

ARTICLE

INTERNATIONAL EXPERIENCES OF WIND ENERGY

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I. INTRODUCTION

Wind energy is not a new technology. Wind mills have been used as water pumps and in grain mills to catch the wind's kinetic energy for at least 2,000 years. Indeed, wind turbines have also been used to generate electricity for over 100 years, converting the rotational energy of the rotor into electrical energy.¹ However, the role of wind energy as a major player on the modern electricity market is a more recent development. Over the years, the popularity of wind-powered electricity has fluctuated with the price of fossil fuels,² and with recent economic and geopolitical factors sending the price of oil to levels exceeding \$100 per barrel, it is of no surprise that renewable energy sources, and wind energy in particular, are receiving a new round of attention.

The amount of available wind power continues to increase. On a global scale, capacity has risen from 18,449 megawatt ("MW") to 59,264 MW between the years 2000 and 2005, an average growth of 26.3%.³ More recently in 2006, capacity grew from 15,016 MW to an estimated total of 74,300 MW.⁴ Some forecasts indicated that, for the period from 2007 to 2011, wind energy capacity will grow at a rate of 17.4%.⁵

Growth is also rapid in terms of actual wind energy production. Statistics reported by the Organisation for Economic Co-operation and Development ("OECD") demonstrate that electricity generated from wind power grew from 3,844 gigawatt hours ("GWh") to 77,166 GWh between

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1. During the winter of 1887–88, American Charles F. Brush built the first automatically operating wind turbine for electricity generation. See Danish Wind Industry Assoc., *A Wind Energy Pioneer: Charles F. Brush*, <http://www.windpower.org/en/pictures/brush.htm> (last visited Mar. 29, 2008). Later, Poul la Cour increased the efficiency by using fewer rotor blades with faster rotation. See Danish Wind Industry Assoc., *The Wind Energy Pioneer—Poul la Cour*, <http://www.windpower.org/en/pictures/lacour.htm> (last visited Mar. 29, 2008). Today wind turbines are built with 3 blades mounted atop a tower and connected to a gearbox and a horizontal axis turbine maintaining a frequency of the out equal to that of the connected grid system. See SARAH J. SCOTT, FRANKLIN H. HOLCOMB & NICHOLAS M. JOSEFIK, ENG'R RESEARCH & DEV. CTR., U.S. ARMY CORPS OF ENG'RS, *DISTRIBUTED ELECTRICAL POWER GENERATION: SUMMARY OF ALTERNATIVE AVAILABLE TECHNOLOGIES* 13–16 (2003).

2. For a short introduction to the history of wind energy, see U.S. Dep't of Energy, *History of Wind Energy* (Sept. 12, 2005), www1.eere.energy.gov/windandhydro/wind_history.html (last visited Mar. 29, 2008).

3. HANS LARSEN & LEIF SØNDERBERG PETERSEN, RISØ NATIONAL LAB., *RISØ ENERGY REPORT 5: RENEWABLE ENERGY FOR POWER AND TRANSPORT 29* (2006) [hereinafter *RISØ ENERGY REPORT 5*], available at <http://www.risoe.dk/rispubl/Energy-report5/ris-r-1557.pdf>.

4. Press Release, BTM Consult ApS, Int'l Wind Energy Dev.: World Market Update 2006 (Mar. 26, 2007) [hereinafter *BTM Press Release*] (on file with author).

5. See BTM CONSULT AP S, INT'L WIND ENERGY DEV. WORLD MARKET UPDATE 2006 (2007) [hereinafter *WORLD MARKET UPDATE*]. The capacity of wind power only indicates how much electricity could have been produced, if the wind allows the turbines to work constantly at their maximum capacity.

1990 and 2004, an average annual growth of 23.9%.⁶ These growth rates are much larger than the growth rates for other renewable technologies.⁷

In the 1980s, the world market for wind turbines relied heavily on California and Denmark. At present, more than fifty countries around the world have established wind power generation facilities.⁸ Currently, the leading producers of wind power include Spain, Germany, the United States, India, and Denmark. Other nations have reached the 1,000 MW mark, including Italy, the United Kingdom, the Netherlands, China, Japan, and Portugal.⁹ In 2005, Denmark led all European nations by meeting 20% of the country's total electricity demand with wind power.¹⁰ For its part, Germany is also developing plans to ensure that a certain amount of its power production in the future comes from renewable energy sources, including wind power.¹¹ The four main OECD wind power producers—Germany, Spain, the United States, and Denmark—supplied 80.3% of OECD wind production in 2004.¹² The European Union (“EU”) continues to be a front-runner in global wind power with roughly a 70% world market share and the EU is expected to continue to be so for a number of years.¹³ In fact, 77% of wind power production in the OECD was produced in Europe in 2004.¹⁴ Nevertheless, the market is changing, and China, North America, and Asia—India, in particular—are expanding their wind power production substantially.

Another important change facing the wind power industry is increased globalization. Whereas, in previous years, the majority of manufacturers were backyard manufacturers or fairly small plants, there are now relatively few leading wind equipment manufacturers. This new development has been characterized by the entry of multi-national corporations, such as General Electric and Siemens, into the wind power market.¹⁵ In 2006, the top ten wind turbine manufacturers supplied 95.2% of the installations worldwide.¹⁶ Sub-suppliers are similarly becoming large and global.

6. See INT'L ENERGY AGENCY, RENEWABLES INFORMATION 2006 58 (2006).

7. See *id.* at 4.

8. GREENPEACE INT'L & GLOBAL WIND ENERGY COUNCIL, GLOBAL WIND ENERGY OUTLOOK 2006 5 (2006), available at <http://www.greenpeace.org/raw/content/usa/press-center/reports4/global-wind-energy-outlook.pdf>.

9. See *id.* at 5. The installed capacity for each of the five leading countries in 2005: Germany 18,428 MW; Spain 10,027 MW; the USA 9,149 MW; India 4,430 MW; and Denmark 3,122 MW.

10. *Id.* at 5.

11. *Id.* at 11.

12. See INT'L ENERGY AGENCY, *supra* note 6, at 10.

13. Press Release, Global Wind Energy Council, Record Year for Wind Energy: Global Wind Power Mkt. Increased by 40.5% in 2005 (Feb. 17, 2006), available at http://www.gwec.net/uploads/media/06-02_PR_Global_Statistics_2005.pdf.

14. INT'L ENERGY AGENCY, *supra* note 6, at 13.

15. See WORLD MARKET UPDATE, *supra* note 5; BTM Press Release, *supra* note 4.

16. In 2006 the main wind turbine suppliers were Vestas, Denmark (28.2%), Gamesa Eólica, Spain (15.6%), GE Wind, USA (15.5%) and Enercon, Germany (15.4%). Suzlon, India came in No. 5 (7.7%) and Siemens Wind Power, Germany/Denmark No. 6 (7.3%). See WORLD MARKET UPDATE,

Furthermore, the International Electrotechnical Commission's ("IEC") 61400 series of technical standards for wind turbines applies almost all over the world, making globalization more readily achievable.¹⁷ The IEC also issued a related set of rules, the IEC WT 01, to ensure international recognition of these standards.¹⁸ Nevertheless, the actual construction site remains regulated at the local and national levels.

Previously, most wind turbines were owned primarily by consumers, consumer cooperatives, and other non-utility investors. This is no longer the case, though these parties continue to play a major role in the market. More recent trends show multi-national energy giants, such as BP and Shell, along with other former oil companies, utilities, and energy companies, are supplementing other electricity generation technologies with substantial investments in wind energy projects.¹⁹ At times, these companies, referred to as "developers," act as intermediaries between more traditional, smaller owners of wind turbines and the wind turbine manufacturers.²⁰ The developers provide assistance to the more traditional turbine owners in terms of fundraising and arranging for the permits necessary to operate the turbines. In assuming this increasingly important role, these companies have become more important market players.

Manufacturing of wind turbines is now a large industry, in many countries generating an estimated \$18 billion worldwide and employing around 150,000 people.²¹ Estimates suggest that each MW of installed

supra note 5; BTM Press Release, *supra* note 4.

17. See generally Am. Wind Energy Ass'n, IEC Wind Turbine Standards, http://www.awea.org/standards/iec_stds.html (last visited Mar. 30, 2008) (summarizing the various wind turbine standards developed by the IEC).

18. See generally INT'L ELECTROTECHNICAL COMM'N, IEC SYSTEM FOR CONFORMITY TESTING AND CERTIFICATION OF WIND TURBINES (2000), available at http://www.nrel.gov/business_opportunities/pdfs/31235sow_lwt2-1.pdf (describing the IEC WT 01 international certification system for wind turbines).

19. See European Wind Energy Ass'n, *New Players on Board*, WIND DIRECTIONS, Mar./Apr. 2007, at 39-44 (discussing ownership), available at http://www.ewea.org/fileadmin/ewea_documents/documents/publications/WD/2007_march/WD0703-focus.pdf. BP operates two wind farms in the Netherlands and has also entered the U.S. market by buying wind power developers Greenlight Energy and Orion Energy. Press Release, British Petroleum, BP Alternative Energy Buys US Wind Company (Aug. 15, 2006) [hereinafter BP-Greenlight Press Release], <http://www.bp.com/genericarticle.do?categoryId=2012968&contentId=7020896>; Press Release, British Petroleum, Orion Energy, LLC Announces Acquisition by BP Alternative Energy (Dec. 20, 2006), <http://www.bp.com/genericarticle.do?categoryId=7014&contentId=7028964>. Shell is engaged as partner in the UK and the Netherlands with more projects to come. See Agence France-Presse, *Offshore wind farm opens off coast of the Netherlands*, INT'L HERALD TIMES, Apr. 18, 2007, available at <http://www.iht.com/articles/2007/04/18/business/wind.php>; see also Press Release, Shell WindEnergy, Meeting the energy challenge – Shell's commitment to alternative energy (Feb. 2, 2006), http://www.shell.com/home/content/media-en/news_and_library/press_releases/2006/ren_announcement_02022006.html.

20. Developers can be owned by energy companies such as BP, which recently acquired Greenlight Energy. See BP-Greenlight Press Release, *supra* note 19.

