1.0 Introduction
In Finland, 31% of electricity generation was by renewables in 2010. Finland’s generating capacity is diverse. In 2010, 25% of gross demand was produced by nuclear, 15% by hydropower, 33% from combined heat and power (coal, gas, biomass, and peat), and 15% from direct power production from mainly coal and gas. Biomass is used intensively by the pulp and paper industry, raising the share of biomass-produced electricity to 12% in Finland. About 12% of electricity was imported, mainly from Russia, so the renewable share of gross electricity demand in Finland was 27%. The electricity demand, which is dominated by energy-intensive industry, grew by 8% to 87 TWh, after a decrease of 7% in 2009 due to economic recession.

The national energy strategy foresees biomass as providing most of the increase in renewables. The hydropower resource has the potential for only about 1 TWh/yr more. This makes wind power the second largest source of new renewables in Finland, with a target of 6 TWh/yr in 2020.

Wind energy potential is located mostly on coastal areas. There is a huge technical potential offshore, with ample shallow sites available. Wind energy deployment has been very slow, but a new target of 6 TWh/yr for 2020 (2,500 MW) and a market based feed-in tariff system starting in 2011 has led to a rush for the best sites. At the end of 2010, there were 17 new turbines installed with the total capacity of 52 MW. These turbines are sited in Pori (1 at 2.3 MW), Raahõ (4 at 2.3 MW) and Tornio (8 at 3.6 MW). The single turbine in Pori is a pilot offshore turbine for a larger planned offshore wind farm. Wind turbine manufacturer WinWinD has developed an ice prevention system for its 3-MW turbines in collaboration with VTT Technical Research Centre of Finland. Moventas is developing its gearboxes for larger turbines, and ABB and The Switch are developing generator and frequency converter solutions for wind power.

2.0 National Objectives and Progress

2.1 National targets
The target for wind power in the climate and energy strategy set in 2008 is 6 TWh/yr (2,500 MW) in 2020. This would be about 6% of the total electricity consumption in Finland. This reflects the increased targets for renewables arising from the EU target of 20% of energy consumption from renewable sources in 2020. The target for Finland is 38% of final energy consumption by RES (current RES share 28.5%).

2.2 Progress
The development in wind power capacity and production is presented in Figure 1. In 2010, there were 17 new turbines installed with the total capacity of 52 MW. These turbines are sited in Pori (1 at 2.3 MW), Raahõ (4 at 2.3 MW) and Tornio (8 at 3.6 MW). The single turbine in Pori is a pilot offshore turbine for a larger planned offshore wind farm. Wind power technology exports from Finland amount to about 0.8 billion euro (1.08 billion USD). The wind turbine manufacturer WinWinD has developed an ice prevention system for its 3-MW turbines in collaboration with VTT Technical Research Centre of Finland. Moventas is developing its gearboxes for larger turbines, and ABB and The Switch are developing generator and frequency converter solutions for wind power.

Table 1 Key Statistics 2010: Finland

<table>
<thead>
<tr>
<th>Category</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total installed wind generation</td>
<td>197 MW</td>
</tr>
<tr>
<td>New wind generation installed</td>
<td>52 MW</td>
</tr>
<tr>
<td>Total electrical output from wind</td>
<td>0.29 TWh</td>
</tr>
<tr>
<td>Wind generation as a percentage of national electric demand</td>
<td>0.3%</td>
</tr>
<tr>
<td>Target</td>
<td>6 TWh/yr (2,500 MW) in 2020</td>
</tr>
</tbody>
</table>
Although the wind resource was lower than average during 2010, the total wind energy production in 2010 increased by 6% compared to 2009. The production of 292 GWh corresponds to 0.3% of the annual gross electricity consumption of Finland (Table 1). The environmental benefit of wind power production in Finland is about 0.2 million tons of CO₂ savings per year.

At the end of 2010, 130 wind turbines were in operation in Finland (Figure 2). The average wind turbine size is 1,520 kW. About 37% of the capacity is from turbines originating from Finland, 46% from Denmark, 14% from Germany, and 3% from the Netherlands. The size of the installed capacity ranges from 75 kW to 3.6 MW. The 17 turbines installed in 2010 were from 2.3 MW to 3.6 MW.

In early 2011, there were 10-50 MW worth of wind power projects preparing for construction, with most sited in the Åland islands. Other places of interest for wind power projects are Raahen and Merijärvi.

