Technology Action Plan

WIND ENERGY TECHNOLOGIES

MAJOR ECONOMIES FORUM ON ENERGY AND CLIMATE

DECEMBER 2009

Technology Action Plan: Wind Energy

Report to the Major Economies Forum on Energy and Climate

Prepared by Germany, Spain, & Denmark
in consultation with MEF Partners

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PREFACE

The Leaders of the 17 partners[1] of the Major Economies Forum on Energy and Climate (MEF) agreed on 9 July 2009 that moving to a low-carbon economy provides an opportunity to promote continued economic growth and sustainable development as part of a vigorous response to the danger posed by climate change. They identified an urgent need for development and deployment of transformational clean energy technologies, and established the Global Partnership to drive such low-carbon, climate friendly technologies.

Plans were created to stimulate efforts among interested countries to advance actions on technologies including advanced vehicles; bioenergy; carbon capture, use, and storage; buildings sector energy efficiency; industrial sector energy efficiency; high-efficiency, low-emissions coal; marine energy; smart grids; solar energy; and wind energy. These plans include a menu of opportunities for individual and collective action that may be undertaken voluntarily by interested countries, in accordance with national circumstances. Further actions may be identified in support of these plans in the future.

[1] Australia, Brazil, Canada, China, the European Union, France, Germany, India, Indonesia, Italy, Japan, Korea, Mexico, Russia, South Africa, the United Kingdom, and the United States. The authors of the *Technology Action Plan: Wind Energy* would like to express their gratitude to the experts of the MEF countries and those of the IEA. This plan benefited significantly from their expertise.

OVERVIEW

For more than 3,500 years, wind turbines have supplied mankind with power. In the context of the transition towards a low carbon economy, wind power has the potential to help reduce greenhouse gas (GHG) emissions significantly and become a major modern and sustainable energy source. Wind power is free, inexhaustible, and secure. Wind turbine operation needs no fuel, emits no carbon dioxide (CO_2) emissions or residues, can be installed quickly (once permits are obtained), and allows total site restoration when decommissioned.

The advantage of wind technology is that it is ready to be deployed on a massive scale at reasonable low costs. Wind power is a mature technology that has already achieved competitiveness on land in circumstances where the cost of carbon is reflected to some extent and where the wind resource is of high quality and is close to overall competitiveness with conventional electricity generation. Costs are expected be further reduced by massive, policy-driven deployment, which allows for increasing market pull, technology progress and economies of scale. Support costs are offset by the external costs of inaction, including environmental, climate change and healthcare costs. Additional benefits that result from investing in wind technology include long-term energy security, avoided costs of energy imports, economic growth and new jobs in dynamic renewable energy markets, spillover innovation effects in the whole economy, and know-how transfer and investments in developing markets.

Countries are currently employing a range of policies and practices to overcome barriers for wind development and deployment.

HIGHLIGHTS OF THE WIND ENERGY TECHNOLOGY ACTION PLAN

1. GHG Emissions and Mitigation Potential
   - Fossil fuel-based power generation accounts for 41% of global energy-related CO_2 emissions, and its emissions are expected to increase by almost 50% from now to 2030,[2] considering business-as-usual policies. Wind power will help to reduce GHG emissions in the power sector.
   - Rapid wind deployment is required to cost-effectively meet abatement targets. The IEA estimates in its BLUE Map (2008) scenario that wind could contribute 5,200 terawatt-hours (TWh) of electricity generation per year in 2050, corresponding to a 12% share of global electricity generation. Thereby, about 3.3 gigatonnes (Gt) of CO_2 emission reductions could be achieved in 2050. The wind industry expects figures that are nearly twice as high. In 2020, wind energy could contribute approximately about 1 Gt of the additional CO_2 emission reductions needed by 2020 to remain on track towards the 2°C target, according to the IEA BLUE scenario.

2. Development and Deployment: Barriers and Best Practice Policies
   - Barriers to the development and deployment of wind technologies include economic, technological, grid and system integration, and attitudinal hurdles.

[2] In an International Energy Agency (IEA) reference case under business-as-usual policies.

- Best practice policies to foster the growth of wind power aim to increase demand; improve consumer confidence and public awareness; enable grid access and system integration; provide sufficient and affordable financing; improve planning and reduce administrative burdens; ensure legal certainty; support technology research, development, and demonstration; and expand technology cooperation.

3. Actions to Accelerate Development and Deployment
   - Supporting innovation:
     - Follow a combined approach of RD&D and consequent deployment policy to benefit from cost reductions due to technology progress along the learning curve and economies of scale effects, as well as from spillover effects between research and mass-scale testing.
     - Pursue a balanced set of instruments that ensure support of new, innovative concepts and all promising renewables technologies for a broad technology basket for future energy security.
     - Increase and coordinate public sector investments in RD&D in line with the L'Aquila declaration, while recognizing the importance of private investment, public-private partnerships, and international cooperation, including regional innovation centers.
   - Accelerating deployment:
     - Set ambitious concerted targets and establish reliable support schemes to provide long-term investment security for wind energy; formulate these targets as minimum targets to achieve sustainable market development without -stop-and-goll cycles.
     - Internalize external costs for all energy technologies in order to enhance demand-pull technology progress.
     - Ensure sufficient grid capacity through extending and upgrading the grid and/or optimized grid operation, and through facilitating technologies and concepts that enable system and market integration of high shares of wind electricity.
     - Promote strategic dialogue with investors to access untapped financing sources and establish public-private partnerships to accelerate investment in developing and emerging countries.
     - Follow a holistic approach in planning activities to integrate renewable energy into the overall system and balance rival interests.
   - Facilitating information sharing:
     - Support transparent consumer information on the effect that their green power purchase agreements have on the deployment of additional renewables installations.
     - Develop jointly a global wind atlas with all relevant information to attract cross border investments.
     - Make information accessible and facilitate know-how transfer by training, workshops, and Internet libraries/databases.
     - Support international institutions, such as IRENA, that focus on capacity building in cooperation with existing institutions (e.g., REEEP).

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1. WIND ENERGY: GHG EMISSIONS PRODUCTION AND MITIGATION POTENTIAL

GHG Emissions from the Power Sector

The power sector's current reliance on fossil fuels and rapid projected growth raise grave concern over the impact of sector emissions on climate and the environment. If business continues as usual, the power sector is projected to account for 44% of total global emissions in 2050. Today, power generation accounts for 41% of global energy-related CO_2 emissions, with such emissions projected to increase by almost 50% by 2030 (IEA 2009d).[3] The burning of fossil fuels in member countries of the Major Economies Forum (MEF) accounts for 78.8% of the global CO_2 emissions (with wide variance among member countries) (IEA 2009a).