21. GREENPEACE INT'L & GLOBAL WIND ENERGY COUNCIL, *supra* note 8, at 5. The figure in the report is Euro 13 billion equivalent to \$18 billion as of July 2007.

wind capacity creates sixteen years of employment and fifteen to nineteen jobs.²² The success of the industry has attracted investors from both mainstream finance and traditional energy sectors. Additionally, labor unions have expressed increased interest in promoting an industry with such numbers of employees.²³

To date, wind turbines have not been considered commercially competitive in comparison to more traditional forms of electricity production. In fact, the major reason for growth in this market has been certain policy-created incentives—mostly economic incentives—as opposed to market incentives. Historically, wind turbine activity has dropped dramatically without such incentives.²⁴

The production costs of wind energy have dropped considerably over the last several years. The projected cost of energy from larger wind farms—so-called “utility-scale” wind power production—has been as low as four cents per KWh to six cents per KWh in many areas of the United States.²⁵ At the same time, the cost of fossil fuels has greatly increased, and as a result, the competitiveness of wind energy has improved.²⁶ A factor in driving the decrease in wind power costs is production of scale and scope. Furthermore, an increase in tower height and swept rotor area provide a larger output in relation to cost. However, taller turbines and larger rotor blades have also created new problems, such as higher prices of wind turbines due to increased market demand and adverse impacts on wildlife.²⁷

22. COMM. ON ENVTL. IMPACTS OF WIND ENERGY PROJECTS, NAT'L RESEARCH COUNCIL, ENVTL. IMPACTS OF WIND ENERGY PROJECTS 166 (2007). See Avi Brisman, *The Aesthetics of Wind Energy Systems*, 13 N.Y.U. ENVTL. L.J. 1, 53 (2005) (noting that approximately 8 job-years are created for every megawatt of wind capacity installed).

23. Perhaps on account of the large amount of steel required in wind turbine tower construction, the United Steelworkers—trade union of U.S. and Canadian steel workers—and the Sierra Club teamed up to call for the United States to commit to developing renewable energy sources from wind, solar, geothermal, and biomass technologies among other things in order to create “thousands of new jobs.” See Press Release, Sierra Club, Steelworkers, Sierra Club Join Lee Fisher in Calling for Action on Renewable Energy (Nov. 2, 2006), <http://www.sierraclub.org/pressroom/releases/pr2006-11-02.asp>.

24. The United States in the 1980s and Denmark in 2004 represent examples of dramatic decreases in the demand for new onshore wind turbines caused by political changes and the cut in political incentives. Uncertainty regarding the planning regime in Germany in 1999 has also resulted in declines. See 3 EUROPEAN WIND ENERGY ASS'N, WIND ENERGY: THE FACTS—INDUSTRY & EMPLOYMENT 116 (2004) [hereinafter THE FACTS: INDUSTRY & EMPLOYMENT], available at http://www.ewea.org/fileadmin/ewea_documents/documents/publications/WETF/Facts_Volume_3.pdf.

25. INT'L ENERGY AGENCY, *supra* note 6, at 20. It is mentioned that the cost of wind energy in Norway, New Zealand, Ireland, Greece, and Finland was comparable to that of the United States.

26. “Higher fossil fuel prices, particularly for natural gas in the electric power sector, allow renewable energy sources to compete economically in some areas. Where they are not economically competitive with fossil fuels, renewable energy sources may be supported by government policies and incentives.” ENERGY INFO. ADMIN., WORLD ENERGY OUTLOOK 2007 4 (2007), available at [http://www.eia.doe.gov/oiaf/ieo/pdf/0484\(2007\).pdf](http://www.eia.doe.gov/oiaf/ieo/pdf/0484(2007).pdf).

27. See *infra* Part III.B regarding problems related to the effects on the landscape and certain nuisances from the wind turbines.

II. PRIMARY POLITICAL INCENTIVES FOR WIND POWER DEVELOPMENT

A. Security of Supply

Security of supply has once again become an issue for countries dependent on imported energy. Many regions are expecting increased dependence on imported primary energy. An increasingly large part of the known, remaining accessible reserves of oil and gas are concentrated among an increasingly limited group of countries and regions that are not necessarily considered reliable suppliers.²⁸ Global demand for energy is expected to increase more than production of energy.²⁹ Prices are expected to rise to a much higher level than in the 1990s, thereby causing financial problems. This will primarily be of concern to the heavily oil-dependent developing countries and countries with economies in transition. The challenge is to ensure continued access to affordable quantities of energy. Wind turbines represent a technology in which more energy is produced during a turbine's lifetime than it takes to produce the turbine—a positive energy balance. For large turbines, the energy payback period is less than a year,³⁰ and with a lifetime of at least twenty years, wind turbines are able to replace the energy used during turbine production many times over.

In most instances, wind power is a domestic resource, providing more protection in terms of a nation's energy security. Studies of global wind resources indicate that these resources are large and available almost everywhere.³¹ Thus, along with other renewable energy resources, wind

28. "The former Soviet Union and the countries of the middle East hold more than 70% of the world's gas reserves, while the middle East is also thought to possess more than half of global oil reserves. In the OECD countries, domestic oil and gas production is generally declining, while demand for oil and gas is growing rapidly." HANS LARSEN & LEIF SØNDERBERG PETERSEN, RISØ NATIONAL LAB., RISØ ENERGY REPORT 4: THE FUTURE ENERGY SYSTEM—DISTRIBUTED PRODUCTION AND USE 9 (2005) [hereinafter RISØ ENERGY REPORT 4], available at <http://www.risoe.dk/rispubl/energy-report4/ris-r-1534.pdf>.

29. The IEA estimates that consumption the consumption of primary energy will grow by more than 60% for the period 2002–2030. *Id.* at 8. The expectations are that 85% of this increase will be within fossil fuels. *Id.* Additionally, the continued rapid growth occurring in certain developing countries and economies in transition will likely continue to increase the energy consumption. For instance, nearly 1.6 billion people in developing countries lived without electricity in their houses in 2002. RISØ ENERGY REPORT 5, *supra* note 3, at 5.

30. Life cycle assessment of offshore and onshore sited wind power plants based on Vestas V90-3.0 MW turbines—modern offshore turbines—shows an energy payback time, or energy balance, of 6.8 months. For the smaller V80-2.0 offshore turbine the energy payback time is 9.0 months. See VESTAS WIND SYSTEMS A/S, LIFE CYCLE ASSESSMENT OF OFFSHORE AND ONSHORE SITED WIND POWER PLANTS BASED ON VESTAS V90-3.0 MW TURBINES (2006), available at [http://www.vestas.com/en/about-vestas/sustainability/wind-turbines-and-the-environment/life-cycle-assessment-\(lca\).aspx](http://www.vestas.com/en/about-vestas/sustainability/wind-turbines-and-the-environment/life-cycle-assessment-(lca).aspx) (follow "LCA V90-3.0 MW onshore and offshore and energy balance" hyperlink).

31. GREENPEACE INT'L & GLOBAL WIND ENERGY COUNCIL, *supra* note 8, at 6 (stating that "[s]tudies of the world's wind resources have confirmed that these are extremely large and well distributed across almost all regions and countries. Lack of wind is unlikely to be a limiting factor on global wind power development").

power technology can contribute to greater energy independence and can help countries avoid the problems associated with continued dependence on energy imports.

B. Climate Change

For a number of years, environmental protection has enjoyed a prominent position on the world stage, especially in developed countries. In particular, greenhouse gases (“GHG”) and their expected contribution to climate changes are turning public attention to energy technologies that lower emissions of GHG such as carbon dioxide (“CO₂”). The energy sector is the main contributor to global GHG emissions; a fact which is heightening public awareness. According to the European Environment Agency, “[e]nergy production and consumption (i.e. transport, industry, households, and services) are the largest sources of greenhouse gas emissions in the [European Union], accounting for 81.5% of the total in 2003.”³² Some evidence shows that, despite the initial decrease in emissions that occurred during the first part of the 1990s, ever-increasing emissions have erased such progress and offset the potential benefits of reduced carbon emissions.³³ Thus, in response to growing concerns surrounding global climate change, environmentalists advocate enhanced efforts to harness wind energy as a potentially meaningful source of energy that can be produced with zero CO₂ emissions.³⁴

III. AFFECTING THE SURROUNDINGS

The environmental benefits of operating wind turbines are widely recognized, especially in terms of reducing waste and emissions into the water and air. However, in spite of their more environmentally-friendly attributes, wind turbines are undeniably large machines that affect their physical surroundings in a variety of ways. These impacts can result during the turbine construction and scrapping phases, as well as during the process of energy production, and can depend on the location of the turbines. For instance, wind turbines are often located in rural landscapes, resulting in concerns related to the undesirable and highly visible aesthetic interruption of otherwise largely untouched stretches of land. In order to avoid or reduce such unwanted consequences, wind projects often endure extensive planning efforts and environmental impact assessments (“EIA”). In the context of larger projects, these measures can be mandatory. However, even in the industrialized world caution may also yield to expediency, resulting in the construction of major wind farms in rural areas

32. See EUROPEAN ENV'T AGENCY, ENERGY AND ENVIRONMENT IN THE EUROPEAN UNION: TRACKING PROGRESS TOWARDS INTEGRATION 14 (2006).

33. *Id.*

34. Pollutants such as SO₂ and NO_x are also avoided during wind power production.

without a governmental body overseeing the project.³⁵

A. Environmental Issues

Much of the concerns relating to environmental impacts often focus upon the effect of wind turbines on plant and animal life. There is a tendency to view all effects as negative and to take the approach that the environment and the ecosystems should be preserved. However, it is also the case in some instances that something detrimental to one species can simultaneously benefit another species or another part of the ecosystem.

On-shore wind turbines are often associated with negative impacts on bird life.³⁶ The typical problems include loss of habitat, disturbance to breeding areas, and avian mortality caused by collisions with rotor blades.³⁷ The first two problems can be remedied by proper site placement. The viability of erecting wind farms near bird sanctuaries should be considered within the context of the species in question, as certain species can take a longer amount of time to become accustomed to wind turbines. With specific regard to rotor blade collisions, some recent risk studies show no major problems. In general, birds and bats rarely collide with wind turbines.³⁸ For example, radar studies conducted in Tjaereborg, Denmark on a 2 MW wind turbine with a 60 meter rotor diameter suggest that “birds—day or night—tend to change their flight route some 100–200 meters before the turbine.”³⁹ However, other studies have found major problems at two locations—the Altamont Pass in California and La Tarifa in Spain—concerning avian mortality in connection with wind farms. Regardless, those locations are the only known sites at which major bird collision problems have been documented, and even in such rare instances, collisions are not overwhelmingly common but are a source of concern as a

35. Denmark is an example of a country demanding EIA by larger wind turbine projects. In New Zealand no government approval is required.

36. Establishment in sensitive areas may of course affect flora, and draining may affect flora and fauna, but that is not different from any other construction on land.

37. 1 EUROPEAN WIND ENERGY ASS'N, WIND ENERGY: THE FACTS—TECHNOLOGY 7 (2004) [hereinafter THE FACTS: TECHNOLOGY], available at http://www.ewea.org/fileadmin/ewea_documents/documents/publications/WETF/Facts_Volume_1.pdf; 4 EUROPEAN WIND ENERGY ASS'N, WIND ENERGY: THE FACTS—THE ENVIRONMENT 182 (2004) [hereinafter THE FACTS: THE ENVIRONMENT], available at http://www.ewea.org/fileadmin/ewea_documents/documents/publications/WETF/Facts_Volume_4.pdf.

