countries contain turbine manufacturers that serve global as well as national markets. Countries reporting a national manufacturer of 1-MW or larger turbines include Denmark, Finland, Germany, Italy, Korea, the Netherlands, Norway, Portugal, Spain, and the United States. A broad spectrum of R&D activities are financed by the industry or supported by state governments to develop larger wind turbines.

Domestic manufacturing is a goal of many countries. In Finland, WinWinD presented its first 1-MW pilot plant in spring 2001 and erected the 3-MW pilot plant in 2004 in Oulu. By the end of 2008, WinWinD had installed 142 MW in seven countries including Estonia, France, Portugal, and Sweden. WinWinD has supplied 39% of all the turbines in Finland (57 MW). In 2008, the number of employees grew to 270 (190 in Finland). In Korea, three new big players—Hyundai Heavy Industries, Samsung Heavy Industries, and Hyundai-Rotem—entered the wind turbine manufacturing market in Korea with megawatt-scale wind turbines. In addition to the existing turbine manufacturers market initially formed by companies such as Unison, Hanjin, Doosan Heavy Industries, and Hyosung Heavy Industries, all major shipbuilding heavy industries are ready to begin manufacture of wind turbines. Competition among these major heavy industries might open a new era of accelerating technology development.

Several countries that do not have local turbine manufacturing capabilities report the manufacture of supporting components

(Australia, Austria, Canada, Greece, Ireland, Mexico, Switzerland, and the United Kingdom). These include blades, control systems, power inverters, generators, gearboxes, nacelle assembly, or towers.

In addition to megawatt-scale wind turbines, intermediate-sized turbines of 660 to 850 kW are being manufactured in several countries for single turbine installations or small wind power plants (Denmark, Germany, Italy, Korea, and the Netherlands).

Small wind turbine domestic manufacturing and encouragement of microgeneration are expanding the market for small wind turbines in Canada, Denmark, Italy, Japan, Portugal, Spain, and the United States. In Ireland, a microgeneration field trial is planned for 2009 and 2010. The study will offer a financial incentive for host sites to get involved. In Canada, several companies are proposing small wind turbines that are at various stages of

Table 6 Capacity in Relation to Estimated Jobs and Economic Impact in 2008 Where Data Available

Country	Capacity (MW)	Estimated number of jobs	Economic impact (million euro)
United States	25,369	85,000	12,206
Germany	23,902	90,000	
Spain	16,740	40,000	2,250
Italy	3,736	18,309	1,800
United Kingdom	3,331	16,000	
Denmark	3,163	25,000	5,300
Portugal	2,819	2,500	900
Canada	2,369	3,340	873
Netherlands	2,214	5,000	850
Japan	1,880	6,000	3,200
Australia	1,306	1,600	1,104
Sweden	1,047		
Ireland	1,002	600	60
Austria	995	2,500	300
Greece	990		
Norway	430		
Korea	236		
Finland	143		
Mexico	85		
Switzerland	14	600	200
Total	91,771	296,449	29,043

development. Some of the designs feature a vertical axis. The Wind Energy Institute of Canada has begun testing the small turbines that were selected following an RFP process completed in December 2007. The turbines being considered under this program have a capacity of not more than 100 kW.

In the United States, more than 10,000 domestically manufactured small wind turbines were sold in 2008, equal to about 50% of the global market share and involving about one-third of the 219 identified manufacturers worldwide. With the increasing number of small turbines entering the market, consumers are questioning product safety and quality. To help consumers compare products or estimate performance, a Small Wind Certification Council (SWCC) has been formed as an independent certification body for North America. Some turbines submitted by manufacturers for certification will be tested in the United States; others may be tested in Canada.

3.2.2 Projects

The size of new wind energy projects is increasing in many countries. In the United States, more than 100 new wind projects larger than 2 MW were installed in 25 states and resulted in nearly 5,000 turbines being commissioned in 2008. The average size of the turbines installed in 2008 was 1.67 MW, a slight increase from the 1.65 MW in 2007. More than half of the turbines were 1.5 MW, and the largest turbines were 3 MW. The average project size was about 70 MW. The world's largest operating wind plant is the 735-MW Horse Hollow facility, which covers 47,000 acres (190 km^2) in Texas. In Spain, the average size of an installed wind farm in 2008 was 24 MW. Canada has also experienced an increase in the size of wind farms, especially in provinces with existing wind installations. This is mainly because smaller projects (less than 50 MW) can cost from 10% to 30% more because of economies of scale.