Wind technology offers an opportunity to produce clean electricity because wind turbine operation does not need any fuel. Only a small amount of carbon dioxide (CO_2) is generated by producing the technology and by enhancing the necessary transmission infrastructure, which would occur with the production and integration of other electricity technologies as well.

Wind power, therefore, holds great promise for helping to reduce the greenhouse gases emitted by the power sector.

Mitigation Potential for Wind Energy

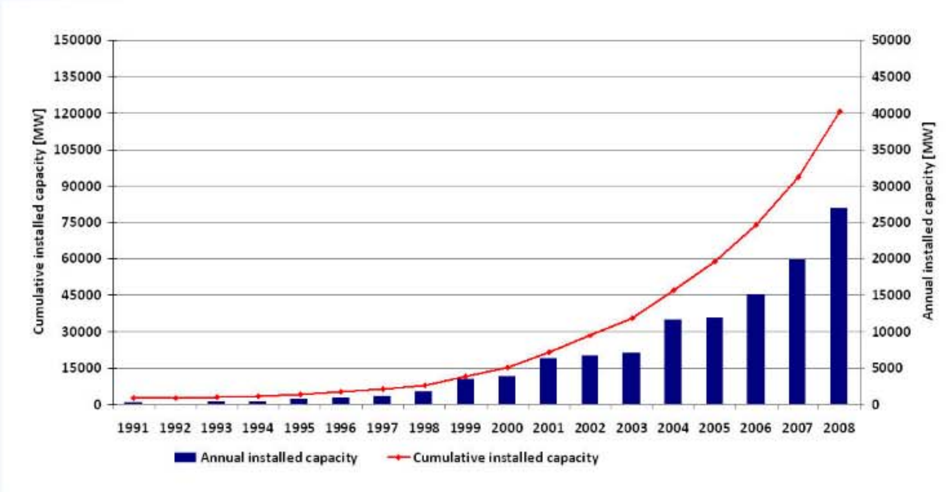
Market Development: Current Status

Wind technology markets have experienced dynamic growth. During 2008, 27 GW of additional wind capacity was installed worldwide, resulting in a cumulative global wind capacity of 121 GW (IEA 2009c; Figure 1). This corresponds to a roughly tenfold increase in wind power capacity in the last 10 years and a 60-fold increase over the last two decades. This global installed capacity is estimated to generate about 260 TWh of electricity annually (GWEC 2008a), which equals 1.0-1.5% of global electricity production. To put this figure into perspective, the currently installed wind capacity worldwide can already provide electricity to approximately 90 million households[4] and reduce CO_2 emissions annually by 163 megatonnes (Mt) (IEA 2009c).

[3] Increase projected in a Reference case under business-as-usual policies.

[4] Each consuming 3,000 kWh per year

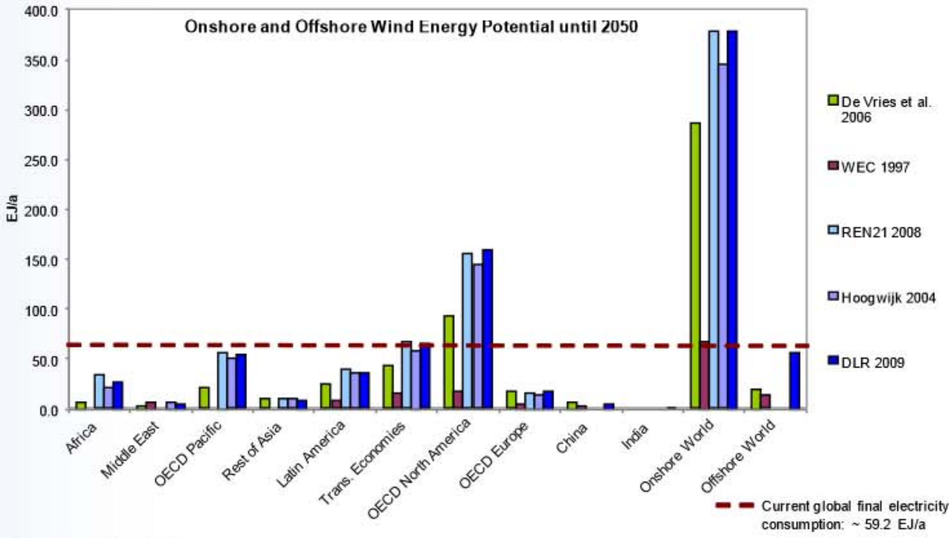
FIGURE 1. ANNUAL INSTALLED GLOBAL WIND CAPACITY, 1991 - 2008



Source: IEA 2009c, modified

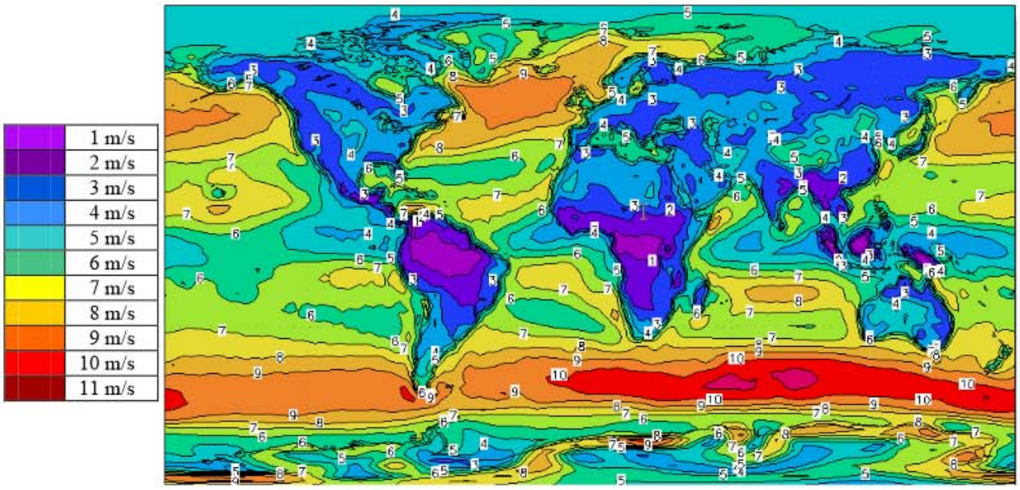
Future growth rates continue to look very promising. The estimated global technical potential for wind energy (i.e., the energy that could effectively be harnessed given current technological progress) is seven times higher than global electricity demand (DLR 2009, Greenpeace 2008). Significant wind energy potential is still untapped. Today, only five leading markets (United States, Germany, Spain, China, and India) account for approximately 75% of the total installed wind capacity (IEA Wind 2009). This global installed capacity represents only about 0.2% of the estimated technical potential for wind (DLR 2009, Greenpeace 2008). On land, only a tiny fraction of the areas with highest wind potential have been exploited so far (IEA 2008c). In addition, the offshore market is just about to take off. Moreover, excellent wind resources are spread throughout the world (Figures 2 and 3).