38. Danish Wind Industry Ass'n, *Birds and Wind Turbines*, <http://www.windpower.org/en/tour/env/birds.htm> [hereinafter *Birds and Wind Turbines*] (last visited Mar. 29, 2008). “One estimate from the United States is that commercial wind turbines cause the direct deaths of only 0.01–0.02% of all of the birds killed annually by collisions with man-made structures and activities.” See GREENPEACE INT'L & GLOBAL WIND ENERGY COUNCIL, *supra* note 8, at 29.

39. *Birds and Wind Turbines*, *supra* note 38; See also M.B. PEDERSEN AND E. POULSEN, EN 90M/2MW VINDMØLLES INDVIRKNING PÅ FUGLELIVET. FUGLES REAKTIONER PÅ OPFØRELSEN OG IDRIFTSÆTTELSEN AF TJÆREBORG MØLLEN VED DANSKE VADEHAV [AVIAN RESPONSE TO IMPLEMENTATION OF THE TJÆREBORG WIND TURBINE AT THE DANISH WADDEN SEA] (1991).

result of the protected species involved.⁴⁰

Along with their land-based equivalents, offshore turbines may affect flora and fauna. Knowledge of impacts associated with offshore wind turbines is more limited because far fewer turbines are sited offshore than on land. However, much can be learned from Denmark, which has fifteen years of experience with offshore wind farms of varying sizes and locations. The two largest Danish wind farms in operation—Nysted I and Horns Rev I—possess a total capacity of 325.5 MW that can be generated from 152 turbines. These two wind farms have provided vast amounts of important environmental data, due in equal parts to an up-front EIA⁴¹ and to an environmental monitoring program that was in place from 2000 to 2006.⁴² Among other things, the monitoring program collected data concerning the introduction of a hard bottom habitat; the distribution of fish around the wind turbines and scour protection; the effect of electromagnetic fields on fish; the distribution of feeding and nesting birds; the risks of collision for migrating birds; and the behavior of marine mammals.⁴³ Much of the present knowledge concerning offshore wind farms is based on these two monitoring programs. As a consequence, one should be careful not to generalize across species and locations.

Regarding benthic fauna, the seabed at the location of the two wind farms consisted mainly of sandy sediments.⁴⁴ The introduction of hard bottom structures at the turbine foundations enhanced “habitat heterogeneity” and changed the benthic communities from mostly “infauna communities to hard bottom communities.”⁴⁵ As a result, local biomass

40. *Birds and Wind Turbines*, *supra* note 38; THE FACTS: THE ENVIRONMENT, *supra* note 37, at 183. Notably, “[m]ost studies have been carried out on smaller turbines [and] newer, larger turbines may have different effects.” *Id.* See also BUREAU OF LAND MGMT., U.S. DEP’T OF THE INTERIOR, FINAL PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT ON WIND ENERGY DEVELOPMENT ON BLM-ADMINISTERED LANDS IN THE WESTERN UNITED STATES 5-57-66 (2005), available at <http://windeis.anl.gov/eis/guide/index.cfm> (discussing avian and bat mortality caused by collisions with wind turbines).

41. See ELSAM ENG’G & ENERGI E2, DANISH OFFSHORE WIND DEMONSTRATION PROJECT: HORNS REV AND NYSTED OFFSHORE WIND FARMS (2005), available at <http://www.hornsrev.dk/Miljoeforhold/miljoerapporter/review%20rapport%202004%20version0.pdf>.

42. See DONG ENERGY, ET AL., DANISH OFFSHORE WIND: KEY ENVIRONMENTAL ISSUES (2006), available at http://www.ens.dk/graphics/Publikationer/Havvindmoeller/havvindmoellebog_nov_2006_skrn.pdf; DANISH ENERGY AUTH., OFFSHORE WIND FARMS AND THE ENVIRONMENT: DANISH EXPERIENCES FROM HORNS REV AND NYSTED (2006) [hereinafter OFFSHORE WIND FARMS AND THE ENVIRONMENT], available at http://www.bluewaterwind.com/pdfs/havvindm_korr_16nov_UK.pdf.

43. The hard bottom surface provided a foundation for the turbines and scour protection. OFFSHORE WIND FARMS AND THE ENVIRONMENT, *supra* note 42, at 19.

44. DONG ENERGY ET AL., *supra* note 42, at 12; OFFSHORE WIND FARMS AND THE ENVIRONMENT, *supra* note 42, at 20. Benthic fauna are “[o]rganisms attached to or resting on the bottom or living in the bottom sediments of a water body.” Nat’l Water Quality Monitoring Council, Glossary of Water-Quality Monitoring Terms, <http://acwi.gov/monitoring/glossary.html> (last visited Mar. 30, 2008).

45. OFFSHORE WIND FARMS AND THE ENVIRONMENT, *supra* note 42, at 20.

increased by 50 to 150 times, a positive environmental impact that increased the availability of food for fish and seabirds.⁴⁶ The survey detected only negligible impacts, if any, “from the changes in the hydrodynamic regimes on the native benthic communities, seabed sediment structure or established epifaunal communities.”⁴⁷

With specific regard to fish communities, the colonization of the foundations has developed into a monoculture of common mussels at one of the wind farms.⁴⁸ Regardless, reef communities can require several years to fully develop,⁴⁹ and a higher diversity and biomass of species is expected to progress over the coming years. At the Nysted wind farm, the effects of electromagnetic fields on fish and fish behavior were studied. Depending on the individual species, both avoidance of the cable and attraction to it was found, although no significant correlation to the strength of the electromagnetic fields was documented.⁵⁰

Marine mammals, such as seals and harbor porpoises, were absent during the more disruptive site construction activities such as pile driving, but the animals returned when normal operation started.⁵¹ However, at one of the wind farms the porpoise population demonstrated only a slight recovery two years after start of the operation.⁵²

Sea birds had species-specific responses to the wind farms. Hazards were documented regarding “barriers to movement, habitat loss and collision risks.”⁵³ Most bird species tended to avoid the turbines, flying instead along the periphery of the wind farms.⁵⁴ However, the migration distances were extended so slightly—generally less than 10 kilometres—that negative consequences for any species are unlikely.⁵⁵ The collision risk was predicted based upon models, which estimated very low risk.⁵⁶ Infrared monitoring confirmed this result, recording no collisions.⁵⁷ These observations also suggest that sea birds avoided flying in the area of the turbines both at night and during poor weather conditions.⁵⁸ In sum,

46. DONG ENERGY ET AL., *supra* note 42, at 12.

47. *Id.* at 13.

48. *Id.* at 52.

49. OFFSHORE WIND FARMS AND THE ENVIRONMENT, *supra* note 42, at 24.

50. DONG ENERGY ET AL., *supra* note 42, at 13; OFFSHORE WIND FARMS AND THE ENVIRONMENT, *supra* note 42, at 26. The investigations on the effects of electromagnetic fields were only made on one of the wind farms. Regarding electromagnetic interference onshore, *see* THE FACTS: THE ENVIRONMENT, *supra* note 37, at 184.

51. DONG ENERGY ET AL., *supra* note 42, at 86–89.

52. *Id.* at 14; OFFSHORE WIND FARMS AND THE ENVIRONMENT, *supra* note 42, at 7 fig. 2, 30.

53. DONG ENERGY ET AL., *supra* note 42, at 14.

54. *Id.* at 15.

55. *Id.* at 15, 108.

56. For the common eiders passing the one wind farm, the predicted modelled collision rates were 0.02%. *Id.* at 15.

57. *Id.* at 15, 94. Generating empirical data on collision rates by collecting carcasses is possible for onshore wind farms but is not practicable for offshore wind farms. *Id.* at 110.

58. These observations pertain to the Nysted wind farm. *See id.* at 111; *see also* JAN

offshore wind farms, as opposed to some of their land-based counterparts, have not demonstrated a significant adverse impact on avian collision risks.

Though offshore wind projects do not appear to cause direct negative impacts on sea and bird life, some evidence indicates that offshore projects are responsible for some habitat loss. Divers and scoters were almost completely absent from the Horns Rev Offshore Wind Farm.⁵⁹ The long-tailed duck also almost completely disappeared from the Nysted Offshore Wind Farm.⁶⁰ However, no evidence demonstrated any changes in habitat for other species.⁶¹ Neither wind farm is near seabird nesting areas, and each project occupies only part of the seabirds' natural habitat.⁶² However, these results indicate that, in the aggregate, wind farms can cause significant habitat loss.⁶³

B. Affecting Human Life

People in densely populated areas demonstrate a growing opposition to the location of nearby wind turbines, especially when it comes to siting larger wind farms. A major rationale for this backlash against land-based wind farms stems from perceived negative aesthetic effects on the natural landscape. Yet another rationale relates to potential nuisances created by wind turbines, including (1) the noise and vibrations that echo from the rotor blades, gearbox, and generator, and (2) the shadows and reflections created by the rotor blades and the tower.⁶⁴ Of course, the perceived negative impacts of wind turbines on the landscape and creation of public nuisances are also highly subjective.

During standard operation, a wind turbine causes both mechanical and aerodynamic noise.⁶⁵ The noise level depends on the design of the tower and rotor blades, as well as the rotational speed of the rotor blades.⁶⁶ Technological innovations have reduced mechanical noise such that the noises alone are not considered a problem in a properly designed wind turbine. While the nature of wind turbines likely mean that a certain measure of aerodynamic noise will remain, even that type of noise has been reduced with newer turbines, and the amount of noise created by wind turbines is often considered low when compared with other common

PETTERSSON, THE IMPACT OF OFFSHORE WIND FARMS ON BIRD LIFE IN SOUTHERN KALMAR SOUND, SWEDEN 124 (2005).

59. DONG ENERGY ET AL., *supra* note 42, at 94.

60. *Id.*

61. *Id.*

62. *Id.* at 15, 94.

63. *Id.* at 19.

64. See COMM. ON ENVTL. IMPACTS OF WIND ENERGY PROJECTS, *supra* note 22, at 157–62.

65. Mechanical noise comes from equipment such as gearbox and generator. *Id.* at 157. Aerodynamic noise is created by the flow of air over the blades.