The Åland islands between Finland and Sweden constitute an autonomous region with its own legislation, budget, and energy policy. How the feed-in tariff system will be implemented to this autonomous region is still unclear. Wind energy covered 18% of electricity consumption in 2010 with 22 MW installed capacity. A transmission line to mainland consumption in 2010 with 22 MW installed capacity. The 17 turbines installed in 2010 were from 2.3 MW to 3.6 MW.

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The progress in wind power capacity in Finland has been slow compared with other European countries. The funds available for investment subsidies have been inadequate to achieve any large increases in wind-power capacity. From 2005 to 2008, no specific goal for wind power was set.

To overcome planning and permitting problems, the Ministry of Environment published guidelines for planning and building permission procedures for wind power plants. Sites for wind power have been added to regional plans by the authorities. This will help future wind power projects.

2.4 Issues affecting growth

The progress in wind power capacity in Finland has been slow compared with other European countries. The funds available for investment subsidies have been inadequate to achieve any large increases in wind-power capacity. From 2005 to 2008, no specific goal for wind power was set.

The target of 6 TWh/yr for 2020 (2,500 MW) and the anticipated feed-in tariff system has led to a rush for the best sites. At the beginning of 2011, there were 2,900 MW of wind power projects in various phases of planning onshore, and 3,000 MW of announced projects offshore.

2.3 National incentive programs

Up until 2010, the main incentive to promote wind investments has been an investment subsidy of up to 40% depending on the level of novelty of a wind energy installation. In addition to the investment subsidy, a tax refund of 6.9 euro/MWh (9.3 USD/MWh) has been awarded. Projects that applied for a subsidy between 2001 and 2006 received an average investment subsidy of 35%, but the number of projects and MW installed has been low (3 to 30 MW/yr, 2 to 14 million euro/yr or 2.7 to 18.8 USD/yr in subsidies). In 2009, additional funds for investment subsidies were made available and about 60 MW of wind power projects received an investment subsidy decision.

A feed-in premium entered into force on 25 March 2011 in Finland. A guaranteed price of 83.5 euro/MWh (9.3 USD/MWh) is set for wind power, where the difference between the guaranteed price and spot price of electricity will be paid to the producers as a premium. The initial proposal of collecting the costs from consumers in an electricity tariff proved to violate the constitutional law and so the cost will be recovered by electricity taxes. There is an increased level of 105.3 euro/MWh (141.5 USD/MWh) until the end of 2015 (maximum 3 years) to encourage early projects. A three-month average spot price will be the comparison price to determine the payments to the producers (the guaranteed price minus the average spot price). Should the average spot price rise to above the guaranteed price, the producers will get this higher price. However, wind power producers will also be responsible for paying the imbalance fees from their forecast errors. If the impacts of emission trading continue to raise electricity market prices, this will reduce the payments for this subsidy. A special subsidy for offshore wind power will still be considered.

To help reduce uncertainty when estimating the production potential of the taller multi-megawatt machines in the forested coastal areas of Finland, a new wind atlas was made by FMI with government funding. The first part (2.5-km grid) was published in November, 2009 and the second part (coastal area with a 250-m grid) was launched at the end of March 2010.

An addition to the Electricity Market Act set a ceiling to the distribution network charges for distributed generation, including wind. The act also stated that grid reinforcement payments must be borne by the consumers, not by the producer. However, project size for the grid reinforcement exemption was limited to 2 MW, limiting the promoting effect of the grid reinforcement exemption for wind power.

Figure 1 Wind power capacity and production. FMI Wind energy index is calculated from Finnish Meteorological Institute (FMI) wind-speed measurements converted to wind power production, 100% is average production from 1987 to 2001.
The proposed feed-in tariff is not sufficient to start offshore projects, and the ministry will come up with a proposal for offshore project subsidies later (the projects are anticipated to start after 2012). Permitting will probably be a challenge for many of the planned projects. Radar influence has become an issue and a study is currently being carried out to estimate the impacts in order to give green light to wind power projects that will not cause problems. There is also growing concern about eagles (Haliaeetus albicilla). A study of wind turbine impacts on nesting and behavior of eagles has been proposed by the World Wildlife Fund.

3.0 Implementation

3.1 Economic benefits

The estimated value of all business activity related to wind energy development in Finland is presented in Figure 3. Direct and indirect employment in the energy sector of the wind power industry is still quite low (less than 100 people). However, the technology sector is strong. There are about 20 technology and manufacturing companies involved in wind power in Finland, employing more than 4,000 people, with an economic turnover of about 0.8 billion euro/yr (1.08 billion USD). Maintaining current market share in global wind power markets would mean increasing economic turnover to a level of 3 billion euro/yr (4.03 billion USD/yr) in 2020. However, if global market share increased, there is the potential to raise technology exports to a level of 12 to 14 billion euro/yr (16.1 to 18.8 billion USD/yr) in 2020. Employment in the wind power sector in Finland could increase to 14,000 to 36,000 person-years in 2020.