FIGURE 2. TECHNICAL POTENTIAL FOR ON- AND OFFSHORE WIND ELECTRICITY FOR DIFFERENT REGIONS UNTIL 2050



Source: DLR 2009

FIGURE 3. OVERVIEW OF WORLD WIDE WIND SPEEDS[5]



Source: Risø National Laboratory for Sustainable Energy 2005

Scenarios Estimates: Market Potential and Emissions Reductions[6]

As shown in Table 1, wind could provide 5,200 terawatt hours (TWh/a) or 12% of global electricity in 2050 according to the IEA BLUE scenario (IEA 2008c; see also Figure 4). Such growth in wind power would reduce global CO_2 emissions by 3.26 gigatonnes (Gt) per year in 2050.

In its estimates, the wind industry projects far quicker growth in wind power with an attendant acceleration in CO_2 emissions reductions. Industry projections suggest that wind power could provide 12% of global electricity by *2020* (i.e., 30 years earlier than the BLUE scenario projects), reducing CO_2 emissions by 1.59 Gt.[7]]

CITED CARBON REDUCTION SCENARIOS

This document refers to several CO_2 emissions reduction scenarios, which are summarized briefly below.

The International Energy Agency's Energy Technology Perspectives 2008 (IEA 2008c) set forth several scenarios for energy-related CO_2 emissions through 2050: the Baseline (business as usual) scenario puts the world on track for a global temperature increase of around 6ºC, which is not sustainable, while a set of BLUE scenarios outline how CO_2 emissions could be reduced to 50% below 2005 levels by 2050. The BLUE scenarios are consistent with stabilizing CO_2 concentrations at 450 ppm, implying a 2ºC temperature rise. To attain this, emissions would need to be lowered from 41 Gt to 26 Gt in 2030—a 15 Gt reduction relative to the Baseline scenario.

The Global Wind Energy Council projects includes in its -GWEC Moderate‖ scenario all policy measures to support renewable energy that are either already enacted or in the planning stages around the world (GWEC 2008b). The -GWEC Advanced‖ scenario is based on more ambitious support policies.

Nicholas Stern has provided further input on scenarios, in particular, presenting a scenario (Stern 2009) in which a target of 44 Gt of CO_2 equivalent (CO_2e) emissions should be achieved by 2020 to keep the world on the trajectory for the 2°C target.

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5 Mean wind speed in ms^{-1} at 10 meters above ground level for the period 1976-95, according to the NCEP/NCAR reanalysis data set (more detailed and reliable information is usually required for wind resource assessments).

6 Long-term projections for the potential of wind power to mitigate CO_2 emissions are necessarily tied to defined scenarios. Scenarios are, by their nature, subject to a number of uncertainties and assumptions. Nevertheless, as existing scenarios have been revised, the share of wind energy has tended to increase rather than decrease, reflecting improved support policies for wind energy.

7 The IEA estimates are also lower than those of industry because the IEA takes into account the competition of renewables with other energy technologies such as nuclear or CCS, whereas the industry projections are based on the assumption that renewables will be prioritized to the extent they can be deployed at appropriate costs and thus, will not be hindered by conventional energy technologies (IEA 2008e, GWEC 2008b).

Table 1. Scenario of Wind Capacity, Electricity Production and CO_2 Savings Until 2050

Year	Capacity Installed (GW up to about)		Electricity Production (TWh/a □)		Share in Global Electricity Production (□)		CO_2 Abatement (Gt □)[8]	
	IEA (BLUE/ Wind roadmap)	Industry (GWEC 2008a)	IEA (BLUE/ Wind roadmap)	Industry (GWEC 2008a)	IEA (ETP BLUE)	Industry (GWEC 2008a)	IEA (IEA and calculation based on IEA)	Industry (calculation based on IEA)
2020	671	1,080	1,754	2,650	6%	12%	1.18[9]	1.59[10]
2030	1,000	2,400	2,700	5,400	9%	24%	1.50	3.10[11]
2050	2,000	3,500	5,200	9,100	12%	30%	3.26	4.60[12]

Source: IEA 2008c and GWEC 2008a

Both, the IEA and industry estimate that, in 2020, the wind energy contribution to global CO_2 abatement will be about 1.0 Gt over the IEA reference scenario.[13] This means that wind would provide about 26% of the 3.8 Gt of additional CO_2 emissions reductions, beyond current efforts, that the IEA recently stated[14] were needed by 2020 to remain on track with the IEA Blue Scenario and the 2°C target. It would similarly provide about 20% of the 5 Gt in additional CO_2e emission reductions needed to meet the ―Stern 44 Gt scenario‖ for 2020 (Stern 2009).[15]

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8 Estimates based on TWh estimates in the IEA ETP Blue and Industry scenarios. With respect to CO_2 abatement, figures are based on IEA data on the global average of energy related CO_2 emissions in 2020, 2030 and 2050 (IEA 2009c and IEA 2008c). For 2020, on average globally, one generated MWh of wind electricity saves about 600 kg of CO_2 (dividing the current CO_2 emissions from estimated conventional power generation [=11,896 Mt] by the generated electricity from the estimated conventional power mix [coal, oil, gas, nuclear and hydropower =19,256 TWh, IEA 2009c]). Until 2050, conventional power plants will become more efficient, and the mix of conventional power generation will change. As a result, one generated MWh of wind electricity will, on average globally, save about 500 kg of CO_2 by 2050 (IEA 2009c and IEA 2008c). Please note that the regional mix of power generation may deviate from these average values and may consequently lead to lower or higher regional CO_2 savings.