66. *Id.* at 159.

sources.⁶⁷ However, low-frequency noise remains a problem, even if the actual impact of low-frequency noise on human beings is not yet very well understood.⁶⁸

Moving rotor blades also project flickering shadows onto land and buildings that can result in a common yet predictable nuisance known as “shadow casting.”⁶⁹ Shadow casting represents a potential nuisance to those living or working close to wind turbines, and the negative impacts associated with this nuisance are considered greatest in the context of larger wind turbines, whose flickering shadows can sweep great distances. In spite of the nuisance effect of shadow casting, the severity of the problem can depend on location. For instance, in Northern Europe, shadow casting is considered a larger problem than in other areas like the United States.⁷⁰ Additionally, the problems of shadow casting are constrained by natural limitations on the circumstances in which this nuisance takes place. More specifically, shadow casting poses fewer problems during winter when the sun’s angles are low and during the early and late hours of the day.

Another turbine-related nuisance occurs when sunrays reflect directly from moving turbine rotor blades, causing a disorienting and inevitable flashing effect in the area of the turbine. The magnitude of this nuisance, also known as “blade glint,” may depend on various factors, including (1) the orientation of the nacelle, (2) the angle of the rotor, and (3) the color, reflectivity, and age of the turbine blades.⁷¹ The blade glint phenomenon is visible at distances of 10 km to 15 km, depending on the contours of the landscape.⁷² Again, the impacts related to blade glint may be mitigated by innovations in wind turbine design and cautious turbine siting. For instance, the use of non-reflective paint has proven particularly effective in managing blade glint.⁷³

Additionally, national aviation legislation often requires cautionary lighting on turbine towers. For instance, the current guidelines of the Federal Aviation Administration, effective in January 2007, require lighting to define the periphery of a wind turbine installation.⁷⁴ At night,

67. THE FACTS: TECHNOLOGY, *supra* note 37, at 7; THE FACTS: THE ENVIRONMENT, *supra* note 37, at 152. At distances more than 300 meters, background noise will normally hide the aerodynamic noise. Ambient noise may mask the noise from the wind turbine as the wind speed increases. See COMM. ON ENVTL. IMPACTS OF WIND ENERGY PROJECTS, *supra* note 22, at 162.

68. COMM. ON ENVTL. IMPACTS OF WIND ENERGY PROJECTS, *supra* note 22, at 158–59.

69. See Danish Wind Industry Assoc., *Shadow Casting from Wind Turbines*, <http://www.windpower.org/en/tour/env/shadow/index.htm> (last visited Mar. 10, 2008); see also BUREAU OF LAND MGMT., *supra* note 40, at 5-92, 5-93; COMM. ON ENVTL. IMPACTS OF WIND ENERGY PROJECTS, *supra* note 22, at 160–62 (discussing the nuisance of “shadow flicker”).

70. COMM. ON ENVTL. IMPACTS OF WIND ENERGY PROJECTS, *supra* note 22, at 160; THE FACTS: THE ENVIRONMENT, *supra* note 37, at 185.

71. BUREAU OF LAND MGMT., *supra* note 40, at 5-94.

72. *Id.*

73. *Id.* at 5-97.

74. See DEP’T OF TRANSP., FED. AVIATION ADMIN., ADVISORY CIRCULAR: OBSTRUCTION

such lighting, intended to be highly visible, can dot the landscape, thereby presenting another aesthetic impact that some people find offensive.

Nuisances are normally regulated either by public law, especially environmental law, or by local laws that limit the level of disturbances permitted by neighbouring activities including wind turbines. Turbine-related nuisances are most problematic in densely populated areas, in which it can be difficult to site wind turbines at a suitable distance from communities and homes.

Wind turbines are highly visible elements in the landscape, and in order to ensure the best possible wind access, turbines often must be sited in a manner that retains their visibility. In some countries, even mountain ridges are used for turbines. Large modern wind turbines are sometimes the largest structures in the vicinity of certain urban and rural areas, and the combined effects of rotor blade motion and the expansive areas of land required for optimal wind energy production serve to draw further attention to the wind turbines.⁷⁵

The acceptance of such structures in the landscape may differ significantly from area to area. Many people find wind turbines intrusive from an aesthetic point of view, and changes to the landscape may meet opposition from aesthetic, preservation-oriented environmentalists and neighbouring groups, especially in developed countries.⁷⁶ Planning laws normally contain regulations that preclude wind turbines and other structures from being sited within certain areas, such as nature reserves. Furthermore, special regulations regarding minimum distances to neighbouring houses exist in some countries.⁷⁷

Modern wind turbines are generally taller and have longer rotor blades than older wind turbines. At present, the largest designs involve rotor diameters in excess of 100 meters and a capacity of more than 5 MW.⁷⁸

MARKING AND LIGHTING 33–34 (2007), available at https://oeaaa.faa.gov/oeaaa/external/content/AC70_7460_1K.pdf; see also BUREAU OF LAND MGMT., *supra* note 40, at 5-94–95.

75. In general the spinning of the rotor will be slower on large wind turbines than on small ones. A slower rotation will often be considered less disturbing. With regard to the amount of land required for wind farms, turbines must be spread over large areas in order to avoid obstructing the wind for other turbines, a phenomenon known as “wind shade.” See Ill. Inst. of Tech., *Wind Shade Calculations*, http://www.iit.edu/~ipro301s05/turbine/wind_shade_summary.html (last visited Mar. 29, 2008) (discussing how wind shade can be calculated).

76. Also referred to as “NIMBY”—Not In My Back Yard—groups. The opposition may relate to changes to original nature as well as culturally formed landscapes. See Roy Fuller, *Wind Energy Development on BLM Lands*, 24 J. LAND RESOURCES & ENVTL. L. 613, 616 (2004) (discussing NIMBY in the context of wind farms).

77. For instance, Danish planning law regulates the minimum distance to neighbouring housing. The minimum distance depends of the height of the turbine inclusive of blades.

78. The largest single turbine in operation is the 6 MW Enercon E112. GREENPEACE INT’L & EUROPEAN RENEWABLE ENERGY COUNCIL, *ENERGY REVOLUTION: A SUSTAINABLE WORLD ENERGY OUTLOOK 75* (2007) [hereinafter *SUSTAINABLE WORLD ENERGY OUTLOOK*], available at http://www.energyblueprint.info/fileadmin/media/documents/energy_revolution.pdf. The average size of a wind turbine installed in 2005 was 1,282 KW. *Id.*

Longer rotor blades enable wind farms to operate with fewer turbines, which also provide indirect advantages such as lower maintenance costs and higher production. Additionally, the lower rotational speed of longer turbine blades results in reduced visual distraction in comparison with faster moving blades of smaller turbines.⁷⁹

IV. THE VARIABLE PRODUCTION

Because they are completely dependent upon the wind, wind turbines are a variable output technology. Output cannot be regulated up, and if down-regulated, unused wind power is lost forever. The input and output of a power grid system needs to be in continuous balance. In addition, large amounts of electricity cannot be stored.⁸⁰ As electricity in a modern world is considered a universal service, non-wind power generation capacity must be capable of meeting demand at peak hours. Hence, wind turbines must either constitute an “extra” generation capacity, or the system must be balanced by imports, if possible, to avoid closing down the supply to consumers.⁸¹

A few short years ago, strong concerns existed regarding whether the grid systems could integrate large amounts of variable wind power. Today, it is estimated that the EU grid and supply system, including already established control methods and backup capacity, is more than adequate to handle the additional variable supply of wind power at penetration levels up to around 20%.⁸² For example, in Denmark, high amounts of wind energy are normal. In western Denmark, up to 25% of the demand for electricity is met by wind power, and on some occasions, wind power production meets more than 100% of instantaneous demand.⁸³ A 2007 study shows that a 50% share of wind power is technically possible and economically feasible to integrate into the grid system by 2025.⁸⁴

Additionally, wind turbine producers have difficulty predicting

79. The speed on wind tip is about the same for both large and small turbines. Regardless, more important is the time required for the blades to turn one revolution.

80. Note, however, certain methods exist to convert electricity to other energy forms, such as heat or hydrogen.

81. Another balancing option might be for authorities to negotiate an agreement with industrial consumers to limit the industrial electricity consumption when needed.

82. In 2004, “[Danish] electricity production from wind turbines accounted for approximately 19% of domestic electricity supply.” DANISH ENERGY AUTH., OFFSHORE WIND POWER: DANISH EXPERIENCES AND SOLUTIONS 23 (2005) [hereinafter DANISH WIND POWER EXPERIENCES AND SOLUTIONS], *available at* http://www.ens.dk/graphics/Publikationer/Havvindmoeller/uk_vindmoeller_okt05/pdf/havvindmoellerapp_GB-udg.pdf. The share depends on the amount of wind in the particular year.

83. Am. Wind Energy Assoc., Wind Energy Potential, http://www.awea.org/faq/wwt_potential.html (last visited Mar. 30, 2008).

84. See EA ENERGY ANALYSES, 50% WIND POWER IN DENMARK IN 2025—ENGLISH SUMMARY (2007), *available at* <http://www.ea-energianalyse.dk/projects-eng19.html> (follow “Summary of the report (folder)” hyperlink).

production. This difficulty results in an increased demand for balancing power and for a generation capacity that is standing by to be regulated up or down. In some countries, imbalance is penalized by counterbalancing payments.⁸⁵

Producers of wind energy and receiving grid operators are also dependent upon accurate methods of wind forecasting. Accurate methods are widely available for short-term forecasting, and the better the short-term predictions are, the fewer imbalances will occur due to wind power production. In general, the wind power industry advocates a reduced forecast horizon on the spot markets or at the system operators. Some grid operators demand prediction of production up to forty-eight hours in advance, others only a day ahead.⁸⁶

Selling electricity at the spot market presents the same problem.⁸⁷ If long gate-closure times could be reduced to a few hours, the balancing costs for wind power generators could be reduced significantly.⁸⁸ Markets with the ability to trade electricity up to one hour before production exist at the Scandinavian Nord Pool power exchange (the “ELBAS market”),⁸⁹ but so far the ELBAS market has only been used to trade wind power to a limited extent.

Pooling wind power for a larger area with a view toward counterbalancing payment may also be a method of reducing cost, although this would not change the physical need for balancing power. The need to have extra balancing power and to view wind power generating capacity as “extra” capacity implies extra costs for the power system in connection with wind turbines.

V. LEGAL AND ECONOMIC INCENTIVES

In spite of its long historical development, wind power still may not be considered a commercially competitive technology for many years.⁹⁰ If

85. See INT’L ENERGY AGENCY, DENMARK 2006 REVIEW 109 (2006) [hereinafter DENMARK 2006 REVIEW] (discussing wind power intermittency and balancing).

86. See generally Ismael Sánchez, *Short-term Prediction of Wind Energy Production*, 22 INT’L J. FORECASTING 43 (2006) (describing “a statistical forecasting system for wind energy prediction”).