Interest in offshore wind development even in lakes is growing because it offers the possibility of huge increases in capacity with fewer public acceptance obstacles and fewer issues of complex terrain. By the close of 2008, more than 1,400 MW of capacity was located offshore in seven IEA Wind member countries, with about 300 MW added for the year. Many countries report enormous offshore wind potential. The significant technical issues remaining for offshore wind development are the topic of research in many of the participating countries and within the IEA Wind agreement in Task 23 Offshore Wind Technology Deployment.

3.2.3 New products and applications

The Dutch company Advanced Tower Systems, designed and developed a hybrid concrete/steel tower for wind turbines on land with hub-heights of 100 m to 150 m. The tower is a prefabricated segmented pre-cast concrete tower with a conventional tubular steel tower on top. The concrete part is made of sections that are easy to transport with ordinary trucks. The expected reduction in the costs of energy is up to 10%. At the end of 2008, the construction of the demonstration project with the 100-m-high ATS tower and a Siemens Wind Power SWT2.3-93 wind turbine started at Windtest Grevenbroich in Germany.

The wind turbine manufacturer DarwinD developed a 5-MW direct-drive wind turbine with a rotor diameter of 115 m for offshore applications. It includes a 5.3-m-diameter 3-kV direct-drive generator with permanent magnets, a single main bearing, innovative blades, a modern fully sealed overpressured tower and nacelle, external air generator cooling, and an integrated management control system. The tower head mass is only 265 tons and promises a minimum of maintenance because there are fewer components. The first prototype will be erected late in 2009 on a 100-m tower at the ECN test field in Wieringermeer in the province of Noord Holland.

ChapDrive AS is a newly established company in Norway developing a system for hydraulic transmission of wind power.

The gearbox and the generator will be at ground level to reduce the weight at the top of the tower. A pilot project has been operating on a 225-kW wind turbine at VIVA AS test facility. An upgraded version will be connected on a 900-kW wind turbine by spring 2009. A 5-MW version is planned.

Another system for locating the generator at ground level is being developed by Anglewind, Norway. The system uses an "angle" concept and a new drivetrain system for mechanical transmission of power. Installation of a prototype (225 kW) is expected by the end of 2009.

Autoproducers have on-site generation installed with the aim of displacing purchased electricity at retail rates. In Ireland, following the success of the 850-kW turbine installed on campus in Dundalk Institute of Technology, some industrial customers are exploring their options. Several energy services companies offer to take on all the risk in planning, designing, procuring, installing, and operating megawatt-scale turbines. They then offer to the energy user on site a tariff for the power produced that is guaranteed to be a percentage below the retail rate for the period of the long-term contract. With competitiveness becoming increasingly difficult for industry in Ireland, this arrangement is likely to be attractive to high energy users with suitable sites.

In Norway, a wind/hydrogen demonstration project at Utsira has now been in operation for two years. The purpose of the project is to demonstrate how renewable energy can provide safe and efficient energy supply to isolated areas. The system is based on wind energy as the only energy source. Excess power is used to produce hydrogen, which is to be used later in a fuel cell.

3.2.4 Operational experience

Turbine availability is high in all countries, ranging between 80% (for isolated areas) and 99%, with most countries reporting 98% or higher. In Denmark, the technical availability of new wind turbines on land is between 98% and 100%. For offshore wind, the availability of turbines on the small nearshore farms is also high. Since 2005, all Horns Rev offshore turbines operated at nearly 100%, with an availability of 95% to 97%. In Sweden, the availability of turbines at Lillgrund offshore wind park during its first full year of operation in 2008 was 94%.

Productivity is also relatively high—the result of good siting of farms based on national wind atlas data and the use of taller towers to reach better wind resource. Reported capacity factors ranged from 16% (Switzerland) to 40% (Japan). In Mexico, wind power plants La Venta I (1.3 MW) and La Venta II (83.3 MW) operated at an annual capacity factor of 34%, according to the manager of the wind power plants. It had been expected that the capacity factor of La Venta II would exceed 40%; however in 2008, there were some constraints regarding the availability of the transmission line and some of the wind turbines.

Reports are becoming available on offshore projects. In the Netherlands, for example, results of the monitoring and evaluation program of the offshore wind farm OWEZ, formerly known as NSW, became available in 2008. The General Report covers the period from June 2005 until commissioning at the end of 2006.

In its Operations Report 2007, NoordzeeWind gives an account of the first year of operation of the wind farm. It contains monthly statistics and figures about the availability of the wind farm and its energy production. Calculated losses and downtime per subsystem affecting this energy yield are also presented. It also contains a complete overview of all data and reports delivered by NoordzeeWind on behalf of the MEP-NSW in 2007. NoordzeeWind's general conclusion in this Operations Report 2007 is that the wind farm, having generated 330 GWh, has performed satisfactorily. The Operations Report 2008 will be available in mid-2009.