9 IEA figures, email correspondence from 27 October 2009.

10 Industry estimates 1.59 Gt as well (GWEC 2008a).

11 Industry estimates are even higher: 3.2 Gt (GWEC 2008a).

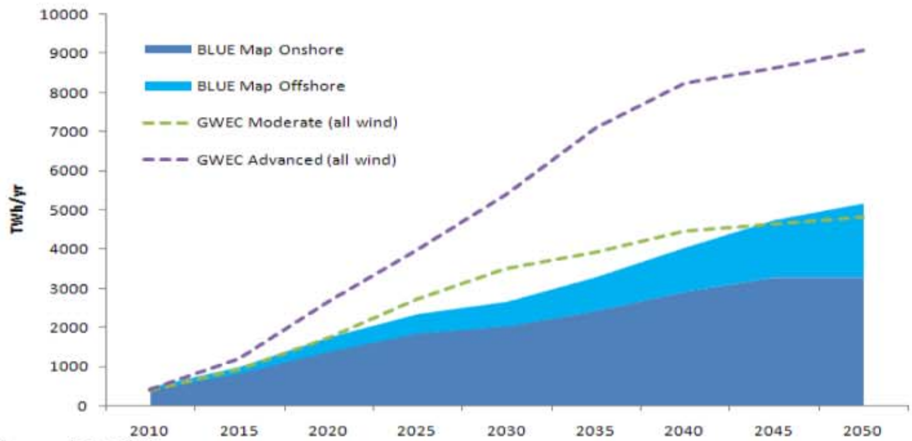
12 Industry estimates are even higher: 5.45 Gt (GWEC 2008a).

13 In the IEA reference scenario, wind power contributes 1,010 TWh per year in 2020 (IEA 2009c), while in the more optimistic industry scenario wind power contributes 2,650 TWh per year in 2020 (GWEC 2008b), which represents about 1.59 Gt in CO_2 emissions reductions. The difference of 1,640 TWh per year corresponds to a CO_2 emission reduction of about 1.0 Gt in 2020. The forthcoming IEA wind roadmap calculates, in its regional map, a total of 890 Mt CO_2 in additional abatement over the IEA reference scenario in 2020.

14 At the MEF meeting in London in October 2009.

15 In 2020, global energy-related CO_2 emissions should be around 30.7 Gt in the IEA BLUE scenario instead of the estimated 34.5 Gt in the IEAWEO 2009 reference scenario in order to comply with the 2°C target (IEA 2009c). The additional 1.0 Gt of CO_2 savings in more optimistic scenarios for wind energy in 2020 represent about 26% of this 3.8 Gt difference. In the Stern ―44 Gt scenario,‖ the world's absolute CO_2e emissions should be reduced to 44 Gt in 2020 to remain on track to the 2°C target. However, current efforts will likely only reduce emissions to 49 Gt in 2020. Therefore, additional efforts are needed to reduce an additional 5 Gt of CO_2e emissions by 2020.

FIGURE 4. WIND ELECTRICITY PRODUCTION IN IEA BLUE MAP AND INDUSTRY ANALYSIS



Source: IEA 2009c

Achieving the Potential: Wind Technology Development and Deployment

To achieve the enormous wind power potential, a combined approach of successive RD&D and mass-scale deployment policy is needed in order to make use of synergetic effects between development, improved technology efficiency along the learning curves and economies of scale.

IEA's analysis of the Global Gaps in Clean Energy Research, Development, and Demonstration (GCERD, IEA 2009b) finds a global annual spending gap of approximately US$1 billion to meet 2050 targets.

The advantage of wind technology, at least on land, is that it is a mature technology which is close to competitiveness with conventional power generation. This offers the opportunity to achieve deployment-driven innovation and technology progress at reasonable low costs. Today's levelized wind electricity generation costs on land are estimated by the IEA to be in a range between US$0.06–$0.13/kWh depending, in particular, on the wind resource (IEA 2008c).

Wind energy has a 7% technology learning rate for investment costs. This means that, for every doubling of global installed wind capacity, investment costs are reduced by 7%. This is a better rate than for several other technologies (e.g., the learning rates for integrated gasification combined cycle and CCS technologies are estimated at 3%) (IEA 2008c, IEA 2009c). In addition, learning rates for electricity generation costs have even been higher in the past (between 18%–32%, IEA 2008c). Thus, substantive deployment policy today would likely drive technology competitiveness and demand-pull, leading to less dependence on support schemes and lower support costs tomorrow.

The IEA estimates onshore wind electricity generation costs will range between US$0.05-0.06/kWh in 2015 and that offshore wind energy will be competitive with conventional electricity generation between 2025 and 2035 (IEA 2008c).

When considering costs for support policies, a system-wide approach is needed that takes into account effects for the whole economy as well as the relative, long-term, economic costs of inaction. Support costs are offset by the external costs of conventional power generation, including healthcare and environmental costs and climate change (Stern 2006). Additional benefits that accrue from investments in wind technology include long-term energy security, avoided costs for energy imports, economic growth and new jobs in dynamic renewable energy markets, spillover innovation effects in the whole economy, know-how transfer and investment in developing markets, and improved energy access in remote areas.

Trends and Emerging Technologies

Today, large, three-bladed megawatt turbines with a rated power of 1-3 MW are standard. Highly skilled staff and advanced operations and maintenance (O&M) concepts have improved the reliability of modern wind turbines allowing them to operate on land with a technical availability up to 97% (meaning that up to 97% of the time, they are ready for use and do not suffer from technical faults).

Despite remarkable technology progress, wind technology development remains dynamic. Further improvement is required to drive down costs and to improve technology efficiency, particularly for more difficult wind sites with complex terrain (e.g., cold climate, offshore, deserts). The integration of large amounts of fluctuating wind power into electric grids, for example, poses one major challenge for mass-scale wind deployment and power management technology.

Several major thrusts in wind power technology development include the following:

- Increasing turbine size and raising hub heights (7-10 MW concepts)
- Advanced real-time online monitoring of turbines and remote intervention capabilities or self-diagnostic systems
- Improvements in wind assessment, energy yield prediction and wind forecasting
- New and improved grid technology and storage technology
- Improved network-support technology for small wind turbines
- New turbine design concepts (e.g., floating turbines for deep offshore applications, vertical axis rotors for small turbines)

All of these advances will require sustained investment and mass-scale deployment enhanced by a range of supportive policies, incentives, and other mechanisms.

Appendix A provides some perspectives and specifications, historical and forward-looking, on wind power potentials, the development of wind technology, and related technology markets, costs and economics.