87. See P.E. Morthorst, *Wind Power and the Conditions at a Liberalized Power Market*, 6 WIND ENERGY 297, 299 (2003).

88. The access to short-time forward and spot markets together with the capability to predict the wind is considered essential to wind power’s future competitiveness. See 2 EUROPEAN WIND ENERGY ASS’N, WIND ENERGY: THE FACTS—COSTS & PRICES 109 (2004) [hereinafter THE FACTS: COSTS & PRICES]. See also RISØ ENERGY REPORT 5, *supra* note 3, at 57 (noting that “[t]he variability and reduced predictability of a number of renewable energy sources, notably wind power, create specific challenges for future energy systems compared to those of today”).

89. See Nord Pool Spot, *The Elbas Market*, <http://www.nordpoolspot.com/trading/The-Elbas-market/> (last visited Mar. 29, 2008).

90. Wind energy’s perceived lack of competitiveness is partly caused by competition from old nuclear and fossil-fueled power plants for which consumers and taxpayers have already paid and which, therefore, can produce electricity at marginal costs. See SUSTAINABLE WORLD ENERGY OUTLOOK,

wind power is to be effectively promoted as a realistic alternative energy solution, an incentive system is necessary in order to cultivate a greater and more practical commercial appeal among energy producers and consumers. Arguably, the lack of competitiveness in the field of wind energy is attributable to the fact that other more conventional technologies have not internalized their environmental costs, thus avoiding the “polluter pays” principle.⁹¹ Incentives, such as economic support for wind turbines, can counteract the failure of the conventional energy industry to internalize these pollution costs.⁹²

In many parts of the world, governments have largely deregulated the electricity industry.⁹³ In general, electricity production and trade are the most competitive areas of the electrical supply sector.⁹⁴ The introduction of competition into the electricity market removed the regulatory risk shield that previously enabled monopolies, including generators, to transfer costs and risks from investors to consumers, and because future prices for electrical power are no longer known, investors will have to internalize these risks and account for them in their investment decision-making. In spite of deregulation, the grid service is still considered a natural monopoly, along with a few other related parts of the sector, and in some regulatory regimes, the promotion of renewable energy is considered a monopolized public service obligation (“PSO”).⁹⁵ This PSO status can be used to support the development of wind power. For example, priority access can be given to renewable generation technologies, thereby creating instruments such as a duty to buy, renewable energy quotas, or other instruments that will keep electricity generated from renewable resources separate from the commercial market.

supra note 78, at 82. The same argument can be used by market actors who wants to introduce new conventional power plants.

91. See generally Eric Larson, *Why Environmental Liability Regimes in the United States, The European Community, and Japan Have Grown Synonymous with the Polluter Pays Principle*, 38 VAND. J. TRANSNAT'L L. 541 (2005) (discussion of the “polluter pays” principle).

92. For a more detailed discussion of externalities and electricity generation, see THE FACTS: THE ENVIRONMENT, *supra* note 37, at 147–57.

93. Though formally liberalised, many power markets still seem dominated by incumbents and protectionism. This is the case within the European Union. See *Inquiry Pursuant to Article 17 of Regulation (EC) No 1/2003 into the European Gas and Electricity Sectors (Final Report)*, at 5, COM (2006) 851 final (Oct. 1, 2007).

94. In contrast to grid services, no natural monopolies exist in power production and trade.

95. PSOs constitute “[s]pecial tasks put on electricity companies by authorities in order to look after public interests. Authorities have legal title to do so. Electricity consumers pay a particular fee per kWh to cover the expenses of electricity companies.” DANSKENERGI, DANISH ELECTRICITY SUPPLY: STATISTICAL SURVEY 87 (2004), available at http://www.delederforum.dk/~media/Energi_i_tal/Danish_Electricity_Supply_2004.pdf.ashx. Within the European Union, member states may “impose on undertakings operating in the electricity sector, in the general economic interest, public service obligations which may relate to security, including security of supply, regularity, quality and price of supplies and environmental protection, including energy efficiency and climate protection.” Council Directive 2003/54, art. 3, 2003 O.J. (L 176) (EC).

In order to make wind energy incentives work together in a competitive market, it is logical to regulate wind energy production under nearby market conditions. Mechanisms such as premiums, investment aid, or green certificates will keep the electricity generated a part of the market. These incentives take many forms, such as command and control, economic incentives, and planning, and they relate to the investment and production phases, as well as to special regulations regarding scrapping.⁹⁶ Different types of support mechanisms for renewable power production technologies, including wind turbines, can be systematized in different ways, such as (1) legal and economic incentives; (2) voluntary and compulsory incentives; (3) aid for investments and aid for operation; (4) financial aid and non-financial aid; and (5) direct and indirect aid. Some of the most frequently employed incentives will be discussed in the subsections that follow.

A. Grid Access and Priority

Wind turbine technology involves high capital costs.⁹⁷ However, marginal production costs are low because wind is free.⁹⁸ Economic efficiency calls for the dispatch rules to start with the plant with the lowest marginal production costs and finish with the plant with the highest marginal production costs. For that reason, access to grids is often guaranteed to wind power according to market dispatch rules, starting in sequence from lowest to highest marginal production costs until demand is met. The reverse applies when it comes to stopping the production from power plants. In such cases, the market dispatch rules call for the plants with the highest marginal production costs to be stopped first, leaving the wind turbines running in most cases.⁹⁹ This guaranteed connection and access to the grids is a crucial element of advancement of the wind energy industry.¹⁰⁰ Other incentives, such as feed-in tariffs, are of little importance

96. A special premium is paid in Denmark for the replacement of numerous old, small land-based wind turbines with a lower number of more efficient wind turbines in order to achieve a more aesthetically pleasing landscape. See DENMARK 2006 REVIEW, *supra* note 85, at 100, 125. This instrument makes sense in Denmark because of the limited number of suitable onshore wind locations but may not be necessary in countries with different geographic features.

97. "Capital costs of wind energy projects are dominated by the cost of the [wind turbine] itself." THE FACTS: COSTS & PRICES, *supra* note 88, at 98.

98. Of course, the cost of the site can depend on how good the site is in relation to wind, but this does not affect marginal production costs.

99. Within the EU, member states may "require the system operator, when dispatching generating installations, to give priority to generating installations using renewable energy sources or waste or producing combined heat and power." Council Directive 2003/54, art. 11, 2003 O.J. (L 176) (EC).

100. 5 EUROPEAN WIND ENERGY ASS'N, WIND ENERGY: THE FACTS—MARKET DEVELOPMENT 214 (2004) [hereinafter THE FACTS: MARKET DEVELOPMENT], available at http://www.ewea.org/fileadmin/ewea_documents/documents/publications/WETF/Facts_Volume_5.pdf (noting that "[g]ood planning and grid connection frameworks are a precondition for any mechanism to be successful").

if wind-generated energy is denied grid access in the first place.

Minor turbines can be connected to distribution grids, while large turbines and wind farms should normally be connected to stronger grids like transmission grids. Indeed, the establishment of larger and more efficient modern wind farms may call for added grid capacity. This issue is often neglected when the decision to build a wind turbine is made. In order to control distributed systems, there may be a need for the system operator to limit the production from a wind farm in order to secure the stability of the grid. Arguably, such a limitation interferes “with the requirement for priority dispatch of electricity from renewable sources.”¹⁰¹ However, such limitations of production are not expected to decrease the total production of large amounts of energy.¹⁰²

The use of recognized technical standards is also essential to securing access to the grids for wind energy. For instance, the IEC issued specific technical standards and created a certification system for wind energy—IEC standard WT 01.¹⁰³ Along with the IEC, the U.S. Institute of Electrical and Electronics Engineers (“IEEE”) provided leadership in addressing obstacles to integrating distributed generation (“DG”) with the existing electrical grid.¹⁰⁴ Specifically, the organization adopted IEEE standard 1547 in June 2003 “to ensure that DG systems operate safely, reliably and in a uniform way across the US power system.”¹⁰⁵

Aside from physical access to the grid, the decisive factor in establishing wind-generated energy as a viable energy source is the price for electricity from renewable sources on the electricity markets. Priority access is only useful when market parties are willing or required by law to buy electricity from renewable sources at sufficiently high prices.¹⁰⁶

B. Peak Demand and Balancing Capacity

Because wind power generation has high capital costs and decreases during periods of calm wind, there must be sufficient capacity to address peak demand periods and fluctuations in the wind.¹⁰⁷ Therefore, a

101. EUROPEAN COMM’N, CONCERTED ACTION FOR OFFSHORE WIND ENERGY DEPLOYMENT (COD): PRINCIPAL FINDINGS 2003–2005 24 (2005), available at http://www.offshorewindenergy.org/cod/COD-Final_Rept.pdf.

102. The conflict “can also result in more efficient use of existing infrastructure” and “can probably be solved relatively easily, either on a contractual or on a regulatory basis.” *Id.* at 24.

103. See RISØ ENERGY REPORT 4, *supra* note 28, at 26.

104. DG “is characterised by a variety of energy production technologies integrated into the electricity supply system, and the ability of different segments of the grid to operate autonomously. The use of a more distributed power generation system would be an important element in the protection of the consumers against power interruptions and blackouts, whether caused by technical faults, natural disasters or terrorism.” *Id.* at 5.

105. *Id.* at 26.

106. EUROPEAN COMM’N, *supra* note 101, at 25–26.

107. The average capital costs for complete wind farms—mainly the wind turbine—vary from country to country. In general, it ranges from \$1,200 to \$1,550 per installed KW. See INT’L ENERGY

combination of wind power and more controllable power sources is needed.

Such capacity may be available up front but must also be maintained and renewed. One method of doing this in a deregulated power market is to pay for standby balancing capacity or for capacity creation.¹⁰⁸ Examples of such capacity include the use of calls for tenders and the creation of spot markets.¹⁰⁹

The need for backup generating capacity increases the overall cost of implementing wind energy in a larger power supply system.¹¹⁰ There are different methods of financing this cost, but generally speaking, the cost will shift to either the wind generators or the consumers. Shifting the cost to the wind generators creates an incentive to reduce the cost of imbalance. For example, wind generators can reduce costs by becoming better at predicting the level of production. Otherwise, placing the balancing cost on the consumer will constitute indirect aid and may give false price signals for investments in wind turbines.¹¹¹

Another possibility is combining wind power with other technologies that can supply backup power in a cost-efficient manner. Such technologies might include (1) hydraulic power, which provides flexibility in terms of when to use available water capacity, or (2) combined heat and power plants, which provide flexibility between heat and power production.

A strong transmission grid that includes transnational connections can reduce the need for domestic balancing capacity for various reasons. First, the wind level will rarely be the same everywhere. Second, more generating capacity technologies will be available for backup. However, grid capacity is also quite expensive. The costs of enforcing grid capacity will often shift to the grid owner and ultimately to the consumer.