3.2 Industry status

3.2.1 Manufacturing

The Finnish manufacturer WinWinD presented its first 1-MW pilot plant in spring 2001 and erected the 3-MW pilot plant in 2004 in Oulu. Their turbines operate at variable speed with a slow speed planetary gearbox and a low-speed permanent-magnet generator. By the end of 2010, WinWinD had installed 314 MW in seven countries including Estonia, Finland, France, Portugal, and Sweden. WinWinD has manufactured 37% (73 MW) of the installed wind power capacity in Finland (Figure 4). In 2010, the number of employees was about 800 (311 in Finland). In 2009, WinWinD opened a new manufacturing facility for 3-MW turbines in Hamina, Finland and started an assembly and blade manufacturing plant for 1-MW turbines in Chennai, India. The main owner of WinWinD since 2006 is Siva Group (previously Sterling Group, India) and in 2008 Masdar (Abu Dhabi) became a major shareholder, too.

In 2009, a new turbine manufacturer, Mervento, started to develop its first prototype that is especially designed for offshore applications. The plan is to erect it in 2011. Mervento is planning an assembly line in Vaasa with annual capacity.
of 100 nacelles. Mervento’s long-term goal is to be a global actor in the wind energy sector.

Several industrial enterprises have developed important businesses as suppliers of major components for wind turbines. For example, Moventas is the largest independent manufacturer of gears and mechanical drives for wind turbines. ABB is a world-leading producer of generators and electrical drives for wind turbines. The Switch company supplies individually tailored permanent-magnet generators and full-power converter packages to meet the needs of wind turbine applications, including harsh conditions. In addition, materials such as cast-iron products, tower materials (Rautaruukki), and glassfiber products (Ahlstrom Glasfiber) are produced in Finland for the main wind turbine manufacturers. Sensors especially for icing conditions are manufactured by Vaisala, Labkotec, and Hoxville.

3.2.2 Ownership and applications

Most of the turbines in Finland are located along the coast and are owned by power companies and local energy works. Green electricity is offered by most electric utilities. In recent years, many new customers are purchasing renewable electricity products. The supply of used turbines from the first demonstration projects in Finland and from the Netherlands has encouraged some farmers to acquire second-hand turbines. These farmers are located inland where the wind resource is limited at heights below 60 m.

There is an ever-increasing interest in offshore projects, as good sites for larger wind farms on the coastal areas are scarce. The first semi-offshore projects were built in 2007. Six 2.3-MW turbines were installed on small islands in Åland Bätskär. In 2007 to 2008, ten 3-MW WinWinD turbines were erected in Kemi Ajos. Eight of these turbines (24 MW) are offshore. In 2010, a 2.3-MW turbine was erected offshore, 1.2 km from Pori harbor. This turbine is a pilot for a 90-MW offshore project. Environmental impact analyses have been started for several offshore wind farms and the first of them (Suurhiekka, 288 MW) received a building permit according to the water act early in 2011 (the building permit according to the building act is still to be applied for). Besides this project, six other offshore projects (almost 1,200 MW) have finished their environmental impact analyses. An offshore demonstration will need funding to be realized.

3.3 Operational details

The average capacity factor of wind turbines operating in Finland was 19% in 2010 due to the less than average wind index (production index was 73–91% in different coastal areas in Finland). In the 2000s, the average capacity factor has been 17–24%. As reported in the wind energy statistics of Finland yearly reports, the capacity factor of the MW size turbines is considerably higher than for turbines less than 50 m high. More large turbines are being installed (Figure 5).

The average availability of wind turbines operating in Finland was 90% in 2010 (91 to 96% in 2001 to 2009). Of the 81 turbines reporting, there were five turbines with less than 70% availability in 2010 due to a failure in the gear and problems in the hydraulic and pitch system.