2. Development and Deployment: Barriers and Best Practice Policies

The costs of generating energy from wind technologies have decreased over the years, largely due to major technological improvements and significant economies of scale. In recent years, the latter has become more important□ for onshore wind in particular□ as incremental cost reductions driven by technology development slow. Wind energy has already achieved competitiveness in circumstances where the cost of carbon is reflected to some extent and where high quality wind resources are available and is close to overall competitiveness with conventional electricity generation. Despite the technology progress already achieved, wind energy must still overcome a range of hurdles in order to fulfill its full potential to help reduce global CO_2 emissions.

A brief overview of the main barriers facing wind power provides a useful context for examining some of the best practices and policies currently being used to foster development and deployment around the globe. Understanding the strengths and weaknesses of these policies can facilitate the process of selecting and tailoring supportive policies and practices to maximize effectiveness taking into account national circumstances.

Barriers to Development and Deployment

Wind power faces economic, technological, systems integration, and attitudinal barriers to more widespread deployment around the globe. Strong markets are needed to stimulate the required investment in technology development and deployment, yet further technology advances are needed to increase market demand. The lack of sufficient market pull for wind energy, due to its comparatively higher costs, creates the need for policy-driven support to bridge this cost disadvantage.

Barriers to Development and Deployment of Wind Energy Technologies		
Economic	Inadequate market pull	□ Failure to reflect external costs in energy prices, in particular □ Lack of an effective global carbon market □ Limited consumer influence on additional wind technology deployment in green power purchase agreements □ Lack of consumer awareness of benefits of wind power
	Investment risks Project funding	□ Lack of demand due to higher electricity generation costs □ Long and unpredictable planning and permitting procedures □ Inadequate know-how on wind assessment □ Lack of transparency in international funding schemes □ Restricted access to project funding in developing countries
Technological	Technology needs	□ Lack of technology-specific support schemes □ Lack of expertise, particularly on advance operations and maintenance (O&M) strategies □ Inadequate transfer of knowledge to developing regions

Barriers to Development and Deployment of Wind Energy Technologies		
Technological (continued)	Technology costs	□ Need for further improved technological efficiency and further reduced technology manufacturing costs □ Inadequate demonstration test sites for emerging technologies
Grid, System and Market Integration	Integration of large shares of wind power into the grid and the energy system	□ Need for guaranteed grid connection and priority or guaranteed dispatch □ Need for increased grid capacity (lack of infrastructure or poor grid operation) □ Need for system and market integration for growing shares of wind power (e.g., wind power curtailment, demand-side management, balancing power plants, storage technology, joining adjacent markets)
Attitudinal	Public attitude	□ Public resistance to wind farms and the NIMBY syndrome
	Public confidence	□ Lack of adequate consumer information and confidence in reporting on source of power

Current Best Practice Policies

Accelerating the development and deployment of wind power will require that appropriate frameworks are established to reduce market barriers and attract private investment in the research, development, demonstration, and deployment of wind technologies on a massive scale. A comprehensive approach, integrating renewable energy policy strategies and a balanced set of supportive instruments is proving to be most effective.

The following eight principles have been identified as key drivers of successful wind energy policies:

- Support stronger demand-pull for wind energy
- Grid access and system integration
- Sufficient, affordable financing
- R&D and demonstration projects
- Improved planning of wind plants and transmission infrastructure, and reduced administrative burden
- Legal certainty
- Sufficient labor and intellectual resources
- Technology cooperation

Current best practice policies to address of each of these principals are discussed in the remainder of this chapter. Where appropriate, existing gaps and strategies for addressing those gaps are also identified. Appendix B provides further detail and context for several items in the Chapter.

Support Stronger Demand-Pull for Wind Energy

Today, the most successful approaches to accelerate the deployment of wind energy involve the establishment of a balanced set of technology-specific support measures that will help generate sustained demand-pull. Collectively, these measures can establish enabling frameworks conditions, bring wind technology closer to cost-competitiveness with conventional technologies, and ensure broad technology progress, which is increasingly driven by demand-pull and which will help to ensure a broad technology mix for future energy security. Such support measures should include a balanced set of instruments that accomplish the following:

- Internalize the external costs for all forms of energy production
- Establish reliable and predictable, technology-specific support schemes
- Improve conditions for marketing green electricity

The following table summarizes current approaches in use by various countries.

SUPPORT STRONGER DEMAND-PULL FOR WIND ENERGY		
Policy	Description	Examples / Details
Internalization of external costs: Wind energy would be more competitive if external costs (particularly climate change costs) were more accurately reflected in the costs of conventional power generation. External costs are incurred by society but their extent is generally not included in cost calculations because they are often hard to quantify. Thus, internalizing external costs of all forms of energy production would provide a more level playing field.		
Carbon tax	A market-based instrument to reduce emissions. Many EU member states impose energy taxes, some including a levy on the CO_2 content (carbon tax).	Denmark and Sweden use a carbon tax, and France is considering it. The EU is discussing the introduction of CO_2 content as part of a revision to its energy taxation directive. To avoid distortion of markets by overlapping instruments that set a price on CO_2, energy use that falls within the scope of the European Emission Trading Scheme may be excluded from the CO_2-related tax.
Cap and trade scheme	Places mandatory cap on emissions yet provides sources flexibility in how they comply. Successful cap and trade programs reward innovation, efficiency, and early action and provide strict environmental accountability without inhibiting economic growth.	Since 2005, the European emissions trading system (ETS) has placed a cap on more than 40% of CO_2 emissions and limited the quantity of tradable emissions allowances, with the intent to create a reliable price signal for CO_2 emissions. In 2013, a single EU-wide cap will replace the current system of 27 national caps. The cap on emission allowances for covered sectors (power generation, energy-intensive industry, and as of 2012, aviation) will then be reduced each year after 2013 (allowances in 2020 will be 21% below 2005 levels). Businesses, instead of receiving allowances at no cost, will have to buy a progressively higher share at auction. By 2013, around 50% of all allowances will be auctioned, with the goal of 100% by 2027.
	Gaps: Emission cap and trade schemes and/or carbon taxes alone cannot provide sufficient support for the accelerated deployment of renewables. Energy-intensive sectors facing challenges in global competitiveness would likely continue to receive many or all of their allowances at zero cost as long as they use state-of-the-art technology. A global carbon market would improve cap-and-trade effectiveness in the long run. Cap and trade also does not provide the technology-specific support needed to ensure that each promising technology is developed to its full potential as part of a balanced portfolio of energy technology options. A variety of policy instruments is needed.	