Other data have been collected during 2008 on corrosion and lightning; dynamics of turbines; aeroelastic stability; scour protection; electricity production, disruptions, failure data, availability, maintenance, and reliability; power quality, grid stability and power forecasts; and wind turbine Power/Voltage curve and wake effects. ECN and Delft Technical University have started several projects with some of these data under an NDA agreement with NoordzeeWind.

3.3 Economic details

3.3.1 Turbine and total installed project costs

Although many countries do not report cost information, several member countries reported stable or slightly increasing wind turbine costs from 2007 to 2008 (Figure 2 and Table 7). Turbine costs reported by the IEA Wind member countries averaged from a low of 977 €/kW (U.S.) to a high of 1,800 €/kW (Austria) for 2008. Total installed costs onshore for 2008 in the reporting countries ranged from a low of 984 €/kW (Mexico) to a high of 1,885 €/kW (Switzerland). Total installed costs offshore ranged from 2,100 €/kW (UK) to 3,230 €/kW (Germany).

Some member countries have reported how costs of wind projects are distributed. In Italy, the cost of installed wind turbines is at substantially the same level as it was in 2007. The average installed plant cost of a medium-sized wind farm (30 MW) at a site of medium complexity, with 15 km of paths/roads and 12 km of electric line for connection to the high-voltage grid, is approximately 1,800 €/kW. This cost is generally subdivided as follows:

- Turbines, installation, and commissioning, 1,270 €/kW: 70.6%
- Development, namely site qualification, design, administrative procedures, and so on, 236 €/kW: 13.1%
- Interest on loans, 196 €/kW: 10.9%
- Connection to the grid, 73.8 €/kW: 4.1%
- Civil engineering work, 23.4 €/kW: 1.3%.

Annual cost of operation and maintenance has been estimated to be about 54 € /kW, which includes leasing of terrain, insurance, and guarantees. Decommissioning cost has been estimated at approximately 5 €/kW.

Explanations for higher costs varied by country. Spain reports that the increasing use of large wind turbines (2 MW of nominal power), the increasing prices of raw materials, the shortage of main components, and the excess demand for wind turbines have increased prices for wind generators. In Portugal, the cost depends on the turbines' characteristics and/or the country of manufacture.

In the United Kingdom, the higher capital costs of offshore are due to the increase in size of structures and the logistics of installing the turbines at sea. The costs of foundations, construction, installations, and grid connection are significantly higher offshore than onshore. Typically, for example, offshore turbines are 20% more expensive, and towers and foundations can cost more than 2.5 times offshore than onshore for a project of similar size.

3.3.2 Operation and maintenance costs

Costs for service, consumables, repair, insurance, administration, lease of site, and so on, for new large turbines ranged from 1.3% to 1.5% of capital cost per year. When O&M costs are mentioned by the member countries, they are reported as fairly constant over the years. O&M costs are higher for offshore turbines.

3.3.3 Tariffs and cost of energy

Key to the economic viability of a wind project is the balance of costs and revenue. Wind energy tariffs, feed-in tariffs, and buyback rates are the payments to the wind farm owner for electricity generated. In some countries, this is the market price of electricity. In others, the wind energy tariff includes environmental bonuses or other added incentives to encourage wind energy development. In many countries, the revenue of each wind farm is governed by the contract (power purchase agreement) negotiated with the power purchaser, so the numbers reported by the IEA Wind member countries are estimated averages or ranges. For explanations of revenue to wind park owners, including tariffs and buyback rates, refer to the country chapters of this report.

IEA Wind Task 26 Cost of Wind Energy, which will begin work in 2009, will survey the state of the art of calculating the cost of wind energy in preparation for developing recommended practices for such calculations.

Several countries explained how cost of energy might be calculated. In Finland, on coastal sites the cost of wind energy production could be about 50 €/MWh to 80 €/MWh without subsidies (15 years, 7% internal rate of return), while the cost of offshore production could be about 80 €/MWh to 100 €/MWh. The average spot price in the electricity market Nord Pool was 51 €/MWh in 2008 (30 €/MWh in 2007). Emission trade effects on the operating costs of thermal power have resulted in an increase of spot market prices; however, emission permit prices have been volatile and future and forward prices are about 40 €/MWh for 2009–2010. Wind power still needs subsidies to compete, even on the best available sites in Finland.

In Canada, wind generation costs are estimated to be between 44 €/MWh and 70 €/MWh. For example, provincial calls for power in British Columbia, Ontario, and Québec and the Renewable Portfolio Standard (RPS) in Prince Edward Island resulted in electricity prices from wind energy in the range 45 €/MWh to 56 €/MWh. In most cases, the latest price proposals have shown the highest prices. The primary variables associated with this cost range are the cost of the wind turbines themselves, the quality of wind resources, transmission connection fees, the scale of operation, and the size of turbines.