C. Economic Support Mechanisms

Economic support mechanisms can assume a number of forms, such as investment subsidies or production subsidies. Historically, the former mechanism focused mainly on estimated output or available capacity.¹¹² However, there is a growing trend toward focusing on actual production

AGENCY, *supra* note 6, at 20; *see also* THE FACTS: COSTS & PRICES, *supra* note 88, at 98–99. *See generally* GREENPEACE INT’L & GLOBAL WIND ENERGY COUNCIL, *supra* note 8, at 43–44 (discussing the capital costs of increased turbine capacity).

108. In Denmark, power plants must normally pay for the balancing costs created by deviations of actual production from scheduled production. However, the plants are reimbursed for such costs. DANISH ELECTRICITY SUPPLY ACT § 56 at para. 4.

109. On the Nord Pool Spot Elba Market, electricity can be traded down to one hour before delivery. *See* Nord Pool Spot, *supra* note 89.

110. Systems based on large amounts of hydropower may equally demand backup capacity to compensate for years with unusually low rainfall.

111. NUCLEAR ENERGY AGENCY, ET AL., PROJECTED COSTS OF GENERATING ELECTRICITY 211 (2005).

112. *See* THE FACTS: MARKET DEVELOPMENT, *supra* note 100, at 213.

output.¹¹³ Simply supporting investment in available capacity does not give the optimal incentive to site the wind turbines optimally or to run them efficiently.¹¹⁴ Therefore, generally speaking, production subsidies are more common than investment subsidies because the latter is believed to “lead to less efficient technology development.”¹¹⁵

1. Tariffs and Premiums

Ensuring a reasonable price for the electricity produced—production aid—is one of the most common methods used to support wind power.¹¹⁶ The actual capacity to build will be determined by the market. This focus on output creates incentives to maximize energy production depending on the size of the aid.

Cost-plus tariffs have been in use in many utility sectors working under monopoly conditions.¹¹⁷ However, critics argue that guaranteeing a return for the investor’s cost plus a modest profit does little to promote production efficiency. In some instances, companies working under a cost-plus regime have received public orders to build a certain amount of wind power capacity.¹¹⁸ Because the energy utilities can pass costs down to consumers, the companies have not had any incentive to oppose such orders.

Fixed feed-in tariffs represent another common method of supporting wind power and other renewable technologies.¹¹⁹ Subsequent deployment can then be market driven. However, the trade of electricity will be outside the normal market and, thus, may produce imprecise price signals. Investors seem to prefer feed-in tariffs in order to lower their risk exposure,

113. *Id.* (noting that “[i]t is generally acknowledged that systems that relate the amount of support to the size of the [wind turbines] rather than the production of the electricity are not ideal because they lead to less efficient turbines”).

114. *Id.*

115. *See* SUSTAINABLE WORLD ENERGY OUTLOOK, *supra* note 78, at 85. India is an example of a country where incentives focused on capacity resulted in “poor siting” in the 1990s. *See* THE FACTS: INDUSTRY & EMPLOYMENT, *supra* note 24, at 115.

116. *See* THE FACTS: MARKET DEVELOPMENT, *supra* note 100, at 213.

117. *See, e.g.*, ORGANISATION FOR ECONOMIC COOPERATION & DEV., URBAN WATER REFORM IN EASTERN EUROPE, CAUCASUS, AND CENTRAL ASIA 43 (2003), available at <http://www.oecd.org/dataoecd/1/45/14626557.pdf> (noting that “all [Eastern Europe, Caucasus and Central Asia] countries employ the “cost-plus” tariff scheme to regulate water utilities. It implies that utilities receive an agreed fixed portion of ‘profit’ on top of the cost of service, which gives them no incentive to reduce costs”).

118. Prior to liberalisation of the power supply sector on 13 Feb. 1998, Denmark ordered the power production companies to make projects regarding offshore wind power. This was based on the former article 13 in the Danish Electricity Supply Act. *See* BENT OLE GRAM MORTENSEN, ELFORSYNING – AFVEJNINGEN AF HENSYN I EN SEKTOR PÅ VEJ MOD DET INDRE MARKED [POWER SUPPLY – CONSIDERATIONS TO BE TAKEN IN A SECTOR HEADING FOR THE INTERNAL MARKET] 230 (DJØF Publishing, Copenhagen 1998).

119. With fixed feed-in tariffs, “[o]perators of wind farms are paid a fixed price for every kWh of electricity they feed into the grid. The cost of the system—defined by the difference between the level of the tariff and the market price of electricity—is borne by the taxpayers or the electricity consumers.” THE FACTS: MARKET DEVELOPMENT, *supra* note 100, at 214.

though the political risk of changes in the guaranteed tariffs remains.¹²⁰ Regardless, the risk may be lowered by guaranteeing the feed-in premium for a sufficient period to ensure depreciation of the investment.¹²¹

Germany, Spain, and Denmark effectively used feed-in tariffs to promote wind power.¹²² As opposed to cost-plus tariffs, feed-in tariffs provide utilities with the incentive to keep production costs down. Indeed, the utilities' profit ultimately depends on keeping the costs down. This system can be combined with an obligation to buy a certain amount of energy, usually imposed on the grid or system operator.

As an alternative to the fixed price options detailed above, the market could be used for setting the price. In addition to this market-determined price, fixed premiums could also be used to support wind power. This same premium could be given as a tax credit,¹²³ and if constructed at a guaranteed minimum price, fixed premiums would allow those who finance the premium—including consumers and the public—to save money in periods of higher power prices.¹²⁴ This method brings wind power to the market and ensures better price signals.¹²⁵

Tariffs or premiums that are too generous may lead to inefficiencies, such as siting turbines at sites that are less suitable for wind power.¹²⁶ Regardless, this result can be prevented by legal or regulatory planning methods and by regularly evaluating the support scheme. For example, Denmark currently uses time limits related to the number of production

120. Within the EU, the most common support system is the feed-in tariff, followed by quota obligation schemes accompanied by green certificates. See *The Support of Electricity from Renewable Energy Sources*, at 4–5, COM (2005) 627 final (July 12, 2005). Feed-in tariffs are used in France, Germany, Greece, Ireland, Italy, Portugal, Spain and Sweden. *Id.* at 22. “The political risk of [feed-in tariffs] is usually understood as the risk that a government will progressively lower the tariff to reflect the fact that wind power becomes cheaper as the technology develops.” THE FACTS: MARKET DEVELOPMENT, *supra* note 100, at 215.

121. In Germany, payments have been guaranteed for 14 to 20 years. See THE FACTS: MARKET DEVELOPMENT, *supra* note 100, at 215.

122. RISØ ENERGY REPORT 5, *supra* note 3, at 14; THE FACTS: MARKET DEVELOPMENT, *supra* note 100, at 214.

123. The U.S. Production Tax Credit (“PTC”) for wind and other renewable energy technologies, as extended until Dec. 31, 2008, is an example of such an instrument. The PTC provides a credit of 1.9 cents per kWh electricity generated over the first ten years of a project’s operation. Tax incentives are also used in the Netherlands and India. See also THE FACTS: MARKET DEVELOPMENT, *supra* note 100, at 216.

124. “If the level of the tariff remains constant, the level of support will change as a result of changing electricity prices At times, this has led to the somewhat paradoxical situation that owners of coal power plants receive higher prices for the electricity they supply than owners of [wind turbines].” *Id.* at 214.

125. In power exchanges, wind power and hydropower normally come with the lowest bids due to the low marginal cost. Increasing the amount of wind power on the exchange can therefore lead to lower prices.

126. The incentive to establish wind turbines on locations with insufficient wind exists, especially in highly populated areas where locations can be hard to find due to planning law or neighbouring law demands.

hours.¹²⁷ Such limits help the investor recover on his investment but in the end, do little to ameliorate the continuous premium paid during the lifespan of the wind turbine.

2. Selling Wind Power on a Renewable Power Market

In several places, special programs have been established to differentiate power produced from renewable primary resources—also known as “green power”—from more conventionally produced power. The intent behind such programs is to allow green power to achieve greater returns in the market. Anybody can initiate such programs, including traders, governments, and non-governmental organizations (“NGO”) such as Greenpeace. In some cases, governments support such programs by passing legislation that requires the source of electricity to be documented. For example, the EU has issued regulations requiring guarantees of origin.¹²⁸ This directive allows people to trade green power throughout the entire EU. Green power trade can be based strictly upon the trade of these certificates, and the produced electricity can be sold on the same market as more conventional electricity, leading to lower prices.

Several countries have initiated “green certificate” programs. Certificates are issued to those who generate specifically defined types of renewable energy, and the end-user buys certificates to document a “consumption” of green electricity.¹²⁹ Within the EU and the United States, a number of states have already established publicly-traded green certificate programs.¹³⁰ Other countries have also made similar preparations.¹³¹ Such public programs can also include regulations that require the purchase of a minimum percentage of green power—a quota

127. See generally DANISH EXPERIENCES AND SOLUTIONS, *supra* note 82, at 23 (detailing the mechanics and limits of Danish feed-in tariffs in the context of offshore wind turbines).

128. According to the European Commission:

A guarantee of origin shall: specify the energy source from which the electricity was produced, specifying the dates and places of production, and in the case of hydroelectric installations, indicate the capacity; serve to enable producers of electricity from renewable energy sources to demonstrate that the electricity they sell is produced from renewable energy sources.

Council Directive 2001/77, art. 5, 2001 O.J. (L 283) 3 (EC).

129. According to the European Wind Energy Association:

the mechanism should work as follows: the government sets a specific and gradually increasing quantity – or minimum limit – for the amount of renewable electricity in the supply portfolio. An obligation is placed on either the electricity suppliers or end users of the electricity (it is of little importance who has the obligation). The generators (producers), wholesalers, retailers or consumers (depending who is obliged in the electricity supply chain) are obliged to supply/consume a certain percentage of electricity from renewable energy sources. At the settlement date, they have to submit the required number of certificates to demonstrate compliance.

THE FACTS: MARKET DEVELOPMENT, *supra* note 100, at 219.