<table>
<tr><th colspan="3">SUPPORT STRONGER DEMAND-PULL FOR WIND ENERGY (CONT.)</th></tr>
<tr><th>Policy</th><th>Description</th><th>Examples / Details</th></tr>
<tr><td colspan="3">Renewables energy targets and support schemes: Best practice examples and IEA analysis (IEA 2008c) suggest that an effective renewable support scheme should reflect the following principles:
□ Predictable, reliable support of sufficient duration for re-financing of investment conditions
□ Technology-specific support that accounts for different stages of technology development and the need for a balanced technology portfolio for future energy security
□ Transitional incentives that decrease over time to provide incentives for further cost reductions
□ Incentives for energy produced, as opposed to capacity installed
□ Favorable grid access conditions
□ Grid and market integration of large shares of fluctuating wind power to ensure system reliability and overall cost-efficiency
□ Support that is uncomplicated, with low administrative barriers and easy to implement to attract private investment
□ Efficient interaction with other schemes and other national policy frameworks.</td></tr>
<tr><td>Renewables targets</td><td>Various countries have set targets for deploying renewable energy at a national or regional level. This provides a clear signal to private investors regarding the reliability of the countries' support policies. Different targets may be set by sector and by resource.</td><td>At least 73 countries have set renewable energy targets (REN21 2009). The European Union has adopted a target of 20% of final energy consumption in 2020. This target is distributed among EU Member States. For example, Spain has a target for final energy consumption of 20%; Germany, 18%; Denmark, 30%; Sweden, 49%; France, 23%; and Italy, 17%. The U.S. plans to double its renewable capacity in three years. Germany and Australia have targets for renewable energy in electric power (30% and 45 TWh by 2020, respectively).
Several countries have wind specific targets. China has a wind sector target of 10 GW by 2010 and is considering increasing the 2020 target from 30 GW to 100 GW. The official government target for wind power in Japan by 2010 is 3,000 MW. Kenya has a 350 MW target of wind and biomass.</td></tr>
<tr><td>Support schemes</td><td>Support schemes can generally be divided into price-based mechanisms and quantity-based mechanisms, each with different advantages and disadvantages. They may be combined in various ways.</td><td>Price-based mechanisms include:
□ Feed-in tariffs and premiums
□ Tax and investment incentives
Quantity-based mechanisms include:
□ Quota systems / tradable green certificates (TGCs)
□ Tender schemes</td></tr>
</table>

SUPPORT STRONGER DEMAND-PULL FOR WIND ENERGY (CONT.)		
Policy	Description	Examples / Details
Price-based mechanisms		
Feed-in tariffs	Feed-in tariffs may guarantee a fixed, technology-specific tariff to the operator of a renewable facility over a long period (e.g., 20 years). The grid operator is usually required to purchase all power produced and pay the tariff; the cost is absorbed by the consumers. These schemes are often complemented by soft loans or even additional investment subsidies. Distinct tariffs may be used for different regions or technologies.	Four of the five countries with the highest policy effectiveness in developing wind energy (i.e., Spain, Denmark, Germany, and Portugal) primarily use feed-in schemes (IEA 2008c). At least 63 countries, states, and provinces have applied feed-in schemes, including Turkey, Brazil, and China. If well-designed, they provide effective, cost-efficient and technology-specific support that is transparent and predictable over long periods. This leads to better access to financing and lower interest rates for loans, attracting diverse market players, including small installations by final consumers. Well-designed feed-in schemes tie the remuneration costs to the technology-specific costs of production, thus avoiding excessive market revenues for producers that would have to be paid by the support scheme and thus, consumers. In the current economic crisis, feed-in schemes have provided important backing for the renewables market.
	Gaps: Price determination is not market based. Thus, feed-in tariffs may not progressively employ market forces nor sufficiently provide incentives for further innovation and cost-efficiency. Moreover, fixed feed-in tariffs provide fewer incentives for matching supply and demand to promote system integration; operators do not sell electricity on the market and thus, are not forced to track load curves.	Potential Solutions: To overcome potential drawbacks, feed-in tariffs should be continuously evaluated and decreased as appropriate as, for example, is the approach in the German Renewable Energy Source Act. An appropriate incentive should also be established for the direct marketing of renewable energy. To improve system integration, incentives should be provided for the installation of storage capacity, the provision of firm and dispatchable electricity, and for system (ancillary) services.
Feed-in premiums	This variation of feed-in tariffs intends to improve the integration of renewables into the market by letting operators sell renewable electricity on the wholesale market without specifying it as renewable and receive an additional bonus (premium). This can provide incentives for renewable operators to follow the load curve.	In Denmark, new on- and offshore wind power receives, on top of the spot-market price, a premium of 25 øre/kWh for the first 22,000 full load hours and additional 2.3 øre/kWh for the entire lifetime of the turbine to compensate for the cost of balancing, etc. Apart from this, special tenders for offshore wind farms are applied. In previous tenders, the Horns Rev II wind park (200 MW) and the Rødsand II wind park (200 MW) ended at fixed feed in tariffs of 51.8 øre/kWh and 62.9 øre/kWh, respectively, after 50,000 full load hours. Feed-in-premiums are also applied in Canada and the Netherlands. Spain introduced an optional premium, which lets the operator decide between a fixed tariff and a premium.