In Greece, the cost of wind generated electricity could be assumed to be between 26 €/MWh and 47 €/MWh, depending on

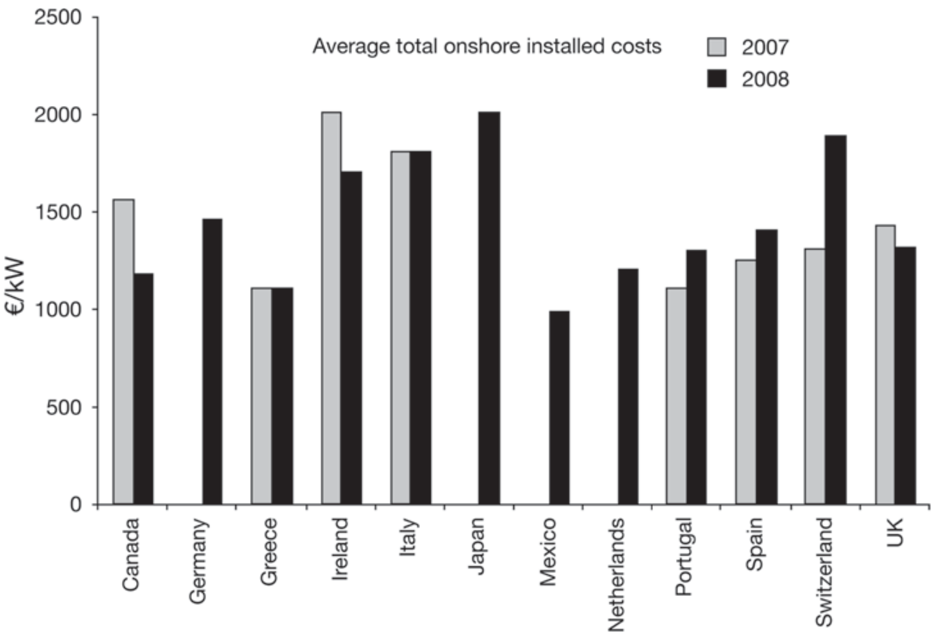

Figure 2 Average total installed costs of wind projects 2007–2008 as reported by IEA Wind member countries. These include costs for turbines, roads, electrical equipment, installation, development, and grid connection.

Table 7 Estimated Average Turbine Cost and Total Project Cost for 2008

Country	Turbine cost (€/kW)	Total installed cost (€/kW)
Austria	1,400 to 1,800	
Canada		1,057 to 1,291
Germany	941 to 1,340 onshore; 1,350 to 1,500 offshore	1,260 to 1,659 onshore; 2,625 to 3,230 offshore
Greece		1,000 to 1,200
Ireland	1,100	1,700
Italy	1,270	1,800
Japan	1,000 to 1,200	1,800 to 2,200
Mexico		984
Netherlands		1,200 onshore; 3,200 offshore
Portugal	1,061	1,297
Spain		1,400
Switzerland	1,450	1,885
United Kingdom		1,050 to 1,575 onshore; 2,100 to 3,150 offshore
United States	977	

the site and project cost. The typical interest rate for financing wind energy projects is 7% to 8%.

In Norway, estimates of production costs from sites with good wind conditions suggest a production cost of about 66 €/MWh, including capital costs (discount rate 8.0%, 20-year period), operation, and maintenance. During 2008, the spot market electricity price on the Nord Pool (Nordic electricity market place) increased until autumn 2008 and then dropped noticeably. The forward price by the end of December 2008 was 38 €/MWh. So far, wind energy is not competitive with the price of many new hydropower projects; hydro still is an option for new green power in Norway.

Wind energy tariffs or buyback rates vary by country according to the incentive structure. In Germany, the wind energy tariff includes an initial remuneration of 92 €/MWh for at least 5 years and a maximum of 20 years. After the initial period, the tariff is 50.2 €/MWh for a maximum of 20 years. Offshore turbines put into operation by 31 December 2015 receive an initial remuneration of 150 €/MWh for 12 years. After that period, the basic tariff is 35 €/MWh until the maximum remuneration period (20 years plus year of commissioning) is reached. Wind farms more than 12 nautical miles away from the coast and in waters deeper than 20 m receive a longer initial period.

In Spain, payment for electricity generated by wind farms is based on a feed-in scheme. The owners of wind farms can choose payment for electricity generated by a wind farm independent of the size of the installation and the year of start-up.

