1.0 Overview
In 2013, 97.5 MW of new wind power capacity was installed in Norway. Total installed capacity was 811 MW at the end of the year and production of wind power in 2013 was 1,898 GWh, compared to 1,569 GWh in 2012. The calculated wind index for Norwegian wind parks in 2013 was 100%, corresponding to a production index of 101%. The average capacity factor for Norwegian wind parks in normal operation was 29.2%. Wind generation amounted to 1.4% of the total electric production in the country.

Electric energy in Norway is generated using a very high share of renewable energy. The primary source of electricity is hydropower, which in 2013 stood for approximately 96% of the country’s electricity production. In recent years there has also been a keen interest in wind power as a commercial source of energy. Norway boasts some of the best wind resources in Europe and the combination of technological advances and renewable energy support schemes mean that these resources will likely be tapped in the form of large amounts of new wind power installations in the coming years. The key statistics for 2013 are shown in Table 1 and Figure 1.

2.0 National Objectives and Progress
2.1 National targets
Renewable sources of electricity amounted to 97.5% of the national electricity production in Norway in 2013. Wind power supplied 1.4% of the electricity production. Two thousand thirteen was a near-average year for both wind- and hydropower production in Norway and the total electricity production for the year was 134.2 TWh. With electricity consumption in the country totaling 129.2 TWh for the year, this meant a net electricity export of 5 TWh.

The already high ratio of renewable energy production combined with concerns about wind power development’s local environmental impacts has provided fuel for considerable public debate on the topic of wind power development in Norway in recent years.

As a member of the European Economic Area, Norway was obliged to accept the EU’s renewable energy directive in 2011. The target for renewable energy was set to 26.4 TWh/yr of new renewable energy production by 2020. This market-based electricity certificate scheme is unique in that the targets are both country- and technology-neutral, meaning that the policy does not dictate which country the new renewable energy production comes from or which type of renewable energy is produced. The objective of this policy is rather to allow the market to dictate what type of renewable energy production comes and where, thus ensuring a cost-effective increase in renewable energy production when seen from a macroeconomic standpoint. In practice this means that Norway has no explicit wind energy target, however considerable new wind energy installations in Norway are seen by analysts as implicitly necessary to reach the targets set forth for new renewable energy production through the joint agreement with Sweden.

2.2 Progress
Norway entered into the electricity certificate scheme with Sweden on 1 January 2012, and so far the only large-scale
Table 1. Key Statistics 2013: Norway

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total installed wind capacity</td>
<td>811 MW</td>
</tr>
<tr>
<td>New wind capacity installed</td>
<td>97.5 MW</td>
</tr>
<tr>
<td>Total electrical output from wind</td>
<td>1.9 TWh</td>
</tr>
<tr>
<td>Average capacity factor</td>
<td>29.2%</td>
</tr>
<tr>
<td>Wind generation as % of national electric demand</td>
<td>1.4%</td>
</tr>
<tr>
<td>Target: EU target of 67.5% energy from RES</td>
<td></td>
</tr>
</tbody>
</table>

Norwegian wind park participating in the scheme is phase II of Midtfjellet Wind Farm.

2.3 National incentive programs

From 2001–2010 financial support for wind power projects in Norway was provided by the state-owned organization Enova SF on a case-by-case basis with the goal to support projects just enough to make them commercially viable. This program was terminated in 2011 and from 1 January 2012, Norway and Sweden established a common electricity certificate market/scheme. The economic incentive is designed to stimulate the combined development of 26.4 TWh/yr of new renewable power production in the countries. Since 2012, Enova has focused on supporting technology development connected to wind power.

A key aspect of the certificate system is that it shifts the cost for supporting renewables from Enova to the electricity consumer. Approved power plants will receive one certificate for every generated MWh from renewable energy sources. Hence, owners of approved plants have two products on the market: electricity and certificates. They can be sold independently of each other.

The demand for certificates is created by a requirement under the act that all electricity users purchase certificates equivalent to a certain proportion of their electricity use, known as their quota obligation. The price of certificates is determined in the market by supply and demand, and it can vary from one transaction to another.

All renewables are included in the system; it is technology-neutral. All technologies receive the same number of certificates per MWh, and there are no specific quotas for wind power. Nevertheless it is expected that these electricity certificates will primarily stimulate new production from

Figure 1. Installed wind capacity in Norway 1997–2013
wind- and hydropower in Norway and bioenergy and wind power in Sweden, since other renewables (e.g., power from ocean energy and solar energy) are still considerably more costly.