Support Stronger Demand-Pull for Wind Energy (cont.)		
Policy	Description	Examples / Details
Price-based mechanisms for solar power (cont.)		
Tax and investment incentives	Tax credits attract private investors as the credits can be sold on the market, allowing private investors to reduce their taxes by investing in renewable technologies. They are particularly useful in the early stage of market development to foster demonstration projects. They are also often used as supplementary support to address upfront costs.	Investment incentive programs are the main strategy pursued in several countries, including Japan, Finland, and Mexico. In the United States, wind power producers benefit from federal tax incentives in the form of a Business Investment Tax Credit (ITC) or a 10-year Production Tax Credit (PTC), which function similarly to a feed-in scheme (IEA 2008b). At the state level financial incentives are often combined with a quota obligation system. According the IEA, a combination of tax credits and financial incentives has fostered substantial growth in wind power (IEA 2008b).
	Gap: Support stability is highly dependent on the dynamics of the overall economy. Tax credits can lose value in times of economic crisis, jeopardizing system stability.	Potential Solutions: In response to the economic downturn and associated decrease in profits and tax liability, a new program was introduced in early 2009 that provides the option of monetizing the ITCs in the form of cash grants of equivalent value (-grants-in-lieul) for a limited amount of time (Bolinger 2009).
Quantity-based mechanisms		
Quota systems based on certificates (TGCs or RPSs)	In a quota obligation scheme, Suppliers must validate their obligation to produce or purchase a set quantity of renewable energy with a certificate. Suppliers can produce renewable electricity themselves or buy certificates from others. Whereas in price-based support schemes, it is the policy maker who is bound by the renewable target, in a quota scheme the producer or supplier is obliged to fulfill the renewable target set by the quota.	Quota systems are applied in 49 countries, states, and provinces, including the UK, Belgium, Sweden, Australia, the United States (together with tax schemes), Poland, and Japan. The certificates are called Tradable Green Certificates (TGCs) in Europe and Renewable Portfolio Standards (RPSs) in the United States. Quota schemes provide market-based incentives for innovation and for integrating renewable electricity into the power system. They support cost-efficient energy generation by the most cost-efficient renewable technology at areas with the best potential (i.e., highest wind resources).
	Gaps: Because demand is not consumer driven, but determined by the quota, when the target has been met, it can lead to a full stop in demand. Difficulty in forecasting prices raises uncertainty and investment costs, thus raising electricity cost. Most quotas today are based on green energy as a whole, not specific technologies. Thus, they support the most cost-efficient technology (often wind). If the quota cannot be met by the most cost-efficient technology, market price is set by the more expensive technology, allowing higher profits for producers but creating higher costs for the support scheme and thus, consumers.	Potential Solutions: One approach is to establish technology-specific quotas. Another solution is technology branding, whereby less mature technologies receive a higher ratio of TGCs, as is the case in the UK. Several RPS programs in the United States also mandate that utilities purchase electricity from different renewable sources at fixed ratios. Another approach recently introduced in the UK introduces feed-in tariffs for small installations with a capacity of up to 5 MW and applies a quota scheme for all other installations. Australia combines its national quota, the Renewable Energy Target, with research development and demonstration grants for less mature technologies

SUPPORT STRONGER DEMAND-PULL FOR WIND ENERGY (CONT.)		
Policy	Description	Examples / Details
Tender schemes	Various countries have various tender schemes for the deployment of offshore wind energy. Normally, government specifies a set amount of renewable capacity to be installed by a certain date, then offers concessions to implement the projects for tender. The project with lowest costs gets the concession and receives a fixed price for a fix amount of production. The tender procedure can be designed for a specific technology, allowing support for less mature technologies that need large scale demonstration projects.	Several countries use tender schemes for the deployment of offshore wind energy. Denmark combines feed-in premiums and tender procedures for offshore projects. For an ongoing tender for a 400 MW offshore wind farm that is expected to start production in 2012, the support is to be settled by a call for tenders on the concession. One possible drawback is that if competition for the concession is too strong, the prices offered become too low and projects are not implemented.
Improving market conditions and consumer awareness: Consumer confidence and public awareness is necessary to improve a market pull-driven deployment of renewable (see Appendix B for further detail).		
Green power purchase agreements and labeling of additionality	Green power purchase agreements could considerably strengthen consumer driven demand for wind power.	The EU has launched the electricity labeling directive to tackle this issue with some progress. But the system does not work at full effectiveness yet due to the complexity of disclosure-related issues.
	Gaps: Even though consumers may pay higher electricity prices for green energy under the firm belief that the additional cost will support accelerated wind deployment, often green power purchase agreements do not actually result in additional wind technology deployment.	Potential Solutions: To assure consumers that the prices they pay for renewables contracts (e.g., to buy green power) actually result in additional deployment of new renewables installations, several private eco-labeling initiatives require that suppliers who want to sell an eco-labeled renewable contract have to invest a given amount of their margins into new renewable installations. Nevertheless, public information on this issue needs to be improved. In Australia, GreenPower is a government accreditation program for renewable energy. The government GreenPower program organizes publicly available independent auditing of energy retailers' sales and purchases, making sure retailers are investing in renewable energy on behalf of the purchaser.
Improving customer awareness	Raising consumer awareness of the benefits from electricity generation from renewables would considerably improve marketing conditions and could provide critical market pull in this sector.	To facilitate demand and an appropriate investment environment, consumers need accessible information on the benefits of wind technology for climate change, the environment, the economy, and energy security. In particular, emphasis appears to be needed on the economic benefits of investing in wind technologies, as this might attract a broader range of customers. Appropriate public campaigns should be launched and all appropriate marketing options used.

Developing demand for and investment in wind power will require reliable and predictable support. Support schemes and incentives need to be consistent with existing regulations ensuring free trade, such as the WTO rules or the provisions of the European Treaty, particularly the principle of the free movement of goods and state aid rules.

The different support scheme options discussed above each provide particular advantages. Feed-in tariffs and quota obligations are the most widely applied support schemes (REN21 2009). Analyses by the IEA and on behalf of the European Commission have concluded that, so far, well-adapted feed-in schemes appear more effective at lower remuneration costs for wind power than quota schemes (IEA 2008c, European Commission 2008).

However, well-adapted quota and other support schemes can be effective drivers for renewables deployment as well. Moreover, with growing shares of fluctuating renewables, both feed-in schemes as well as quota systems need to be adapted in order to fulfill the basic requirement of a reliable and predictable support scheme that allows effective support and cost-efficient system and market integration. This might facilitate new innovative concepts and ideas that may also include inventive combinations of existing support elements (see for instance discussion in Cory et al. 2009).

An ambitious support policy targeted at accelerating deployment on a massive scale could attract investment and spur innovation, thereby facilitating technology progress and improving technology efficiency. This would drive costs down for renewable energy investment and electricity generation (i.e., along the learning curve). Deployment-driven cost reduction, combined approach with internalization of external costs, could create increasing demand-pull. Consequently, an ambitious support policy today would lead to less dependence on support schemes and lower support costs tomorrow.

Provide Grid Access and System Integration

Successful uptake of wind power will require sophisticated grid integration and power management technology to handle the complex connections and flows. The challenges here differ with respect to the level of market development and size of wind turbines.