For 2009, the value is 78.183 €/MWh; the update is based on the Retail Price Index minus an adjustment factor. They can choose instead payment calculated as the market price of electricity plus a premium, plus a supplement, and minus the cost of deviations from energy forecasting. There is a lower limit to guarantee the economic viability of the installations and an upper limit (floor and cap). For instance, the values for 2009 are reference premium 31.27 €/MWh, lower limit 76.098 €/MWh, and upper limit 90.692 €/ MWh. In 2008, the market price of electricity in Spain reached 64.43 €/MWh.

In the United States, the sales price of electricity was estimated by weighing projects by nameplate capacity to represent actual market prices. The average electricity sales price for projects built in 2008 was roughly 51.5 USD/MWh (36.98 €/MWh), up from a low of 30.9 USD/MWh (22.19 €/MWh) for projects built in 2002 to 2003. This price is what the utility pays to the wind plant operator and includes the benefit of the federal production tax credit and state incentives.

4.0 National Incentive Programs

In each country, the mix of incentive types and the level of government at which they are applied is unique and changing. Widely ranging incentives are operating in the IEA Wind member countries (Table 8). Those mentioned most often include direct capital investment such as subsidies or grants for projects, providing a premium price for electricity generated by wind (tariffs or production subsidies), obliging utilities to purchase renewable energy, and providing a free market for green electricity.

Tax credit incentives based on investment or electrical generation are also gaining popularity. In the United States, the very effective production tax credit (PTC) and investment tax credits (ITC) for wind energy development were extended through 2012. The PTC provides an income tax credit based on electricity production from wind projects. The ITC allows 30% of the investment in wind projects to be refunded in the form of reduced income taxes. The ITC may also be taken in the form of an up-front grant equivalent to 30% of the project value. The inflation-adjusted value of the PTC in 2008 was 21 USD/MWh (15 €/MWh) for wind energy. In Canada, the ecoENERGY for Renewable Power program provides tax write-offs as a production incentive to all renewable energy technologies. The 14-year program will invest close to 1.5 billion CAD (0.88 billion €) to increase Canada's supply of clean electricity from renewable sources such as wind, biomass, low-impact hydro, geothermal, PV, and ocean energy. In 2007, the tax write-off was increased from 30% to 50% per year on a declining-balance basis.

Some IEA Wind member countries have national and state governments that require utilities to purchase a percentage of their overall generating capacity from renewable resources. Often called renewable portfolio standards (RPS) or renewables production obligation (RPO), they allow utilities to select the most economical renewable technology. The preferred option by most utilities to satisfy this obligation is wind energy. In the United States, 28 of the 50 states had adopted RPS approaches that collectively called for utilities to procure about 23 billion kWh of renewable energy in 2008.

Wind energy qualifies as green electricity used to meet utility RPOs, to trade as certificates, or to meet consumer preferences. In Australia, a state-based renewable energy target scheme requires electricity retailers and wholesale purchasers in Victoria to acquire Victorian Renewable Energy Certificates. Because wind projects can create these certificates, at least two large wind energy projects were able to move forward. Clear, consistent programs give the industry a firm foundation.

Other kinds of support have also accelerated the development of wind energy in the IEA Wind member countries. For

Table 8 Types of Incentive Programs in IEA Wind Member Countries	
Type of program	Description
Enhanced feed-in tariff	An explicit monetary reward is provided for wind-generated electricity, paid (usually by the electricity utility) at a rate per kilowatt-hour somewhat higher than the retail electricity rates being paid by the customer
Capital subsidies	Direct financial subsidies aimed at tackling the up-front cost barrier, either for specific equipment or total installed wind system cost
Green electricity schemes	Allows customers to purchase green electricity based on renewable energy from the electricity utility, usually at a premium price
Wind-specific green electricity schemes	Allows customers to purchase green electricity from wind plants from the electricity utility, usually at a premium price
Renewable portfolio standards (RPS) or renewables production obligation (RPO)	A mandated requirement that the electricity utility (often the electricity retailer) source a portion of its electricity supplies from renewable energies
Wind requirement in RPS	A mandated requirement that a portion of the RPS be met by wind electricity supplies (often called a set-aside)
Investment funds for wind energy	Share offerings in private wind investment funds plus other schemes that focus on wealth creation and business success using wind energy as a vehicle to achieve these ends
Income tax credits	Allows some or all expenses associated with wind installation to be deducted from taxable income streams
Net metering	In effect the system owner receives retail value for any excess electricity fed into the grid, as recorded by a bidirectional electricity meter and netted over the billing period
Net billing	The electricity taken from the grid and the electricity fed into the grid are tracked separately, and the electricity fed into the grid is valued at a given price
Commercial bank activities	Includes activities such as preferential home mortgage terms for houses including wind systems and preferential green loans for the installation of wind systems
Electricity utility activities	Includes green power schemes allowing customers to purchase green electricity, wind farms, various wind generation ownership and financing options with select customers, and wind electricity power purchase models
Sustainable building requirements	Includes requirements on new building developments (residential and commercial) to generate electricity from renewables including wind microgeneration
Special planning activities	Areas of national interest set aside for considering wind energy development