130. *Id.*

131. Denmark has included provisions regarding green certificates in its electricity supply act but not yet issued such certificates. See DANISH ELECTRICITY SUPPLY ACT §§ 56(2), 56a(7), 56c(4), 57. Until such green certificates will be issued, an extra charge on DKK 0.10/kWh will be given. No green certificates are issued for offshore wind turbines. *Id.* § 56e(4).

system—and other regulations that set a minimum price.¹³² By including such regulations, these programs effectively become aid programs and can serve as alternatives to cash or tax premiums. However, the size of the aid depends on the specific certificate market.¹³³

Green certificate programs can be constructed in many different ways. For example, some programs differentiate between different kinds of renewable technologies, both when issuing green certificates and when buying them. However, keeping different renewable technologies under the same certificate program creates a larger market that generally gives more precise price signals. In Europe, prices paid to wind power generators are currently higher in those countries with quota-based systems than in those countries with fixed price or premium systems.¹³⁴ Additionally, certificate systems are riskier for investors than a fixed price system, due to daily price fluctuations and other problems that come with creating efficient markets for certificates.¹³⁵ Furthermore, a certificate system is more complex and costly to administer than other mechanisms.¹³⁶

D. Planning, Tender, and Quotas

National or even supranational planning is normally required in order to promote renewable energy. This planning often focuses on renewable technologies as a whole, rather than a single technology.¹³⁷ Such a broad focus ensures a certain competition between technologies and is often viewed as politically binding.¹³⁸ Planning efforts occur in combination with a command and control approach, such as ordering a sector to establish quotas pertaining to a fixed amount of MW of wind power.¹³⁹

132. In the context of green certificates, a certificate: serves as evidence that a specific amount of green power has been produced and fed into the grid. If demand for certificates exceeds supply—the amount of renewable electricity produced is lower than the government quota—then the price of certificates will rise. It will continue to do so until the price satisfies investors' requirements for return, whereas new capacity will be installed to meet the quota. THE FACTS: MARKET DEVELOPMENT, *supra* note 100, at 219. The obligation to buy will not necessarily guarantee the wind turbine owner the sale of the certificate. The wind production for a year may exceed the total obligation to buy certificates. However, regulation also can include an obligation for a system operator to buy all remaining certificates at a fixed price.

133. Whether a maximum price is fixed or not, the penalty for unfulfilled quota obligations will constitute a maximum price.

134. See SUSTAINABLE WORLD ENERGY OUTLOOK, *supra* note 78, at 85.

135. THE FACTS: MARKET DEVELOPMENT, *supra* note 100, at 221. Owners of wind turbines would prefer to sell their certificates on long term contracts in order to reduce risks. *Id.* In opposition the buyers may prefer shorter contracts. *Id.* This calls for a market place involving financial arbitrage. *Id.*

136. See *id.*

137. Also referred to as Renewable Portfolio Standards.

138. An example is found within the EU, where the aims are to have renewable sources provide 12% of the electricity generated in EU-25 Member States by 2010. The targets are nationally differentiated. See Council Directive 2001/77, art. 3, 2001 O.J. (L 283) (EC).

139. Prior to liberalisation of the power supply sector, Denmark ordered the power production companies to make projects regarding offshore wind power. This was based on former article 13 of the

However, such an approach is not compatible with a deregulated power market.

Calling for tenders is a more modern way to ensure sufficient investment in wind turbines.¹⁴⁰ The tender process can target renewable capacity generally or can focus upon a particular technology. In a tender procedure, the primary criterion will often be a call for the lowest price during a certain period. Tendering has been used in China, Denmark, France, Ireland and the UK.¹⁴¹ Denmark utilized the tender process in 2005 and 2006 in regard to two separate offshore wind farms—Horns Rev 2 and Rødsand 2—each for 200 MW.¹⁴² The primary criterion in each call for tenders was the lowest feed-in price.¹⁴³ With regard to the Horns Rev 2 project, the winner of the tender process offered prices of approximately \$9.40 per KWh fixed for 50,000 full-load hours—roughly twelve years of electricity production¹⁴⁴—and approximately \$9.00 per KWh fixed for 50,000 full-load hours—roughly fourteen years of electricity production.¹⁴⁵ When these time periods close, the two wind farms must return to selling their production at market price. Horns Rev 2 will begin operation in 2009, while Rødsand 2 will be commissioned in 2010.¹⁴⁶

After the Rødsand 2 award was initially announced, each member of the winning consortium dropped out of the project.¹⁴⁷ This scenario demonstrated the importance of the legal climate in which tenders are offered. Important legal considerations might include contractual clauses that require the project to be completed within a certain period. The United Kingdom Non-Fossil Fuel Obligation tender system demonstrated additional concerns, as many awarded licenses remained unused due to an economically inefficient low price bid.¹⁴⁸

Physical planning schemes for regions or municipalities have also been used in order to secure sites for wind farms.¹⁴⁹ Planning can be used both to ensure the efficiency of sites selected for wind farms and to avoid unsuitable sites. In order to optimize the outcome of the total investment,

Danish Electricity Supply Act. See MORTENSEN, *supra* note 118, at 230.

140. “Developers of wind farm projects are invited to bid for a limited wind energy capacity in a given period. The companies that bid to supply electricity at the lowest cost win the contracts.” THE FACTS: MARKET DEVELOPMENT, *supra* note 100, at 217.

141. See SUSTAINABLE WORLD ENERGY OUTLOOK, *supra* note 78, at 85.

142. DONG, ET AL., *supra* note 42, at 126.

143. DANISH EXPERIENCES AND SOLUTIONS, *supra* note 82, at 7.

144. “[T]he off shore wind farm at Horns Rev 2 will be able to supply approx 200,000 households with electricity annually, corresponding to approx 2% of the Danish electricity consumption.” DONG, ET AL., *supra* note 42, at 126.

145. *Id.*

146. *Id.*

147. See Danish Energy Auth., Invitation to Tender for a New Offshore Wind Farm at Rodsand, Denmark, <http://www.ens.dk/sw63828.asp> (last visited Mar. 30, 2008).

148. See THE FACTS: MARKET DEVELOPMENT, *supra* note 100, at 217.

149. In Denmark, municipalities are in charge of planning for the allocation of wind farms.

planning efforts should be integrated with considerations regarding the power grid, access to balancing power, and the demand for electricity.¹⁵⁰ Further, wind farm developers should pursue EIAs in the planning phase instead of waiting until a concrete project is proposed. Otherwise, investors may encounter unnecessary delays through the EIA hearing process or from protests from local opposition groups, especially in cases of proposed shore-based wind farm sites.

Offshore planning is often overseen by state or federal authorities. Places like the United Kingdom and Denmark have identified strategic areas for development of wind farms.¹⁵¹ Moreover, studies demonstrate that by “bundling” common offshore cables, offshore infrastructure planning could reduce the impact on the ecosystem and the coastline.¹⁵² In some cases, bundling may save costs as well.¹⁵³

E. Zoning

Local and regional planning efforts known as zoning are widely employed in order to regulate problems regarding potential adverse effects on human life, wildlife, and landscape. Much debate occurs in regard to the appropriate level at which zoning should be created, and different countries operate very different zoning regulations. Often, the local authority is also the zoning authority. In other places, regional authorities have zoning control over rural areas, while some countries prefer zoning regulatory power to rest with national zoning or national call-in authorities.¹⁵⁴

Zoning for wind farms at the local level may not always consider the overall picture. For example, some local and regional zoning efforts have been accused of taking too many local interests into consideration. These local interests may involve neighbouring groups or local aesthetic preservation-groups, pushing for a local stop of new wind farm development. In densely populated areas, neighboring groups may have sufficient political power to stop further development of wind farms.

In Denmark, the municipalities are failing to produce the number of wind turbine sites in their local zoning areas that are needed to fulfil the national goals for new wind turbines. Though Danes generally support wind power, neighboring groups regularly oppose onshore wind farms, and

150. For a discussion concerning local planning and zoning efforts, see *infra* Part V.E.

151. See THE COMMITTEE FOR FUTURE OFFSHORE WIND POWER SITES, DANISH ENERGY AUTHORITY, FUTURE OFFSHORE WIND POWER SITES: 2025 (2007), available at http://www.ens.dk/graphics/Publikationer/Havvindmoeller/Fremtidens_%20havvindm_UKsummeraug07.pdf.

152. EUROPEAN COMM’N, *supra* note 101, at 25.

153. *Id.*

154. According to Danish planning law, the Minister of the Environment has a call-in authority regarding the zoning authority of the municipalities. See DANISH PLANNING ACT, art. 3, para. 4. It has been used in connection with zoning for large test turbines.

local politicians frequently acquiesce in such opposition. Resistance becomes especially significant in the context of very large, land-based wind turbines, and accordingly, local producers and owners of offshore wind turbines have endured significant problems finding sites for onshore placement of test turbines.¹⁵⁵

Local interest in general economic development may also lead to wind farm development in more controversial areas of special national or international interest, impacting issues related to culture, landscape, and natural habitats. Especially in less densely populated regions, landowners' interest in the establishment of wind farms may prevail in the local political decision process. This has been seen in areas of migrating birds and other areas of ecological interest.¹⁵⁶

In areas covered by more than one local authority, zoning can become an impediment to the wind farm development due to conflicts between differing local rules. Thus, a more uniform approach to zoning regulation would simplify the wind farm development process. Furthermore, efforts to preserve flora and fauna might be more effectively implemented if proposed wind farm sites were similarly subject to uniform zoning laws.

VI. BIG IS BEAUTIFUL—AND COSTLY

Generally, investors take advantage of economies of scale. In this regard, wind farms gather energy-generating turbines into groups, thereby cutting costs related to turbine maintenance. Further impacting wind farm efficiency, modern turbine size is growing with regard to capacity, tower height, and the swept area of the rotor blades.¹⁵⁷ These natural incentives to enlarge already large wind farm and turbine sizes pose significant problems when considering the limited availability of existing grids to accommodate vast increases in electricity generated by wind farms. For instance, if wind farm operators and investors had focused greater attention on cautiously and appropriately siting wind turbines across large geographical areas, wind generation might have enjoyed greater consistency and more manageable costs in terms of strengthening grid capacity. Regardless, given present circumstances characterized by the market preference for economies of scale, additional investments in

155. From an economical point of view, offshore wind turbines should be tested onshore due to the high costs of performing work on offshore wind turbines. It may also be beneficial to place one or two offshore turbines—identical to others located offshore and already in use—on land in order to have test turbines for the fixing of design problems or further development.

156. See discussion of adverse bird and ecological impacts, *supra* Part III.A.

157. For wind turbines installed in 2005, the average capacity was 1.2 MW. GREENPEACE INT'L & GLOBAL WIND ENERGY COUNCIL, *supra* note 8, at 43. The largest turbines prepared for the market are around 5 MW. *Id.* In the US, the most common commercial wind turbine installed was 1.5 MW with 2.5 MW turbines used at several sites. See COMM. ON ENVTL. IMPACTS OF WIND ENERGY PROJECTS, *supra* note 22, at 143. Some predict wind turbines to be 10 MW with a rotor diameter of 180 metres in about 2015. See RISØ ENERGY REPORT 4, *supra* note 28, at 18.

planning and grid capacity will likely be required in order to accommodate added wind-generated electricity.