3.0 Implementation

3.1 Economic impact
Norwegian industry takes part in component production for wind energy systems, e.g., wind turbine blades and nacelles on a relatively small scale. Companies with experience from the offshore oil industry (e.g., OWEC Tower and Aker Solutions) have widened their scope of interest and engagement to the offshore wind industry. These companies offer offshore wind turbine substructure solutions like jacket quattropod and tripod. Increased construction of wind parks will generate engineering and construction jobs, and ultimately jobs for maintenance personnel.

3.2 Industry status
Production of wind power is dispersed among several energy companies, some of which are small local utilities. The largest wind power projects are operated by large national energy companies. Some Norwegian companies (Fred Olsen Renewables, Statkraft, and Statoil) are also engaged in projects in foreign countries, like offshore wind in the United Kingdom. So far, there is no significant wind turbine manufacturing industry in Norway.

3.3 Operational details
In 2013, the capacity factor of wind parks in normal operation varied between 17–41%. The average capacity factor was 29.2%, and the average technical availability was 96.3%. The technical availability of new wind turbines in Norway is usually in the range of 95–99%. Annual energy per swept area ranged from 622–1,873 kWh/m², with a national average of 1,158 kWh/m².

3.4 Wind energy costs
The total wind park installation costs reported between 2012 and 2013 vary between 10.5–13.5 million NOK/MW (1.3–1.6 million EUR/MW; 1.7–2.2 million USD/MW). Annual maintenance is reported to be between 0.12–0.16 NOK/kWh (0.014–0.019 EUR/kWh; 0.020–0.026 USD/kWh), with an average cost of 0.15 NOK/kWh (0.018 EUR/kWh; 0.025 USD/kWh). Estimates of production costs from sites with good wind conditions (33% capacity factor) suggest a production cost of about 500 NOK/MWh (60 EUR/MWh; 83 USD/MWh), including capital costs (discount rate 6.5%, 20-year period), operation, and maintenance.

4.0 R, D&D Activities
4.1 National R, D&D efforts
In Norway there are two research centers for offshore wind energy, the Research Center for Offshore Wind Technology (NOWITECH) at SINTEF Energy Research and the Norwegian Center for Offshore Wind Energy (NORCOWE) at Christian Michelsen Research. Another center, the Center for Environmental
Design of Renewable Energy (CEDREN) conducts research on environmental issues within wind energy and other renewable energy production. These centers receive half of their funding from the Research Council of Norway; the remainder is jointly funded by industry and the research institutions.

The Research Council of Norway also administers a public research program for sustainable energy, ENERGIX. This program covers renewable energy, energy efficiency, energy system, and sustainable transport (hydrogen, fuel cells, biofuels and batteries). Industry, research institutes, and universities may receive funding for their research based upon proposals in response to regular calls. The budget for 2013 was 385 million NOK (46 million EUR; 63 million USD). In total the Research Council granted 110 million NOK (13 million EUR; 18 million USD) to wind energy research in 2013. In December 2013, the following wind energy R&D projects were approved for funding:

- Crane-free foundation for offshore wind, SEATOWER AS
- Kongsberg on-line Wake model, KONGSBERG MARITIME AS
- Sensors for monitoring of wind turbine blades, KONGSBERG MARITIME AS

In total, 14 R&D projects are funded by ENERGIX, and 32 industrial companies and five research institutes are involved in these projects.

The Norwegian energy agency, Enova, offers capital grants for full-scale demonstration projects of ocean renewable energy production including offshore wind. While up to 50% of eligible costs can be covered, Enova’s funding measured in absolute figures is limited.

Innovation Norway runs a program supporting prototypes within environmentally friendly technology. Wind energy is included in this definition. Projects are supported with up to 45% of eligible costs.

### 4.2 Collaborative research


### 5.0 The Next Term

The next term will be dominated by the impetus given to the wind power industry by the electricity certificate scheme. This scheme has also contributed to a trend toward to the development of wind parks in Norway by large international companies. As of late 2013, one wind park was under construction.

### References:

Opening photo: Midtfjellet Wind Farm (Source: Stein Erik Gilje)

Authors: Harald Rikheim, Norwegian Research Council and David E. Weir, Norwegian Water Resources and Energy Directorate, Norway.