example, publishing wind energy atlases developed with public research money helps developers select productive sites (Austria, Finland, Italy). In Canada, some provincial initiatives require projects to have elements manufactured in the region. This has helped develop a wind industrial base in Canada. To stimulate the industrial base, Portugal has also used domestic manufacturing as a requirement for government-supported project proposals.

Microgeneration (i.e., small wind turbines) is being promoted in several countries with new incentive approaches. An indirect incentive for the deployment of microgeneration is provided in Ireland under the Building Energy Ratings scheme (BER). Irish building regulations require that new dwellings have a portion of their energy demands met by renewable sources on site. The designer has a choice between sourcing this energy through either renewable thermal or renewable electrical means (4 kWh/m^2/year electrical or 10 kWh/m^2/year thermal). The contribution of a wind turbine can be included in the BER once its performance over a year has been verified. In the United States, many states also have policies and incentives for small wind electric systems. These incentives include rebates and buy-downs, production incentives, tax incentives, and net metering. The subsidy or rebate may be as much as 50% of the cost of a small wind turbine. The rebates become even more effective when combined with low-interest loans and net metering programs. In Ireland, there is growing interest in microgeneration. Interest is expected to increase further now that the largest electricity supplier intends to offer 0.09 €/kWh to its domestic customers for electricity they deliver to the grid.

Areas of national interest have been designated in Sweden to promote good management from the point of view of public interest. These areas for fishery, mining, nature preservation, outdoor recreation, and so on, can be of national interest for several kinds of land use. Forty-nine areas in 13 counties have been identified as areas of national interest for electricity production to protect the potential for wind energy development.

5.0 R, D&D Activities

5.1 Setting priorities

An important activity of the wind energy research community is the setting of priorities for investment of precious research money. In 2008, the IEA Wind agreement developed a new strategic plan to guide the agreement for another five years from 2008 through 2013. The key R, D&D areas identified include:

1. Wind technology research to improve performance and reliability at competitive costs
2. Power system operation and grid integration of high amounts of wind generation, including development of fully controllable, grid-friendly "wind power plants"
3. Planning and performance assessment methods for large wind integration
4. Offshore wind in shallow and deep waters
5. Social, educational, and environmental issues

In the EU, the European Wind Energy Technology Platform (TPWind), operating since 2006, is an industry-led initiative to identify and prioritize areas for increased innovation, new and existing research, and development tasks. In June 2008, TPWind issued its Strategic Research Agenda and Market Deployment Strategy documents. In 2009 it will release a list of projects constituting the implementation plan of the strategic research agenda of the European wind energy sector.

In Canada, a wind energy technology roadmap is being developed. The goal is to determine investment areas in research and development required to achieve overall (social, environmental, and technological) cost reductions and to increase Canadian industrial and economic benefits.

In Germany, the aims and priorities of wind power research are determined at regular strategy meetings with experts. The most recent strategy meeting led to the new government funding announcement for research projects to reduce costs, increase yields, and improve the availability of wind turbines. Projects will also develop technologies to expand offshore wind power (including research at the alpha ventus test site) and perform the ecological research and improve the technology of wind turbines to reduce ecological impacts.

In Spain, a new R&D plan was developed in 2008 that covers 2008 to 2011 for the national government. It is based on the national science and technology strategy instead of on thematic areas as in previous calls for proposals.

In the United Kingdom, wind power, both onshore and offshore will be a key growth area. One scenario is that by 2020, offshore wind capacity could be ~14 GW, compared with less than 1 GW today. This would require the installation of a further 3,000 offshore turbines, rated at 5 MW. Initial government models indicate that ~13 GW of onshore wind generation capacity will be required by 2020, as compared with 2.7 GW in early 2009. This equates to approximately 4,300 onshore turbines rated at 3 MW. It is expected that a large proportion of this onshore wind development will take place in Scotland.