With regard to landscaping, planning law and local community concerns may present barriers to large-scale turbines and farms. In countries like Germany and Denmark, the sites for future onshore development are relatively limited, and as turbine size grows, the transportation of tower and rotor blades on roads becomes more difficult. While these obstacles do not exist at sea, their effects carry particular significance in the context of large onshore wind farms that exist in several places.¹⁵⁸

Large wind farms and turbines demand strong grid connections directly into the transmission system in order to transport the electricity from the generation site to the consumer. Thus, the lack of sufficient transmission capacity can be an obstacle to wind farm development.¹⁵⁹ Small wind turbines may be connected to the local distribution grid as DG, but larger wind farms and larger turbines are often located far from consumers in rural areas. The local grids may not be capable of absorbing all generated electricity, and such electricity surpluses are increasing the costs necessary for grid strengthening. These costs can be covered by the transmission grid owner, the wind turbine owner, the consumers, or the tax payers. Regardless, the following question arises: to what extent will increased investments continue to be economically efficient?

From an economic point of view, developers should consider locations that do not require demanding grid investments. Though electricity transmission lines typically provide a service life of approximately thirty to forty years, the lines are also relatively expensive. Further, local groups and other NGOs frequently oppose implementation of new overhead transmission lines. On top of such economic- and location-oriented concerns, wind farm developers should consider whether to expand the current grid capacity in order to be able to transport even the most rare peak-load production from a wind farm. One possible solution is to give the investors a sales guarantee, ensuring that the transmission system operator will be paid for any production he cannot handle. Such terms enable the transmission system operator to weigh the costs of grid reinforcement against the costs of compensating the wind farm investors in extreme situations.

158. Large onshore wind farms have been established in several U.S. states, including California; New York; Texas; and Washington. See GREENPEACE INT'L & GLOBAL WIND ENERGY COUNCIL, *supra* note 8, at 11.

159. Lack of transmissions capacity has been mentioned as a barrier for the development of wind energy in Western Kansas. See Brian Dietz, *Turbines vs. Tallgrass: Law, Policy, and a New Solution to Conflict Over Wind Farms in the Kansas Flint Hills*, 54 U. KAN. L. REV. 1131,1134–35 (2006).

VII. GOING OFFSHORE

Wind turbines are cheaper to establish onshore than offshore. Thus, it is not surprising that most of the wind power capacity is presently established onshore. In fact, offshore wind production capacity in 2004 accounted for only 1.2% of the total global wind capacity.¹⁶⁰ Nevertheless, the number of offshore wind farms is sure to grow, as available and suitable onshore locations become more scarce or protected.

In going offshore, shallow coastal waters close to developed transmission infrastructure represent the most suitable places to establish offshore wind turbines. Plus, in some areas, shallow waters are found so far from the coast that the wind turbines are hardly visible, depending on their height.¹⁶¹

The sea has no “landowner.” The right to establish wind turbines offshore is based on the sovereignty of coastal states. Indeed, according to the United Nations Convention on the Law of the Sea (“UNCLOS”), coastal states have full sovereignty over the sea within 12 nautical miles from the coastal baseline, an area referred to as territorial sea.¹⁶² Established in 1982, UNCLOS also makes it possible for coastal states to declare an exclusive economic zone (“EEZ”) up to 200 nautical miles from the coastal baseline.¹⁶³ Within the EEZ, the coastal state has the sovereign right to exploit the sea, including wind energy production.¹⁶⁴ Moreover, coastal states retain the exclusive rights to construct or to authorize the use of wind turbines.¹⁶⁵ Thus, appropriate consideration must be given to international navigation and due notice must be provided. The coastal state may also order a safety zone of up to 500 meters from the construction.¹⁶⁶

Europe is now the leader in offshore wind power development, due to the combination of available offshore locations and the growing demand for windy areas in which to site much larger projects not otherwise possible on densely-populated land. For instance, sites are readily available in the relatively shallow coastal waters of Northern Europe. Denmark is presently the frontrunner in offshore wind energy, with eight operating wind farms having a total capacity of 423 MW.¹⁶⁷ The largest wind farm

160. See INT’L ENERGY AGENCY, *supra* note 6, at 20.

161. With present technology wind turbines have to be fixed on a bed, which means lower cost on lower water depths. Floating wind turbines are not yet a commercial option. In Denmark, several possible locations are to be found beyond twenty kilometres from the coast. Especially for 3 MW wind turbines visibility from the coast will be insignificant.

162. United Nations Convention on the Law of the Sea, Dec. 10, 1982, 1833 U.N.T.S. 397, arts. 2–3.

163. *Id.* art. 57.

164. *Id.* art. 56.

165. *Id.*

166. *Id.* art. 60.

167. See Danish Energy Auth., Offshore Windfarms in Denmark, <http://www.ens.dk/sw15562.asp> (last visited Mar. 1, 2008).

has a production capacity of roughly 160 MW with an estimated annual production of 600 GWh.¹⁶⁸ A number of offshore projects have been established in Northern Europe, and even more are projected.¹⁶⁹ Other large projects in Europe and North America are planned for the next five to ten years, though not all have been approved. They include large scale projects in:

Location	MW
Kish Bank, Ireland	250 MW
Solway Firth, UK	180 MW
Horns Rev 2 and Rødsand, Denmark	200 MW each
Kriegers Flak, Sweden	640 MW
Stora Middelgrund, Sweden	860 MW
Borkum West, Germany	1040 MW (first phase 60 MW)
NaiKun Offshore Wind Farm, Canada	1,750 MW (first phase 320 MW)
Cape Wind, USA	468 MW

There are many reasons behind the growing popularity of offshore wind farms. As noted earlier, the visual impact of onshore turbines or even offshore turbines that are highly visible from land may produce fierce opposition from neighbours, local communities, and NGOs. However, cautiously sited offshore turbines will likely encounter fewer protests. Additionally, wind resources increase at greater distances from the shore, becoming stronger and more stable. On the other hand, onshore turbines must contend with the obstructive influence of rough terrain contours—also known as orography—while offshore turbines are free from such constraints. Additionally, the power output of two identical turbines will be approximately 50% greater for a turbine sited offshore than a turbine sited onshore.

However, going to sea is also costly for a host of reasons. Stronger structures are required both for the wind turbine and its substructures. Increased installation costs of wind turbines translate into higher capital investments and operating costs. However, in comparison to onshore

168. *Id.*; see also L.W.M. BEURSKENS & M. DE NOORD, OFFSHORE WIND POWER DEVELOPMENTS: AN OVERVIEW OF REALISATIONS AND PLANNED PROJECTS 10 (2003), available at <http://www.ecn.nl/docs/library/report/2003/c03058.pdf>.

169. See Off- & Nearshore Wind Energy, <http://home.planet.nl/%7Ewindsh/offshore.html> (last visited Mar. 1, 2008).

turbines, the amount of electricity generated by offshore wind farms is greater due to higher and more consistent wind speeds.

VIII. CONCLUSIONS

Wind power is currently contributing a fairly small amount to total global energy consumption.¹⁷⁰ A number of factors will determine the extent to which wind power may become a staple source of future global energy supplies. Different scenarios have shown widely disparate development areas for the penetration of wind energy within electricity supply. A conservative view indicates that wind power supply will make up as little as 6.6% of global electricity production in 2050.¹⁷¹ In the moderate and advanced scenarios, penetration would comprise as much as 15.6% and 29.1%, respectively.¹⁷² Under any circumstances, the present growth in electricity production and consumption means that it will be many years before wind energy constitutes a major part of the world's energy consumption. However, in certain parts of the world—for instance, in certain EU countries—wind power is already a vital contributor to the energy supply. In these countries, of the share of overall electricity production occupied by wind energy will continue to grow, aided by legislative and regulatory policies intended to increase renewable energy production.

Studies indicate that sufficient wind resources will be available, even if consumption continues to grow.¹⁷³ However, onshore locations upon which to site wind farms may grow increasingly rare, given the various aesthetic and ecological concerns implicated by siting turbines onshore. In turn, this factor will likely impact the cost of transmission grid investments.

As the competition to deliver abundant environmentally sound and affordable energy continues to intensify, it is impossible to predict the one technology that will prevail. Every time installed capacity doubles, the cost of wind power per KWh seems to fall by approximately 15%, and with stronger wind, the cost falls even more.¹⁷⁴ As a result, wind power stands strong in competition with other renewable energy technologies.¹⁷⁵ Depending on how balancing and pollution costs are calculated, wind

170. The global primary energy system is mainly based on oil, gas, and coal (80.3%). Renewable combustibles and waste account for 12%, nuclear power 6.5%, and hydraulic power 2.2%. Other renewable energy sources such as wind, solar, and geothermal only accounts for 0.5%. Even among the renewable energy supply, wind power accounted only for 0.5% in 2004. *See* INT'L ENERGY AGENCY, *supra* note 6, at 3. The figures are from 2004.

171. GREENPEACE INT'L & GLOBAL WIND ENERGY COUNCIL, *supra* note 8, at 38.

172. *Id.*

173. One 1994 study suggested that “the world's wind resources have the capacity to generate 53,000 [terawatt hours] of electricity per year.” *Id.* at 23. Since then, wind turbine technology has improved.

174. RISØ ENERGY REPORT 4, *supra* note 28, at 53.

175. *Id.*

power appears to be growing more competitive in relation to fossil fuel technologies. Further, the volatility of fossil fuel prices and the risk of oil and gas supply disruptions are issues that favor wind power.¹⁷⁶

Without a doubt, the future will result in more efficient wind turbines. In order to succeed, wind power needs to be able to at least compete with other renewable technologies. More battles between interest groups will occur. Energy companies, wind turbine producers, land owners, and climate change-orientated environmentalists will argue for the expansion of wind farms.¹⁷⁷ Depending on the site, these proponents may be met by opposition from neighboring groups, ecologists, and aesthetic preservation-orientated environmentalists. Of course, in many parts of the world, such opposition may be managed by sending wind farms offshore. However, offshore wind farms are still few in number and large offshore wind farms are young in age. Therefore, it is still premature to judge their outcome and impact.

The Achilles' heel of the wind industry remains the storage of electricity produced at times of insufficient demand. Improvements in converted electricity storage technology may remove or limit this disadvantage. Furthermore, advancements in end-use technologies would allow system operators to regulate demand curves by switching on and off non-urgent energy users during periods of peak demand or peak wind power production. At present, wind power is an operational technology, and even large amounts can be integrated into normal electricity grid systems. However, wind turbine technology seems to be succeeding only because of incentives and policies specifically set up to provide necessary promotion of technical innovation.¹⁷⁸

176. THE FACTS: THE ENVIRONMENT, *supra* note 37, at 157.

177. For instance, farmers stand to generate a potentially substantial income from leasing small portions of their overall farmland to wind farm operators.

178. See RISØ ENERGY REPORT 4, *supra* note 28, at 11.