3.4 Wind energy costs

On coastal sites in Finland, the cost of wind energy production is estimated to be about 60 to 80 euro/MWh (80.6 to 107.5 USD/MWh) without subsidies (2,100 to 2,400 h/a, 1,300 to 1,400 euro/
IEA Wind

kW [1747.20 to 1881.6 USD/kW] investment cost, 20 years, 7% internal rate of return, 26 to 28 euro/kW/yr [34.90 to 37.60 USD/kW/yr] O&M cost, and 2 euro/MWh [2.70 USD/MWh] balancing cost. The estimated cost of offshore production could exceed 100 euro/MWh (134.40 USD/MWh). The average spot price in the electricity market Nordpool was 57 euro/MWh (76.60 USD/MWh) in 2010 (37 euro/MWh or 49.73 USD in 2009). Wind power still needs subsidies to compete even on the best available sites. The planned feed-in guaranteed price of 83.5 euro/MWh (112.22 USD/MWh) for 12 years (105.3 euro/MWh [141.52 USD/MWh] for the first three years but only until the end of 2015) is expected to open the onshore market in 2011.

All wind energy installations are commercial power plants and have to find their customers via a free power market. In most cases, an agreement with a local utility is made that gives market access and financial stability. The new feed-in premium for wind energy fits the Nordic electricity markets, as the producers will sell their energy in the market or by bilateral contracts, and account for the balancing costs for their production.

4.0 R, D&D Activities
4.1 National R, D&D efforts
The Finnish Funding Agency for Technology and Innovation (Tekes) is the main public funding organization for research, development, and innovation in Finland. Tekes funds R&D and innovation activities by companies and research organizations registered in Finland. Tekes invested 633 million euro (850.8 million USD) in R&D projects in 2010. Tekes is the main source of funding for Finnish co-operation with IEA.

Since 1999, Finland has no national research program for wind energy. Individual projects can receive funding from Tekes. Benefit to industry is stressed, as is the industry’s direct financial contribution to individual research projects. A new research program for wind (CLEEN WIPO program) was proposed, stressing a strong industry involvement, with 50% of the R&D work to be carried out in industries. However, it was not approved by Tekes. Instead, the role of wind power is increasing in other R&D programs, like the new GROOVE program for renewable energy commercialization.

Tekes funding for wind power in the last six years is presented in Figure 6. Tekes invested over 4 million euro (5.4 million USD) in wind power R&D projects in 2010. There were 36 ongoing wind power R&D projects in 2010; most of them were industrial development projects. The main developed technologies were power electronics, generators, permanent-magnet technologies, gearboxes, wind turbines (large and small ones), foundry technologies, manufacturing technologies, construction technologies, automation solutions, and services. WinWinD developed an ice prevention system for its 3-MW turbines in 2009, in collaboration with VTT. The first four turbines were erected in Swedish Lapland, Uljabouda in September 2009 and another six in 2010.

VTT is developing technologies, components, and solutions for large wind turbines. An icing wind tunnel for instrument and material research and testing in icing conditions began operation in 2009. Industrial collaboration in the development of reliable and cost-efficient solutions for drive trains for future wind turbines continued. Several technical universities also carry out R&D projects related
especially to electrical components and networks (Lappeenranta, Tampere, Vaasa, and Aalto).

4.2 Collaborative research
VTT has been active in several international projects in the EU, Nordic, and IEA frameworks. As part of the EU project Tradewind (2006-2009), VTT estimated the impact of wind power on cross border flows in the European power system. As part of the EU project UPWIND, technologies to control the shape of composite structures were developed at laboratory scale.

The Finnish Meteorological Institute (FMI) has been active in EU collaboration for wind and ice measurement technology. FMI has been coordinating the COST collaboration “Measuring and Forecasting Atmospheric Icing of Structures.”

VTT is participating in two new Nordic Energy Research projects Offshore DC Grid and IceWind.

Finland is taking part in the following IEA Wind research tasks:

- Task 11 Base Technology Information Exchange (VTT)
- Task 19 Wind Energy in Cold Climates (OA, VTT/Pöyry)
- Task 25 Power Systems with Large Amounts of Wind Power (OA, VTT)
- Task 30 Offshore Code Comparison Collaboration Continuation OC4 (VTT)

5.0 The Next Term
Approximately 10 to 50 MW of new capacity is anticipated for 2011. A huge number of projects are planned, under feasibility studies, or have just been proposed: 2,900 MW onshore and 3,000 MW offshore. A list of wind turbine projects in Finland can be found at http://www.vtt.fi/windenergystatistics. A radar study needs to give first results for some projects to get building permits.

A next-generation blade heating system has been developed in Finland, and further development is ongoing. This will enable the use of the wind resource potential in arctic fell areas of Finland. Increasing global demand for ice-free turbines is foreseen.

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