5.2 Research funding

Some countries report increased budgets for R&D in 2008 and 2009. In the EU, more than 20 R&D projects were running with the support of the Sixth and Seventh Framework Programmes of the EU (the Framework Programmes are the main EU-wide tool to support strategic research areas). Many IEA Wind member countries participate, often in leadership roles, in these joint research projects. Denmark's funding for wind energy R&D was increased about 1.3 million € in 2008. In Germany, R&D support from the Federal Ministry for the Environment grew from 35 million € in 2007 to 40.1 million € in 2008. Additional research into grid integration technologies related to wind energy has also been launched in 2008, for another 14.6 million €. In the United States, the budget for the federal Wind Program was close to 50 million USD (36 million €) for fiscal year (FY) 2008 (1 October 2007 through 1 October 2008). The budget approved for FY 2009 was 55 million USD (39.5 million €). The budget for FY 2010 will be 75 million USD (53.9 million €).

5.3 Test site news

Test sites for large and small wind turbines and for components comprise an important part of the national research programs.

A new research center has been established in Québec, Canada, for the study of wind turbine operation in cold climates. The Corus Centre is surrounded by two wind farms with a total capacity of 108 MW, making it a unique natural laboratory. An icing wind tunnel for instrument and material research and testing in icing conditions was put up in 2008 at the VTT Technical Research Centre of Finland. It will be used to develop technologies, components, and solutions for large wind turbines.

The first German offshore wind farm alpha ventus began construction in 2008 45 km north of the North Sea island of Borkum. The wind farm will begin with 12 5-MW wind turbines from Multibrid and REpower, with a total installed capacity of 60 MW. The transformer substation was completed in 2008 with a height of 60 m and weighing more than 1,300 tons. The transformer substation is located about 2 km from the BMU research platform FINO 1. The submarine cable was also laid in 2008. As a test and demonstration project, alpha ventus will be the first use of offshore wind power in Germany.

A miniature version of a full-scale wind farm was completed for research at ECN, the Netherlands, as an integral part of ECN's test field for multimegawatt-class wind turbines. The scaled wind farm research facility has 10 10-kW turbines and 14 carefully placed wind metering masts at two distinct heights, 7.5 m and 18.9 m.

ECN will use the scaled wind farm for research on wind turbine wake modeling and verification.

In September, a new Wind Turbine Test Laboratory (www.cener.com) was inaugurated at CENER, Spain. It includes a Blade Test Plant to characterize physical properties and to conduct static and fatigue tests for blades of up to 85 m. long. The Power Train Test Bench can perform mechanical durability tests on low speed shaft, multiplier, high speed shaft and generator for turbines of up to 5 MW. The Electrical Test Bench can test generators and power electronics equipment. The Nacelle Test Bench tests complete nacelles and tooling trials and is used to train personnel in assembly and maintenance. The Composite Material Laboratory addresses manufacturing processes of components with composite materials and characterizes process control variables and the physical, chemical and mechanical properties of materials.

5.4 Large turbine development

Larger turbines are being designed for both onshore and offshore applications, and several new designs and approaches appeared in 2008.

In Korea, as a result of government support in previous years, 750-kW and 1.5-MW wind turbines were successfully tested and certified by GL and DEWI Offshore and Certification Centre GmbH, respectively. In 2008, two 2-MW wind turbines from different manufacturers were installed and remained under field testing through mid-2009.

Gearbox reliability was addressed in an IEA Wind Task 11 Base Technology Information Exchange Topical Experts Meeting in 2008. Several countries are conducting research to improve reliability. The U.S. Wind Program initiated a wind turbine Gearbox Reliability Collaborative to validate the design process, including everything from calculating system loads to rating bearings to testing full-size gearboxes. In 2008, an international team of analysts compared their predictions of gear-tooth loads and bearing loads. Next they will compare these predictions with test data, improve design codes, and improve gearbox designs. An instrumented drivetrain and gearbox will be tested in a 2.5-MW dynamometer test facility at NREL in Colorado, United States.

Better understanding of aerodynamics and wind turbines can contribute to improving reliability. This is the goal of the IEA Wind Task 29 MexNex(t) which is the successor of IEA Wind Task 20 HAWT Aerodynamics and Models from Wind Tunnel Measurements. It will use wind tunnel measurements from the EU project Model Experiments in Controlled Conditions (MEXICO) to validate the design codes and aerodynamic models used by wind turbine developers.

5.5 Small wind turbines

Increased interest in small wind turbine technology was mentioned by several countries. In Spain, work is under way to support the small wind turbine sector through promotion, dissemination, sensitization, and information collection. In line with this work, CIEMAT will serve as Operating Agent for the new IEA Wind Task 27 Consumer Labeling of Small Wind Turbines.

In Portugal, the T-URBan project, a prototype small (2.5-kW) wind turbine with horizontal axis, is in the test phase. This turbine has a 2.3-m rotor diameter and is designed for a 10- to 15-m-high tower. This project, designed and constructed using Portuguese technology, continues demonstration testing as part of the urban wind power effort.

In Ireland, a major wind R, D&D activity in 2009 will support 40% of the start-up and short-term-maintenance costs of small wind turbines. The support will be available in approximately 50 trial locations. Overall budget for the study is 2 million €. Data monitoring at all of the sites for the 18-month duration of the study will assess the performance of the technologies and inform future decisions on possible incentives, tariffs, or deployment programs. To protect customers and prescribe best practices in the pilot, turbine suppliers and manufacturers applying for inclusion in the pilot will be required to supply equipment that conforms to the appropriate European standards (EN 61400-2/11/12), as will the associated inverters (EN 50438). Best practices are prescribed in an effort to ensure high-quality and safe installations in a fledgling sector sensitive to the impact of bad customer experiences on future growth.

5.6 Costs

The members of IEA Wind have agreed that a clear, impartial voice regarding the costs of wind systems is needed to avoid the publication of erroneous costs of wind systems. Task 26 Cost of Wind Energy will provide the tools to compare the costs of wind energy with other electricity-generating technologies. It will modify the underlying assumptions that are applied to the different technologies. Finally, this task aims to form the basis for a more comprehensive analysis of the value of wind energy. The Netherlands, for example, participates in Task 26 because it will give insight into international cost data for offshore wind energy that can be used for policy decisions.

5.7 Grid integration

IEA Wind Task 25 Power Systems with Large Amounts of Wind Power published the final report of its first phase showing that the impact of a large share of wind power can be controlled by appropriate grid connection requirements, extension and reinforcement of transmission networks, and integration of wind power production and production forecasts into system and market operation.

A study in the Netherlands of the operational effects, cost/benefits, costs of grid integration, and market effects of storage concluded that integration of 4 GW to 10 GW of wind power in the Dutch Electricity generation system is possible without large-scale electricity storage. This is mainly because of the increasing flexibility of the system and the expansion and better use of interconnectors.

The University of Genoa, Italy, has developed a model to study the variable character of wind energy and its consequences for electrical power systems. The model identifies the optimal allocation of wind power plants over an extended geographic territory. This allows lower temporal variability of the aggregate wind power output and guarantees a contribution to base-load power supply. To date, this model has been applied on the island of Corsica, and by means of this optimization, wind energy fluctuation in the power supply system of Corsica has been reduced by about 58%, with an energy production loss of 23%.

5.8 Environmental impacts

Preserving bats and birds in areas of wind power development is a goal of work in the United States. Changes to operations during low wind conditions at a plant in rural Pennsylvania, owned and operated by Iberdrola Renewables, demonstrated nightly reductions in bat fatality ranging from 53% to 87% with marginal annual power loss. In other studies, an acoustic system to discourage bats from entering wind facilities will be field tested, and researchers are investigating whether artificial intelligence can be used to detect the presence of birds using Next-Generation Radar (NEXRAD) data. NEXRAD is a network of 158 high-resolution Doppler weather radars operated by the National Weather Service. The program is working with the U.S. Geological Survey and Montana State University to develop algorithms to differentiate biological (bird) echoes in the NEXRAD data to help identify migratory flyways.

In the United States, in 2008, a study funded by the Department of Homeland Security concluded that wind farms can interfere with radar tracking of aircraft and weather but that no fundamental physical constraint prohibits the accurate detection of aircraft and weather patterns around wind farms. Interference occurs when radar signals are reflected back by wind turbines, causing clutter on the radar screens. The report also concluded that it is difficult to distinguish wind farm signatures from airplane and weather signatures and that quantitative evaluation tools and metrics are needed to determine when a wind farm poses a sufficient threat to a radar installation.

Environmental impacts were studied during the construction of the German FINO 3 offshore research platform. To reduce noise emissions, an air bubble curtain was constructed with a radius of 70 m around the construction site. Scientists recorded the sound pressure levels at various distances from the site. Initial data analysis suggests that the air bubble curtain achieved a total noise reduction of 12 decibels, with a reduction of 30 to 35 decibels in the frequency range between 1 and 7 kilohertz. Biologists also spent several days studying the effectiveness of measures to protect porpoises. Initial results indicate that during construction, no porpoises entered the hazardous zone around the site. Two weeks later, the number of porpoises had returned to the preconstruction level.

6.0 Next Term

Continued growth in deployment is expected in most IEA Wind member countries. To support the increasing need for durable, cost-effective machinery, larger technology research budgets will be provided by growing national and industrial research programs.

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Author: Patricia Weis-Taylor, Secretary, IEA Wind.