Developing Countries

In developing and emerging countries grid infrastructure must first be installed and rural electrification presents additional challenges. If no high-voltage transmission grid is in place, small wind turbines could facilitate rural electrification. Integrating large amounts of renewables only becomes more complex with substantive shares of electricity supplied from fluctuating renewable sources. Historical development in Western Europe, the United States, and Japan indicates that in an early market stage, system and grid integration can be handled easily (up to 5% of renewables share seems negligible from a power system operations standpoint [IEA 2009c], and even 10-15% with modern network-supporting wind turbines). Significantly increasing shares, however, do raise more complex issues. Thus, deployment of new grid capacity in developing countries should ensure that the power system is robust and flexible enough to absorb progressively larger shares of variable renewables.

Industrialized Countries

Given the existing grid infrastructure in industrialized countries, integrating large amounts of wind energy without negatively affecting grid access is a more complex issue, largely due to grid stability. Three key issues have to be addressed in the context of grid and system integration:

- Grid access for new producers and order of dispatch
- Transmission and distribution capacity (to accommodate additional renewable installations)
- System operation with large amounts of wind power (system and market integration)

PROVIDE GRID ACCESS AND SYSTEM INTEGRATION		
Policy	Description	Examples / Details
Grid access and dispatch: Investors need clear assurances that their wind farms will be able to connected to the grid and be dispatched in a profitable manner. Lacking this clarity, a vicious circle may develop in which neither the wind farm developer nor the transmission operator initiates investments until the other one does.		
Guaranteed grid access and priority or guaranteed dispatch[16]	Three critical elements for investor assurance are: a) Guaranteed connection to the grid, i.e., the grid system operator must connect the wind farm to the grid, if the stability criteria are fulfilled, and give early confirmation on this connection b) Transmission system operators (TSO) should either give priority dispatch (i.e., power from the wind farm is dispatched prior to power from a conventional power plant in cases of capacity conflicts) or guaranteed dispatch to wind power, provided that net grid stability is not jeopardized. c) Appropriate allocation of network connection costs.	The German Renewable Energy Source Acts and the Spanish Royal Decree 661/2207 provide for both guaranteed connection and priority dispatch if the grid stability criteria are fulfilled per the grid codes of the Transmission System Operator (TSO). Standardizing grid codes, including definitions and terminology, would enhance transparency and reliability for investors. The European Directive on the promotion of the use of renewable energy (2009/28/EC) requires Member States to provide either priority or guaranteed access Usually, costs for grid connections are borne by the operator of the renewable installation as part of their investment costs. In some circumstances, this might be different. For example, for offshore wind installations, Denmark and Germany provide free grid connections financed by electricity consumers because the connection costs are very high and the connection is managed by the TSO. In general, the degree to which costs for grid connection are borne by the developer or by the operator may vary depending on a country's electricity market structures.

[16] The issue of guaranteed connection and priority dispatch is often discussed under the term ―guaranteed access,‖ see for instance Article 16 of the European Renewable Directive, 2009/28/EC.

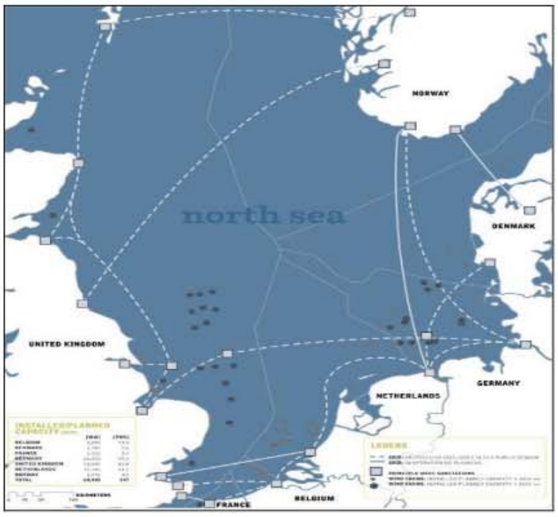
PROVIDE GRID ACCESS AND SYSTEM INTEGRATION (CONT.)		
Policy	Description	Examples / Details
Increasing transmission and distribution capacity: Sufficient grid capacity at both the transmission and distribution levels is a prerequisite to integrating growing shares of renewables into the grid.[17] The grid has to be able to reliably and instantaneously balance supply and demand fluctuations. Grid capacity can then be increased in two ways: by installing new grid infrastructure (or up-scaling existing grid capacity) or optimizing the operation of existing grid infrastructure. Integrated strategic planning can facilitate grid infrastructure projects. Given that renewables help reduce climate change costs and that grid capacity is a central “backbone” for energy security, countries might consider socializing the costs of upgrading grids, rather than imposing them on renewable installation operators. If these costs are socialized, appropriate frameworks conditions are needed to avoid inappropriately increasing costs.		
Integrated strategic and accelerated planning	A strategic, holistic spatial planning approach takes into account an array of options to complement and balance installations using fluctuating renewable sources (see IEA 2009c). It also ensures that different land use interests are addressed early and reflected in the plans, helping to prevent third-party claims during the permitting or construction phases. As spatial planning of large grid infrastructure projects is complex, detailed grid studies, involving system operators, industry, and policymakers, are needed.	The overall need for transmission sea cables can be reduced by an early, comprehensive planning approach that provides for grid hubs that connect surrounding wind farms. The United States has an effort to identify Renewable Energy Zones (REZ) and to conduct transmission planning to access these zones. Similar approaches can be found in several countries in relation to offshore projects. With a target of 100 GW of wind power by 2020, China has proposed a “Green Silk Road” transmission corridor to gather output of seven planned 10 GW wind power clusters, over six provinces. The German DENA grid study identifies grid improvements and transmission priorities to achieve Germany's renewable targets. Ireland's TSO EirGrid published an “All Island Electricity Grid Study” in January 2008.
Installing new grid infrastructure (see Appendix B for further detail)	In many countries, the main bottleneck for integrating higher shares of renewable energy is the lack of transmission capacity. New capacity is needed to connect renewables installation with demand centers.	Much of the existing transmission infrastructure in OECD countries is more than 40 years old and needs to be upgraded regardless of wind energy deployment (IEA 2009c). There is a window of opportunity to ensure that capacity upgrades are conducive to greater integration of intermittent renewable energy sources, including wind power. Upgrading transmission networks should make use of new line technologies that increases grid flexibility. Several options for new grid infrastructure include high voltage direct current (HVDC) transmission, underground transmission cabling (to increase public acceptance), and improved power electronic devices for load flow control. Appendix B provides further information on these options.
Improving existing grid infrastructure* (see Appendix B for further detail)	Beyond the addition of new grid infrastructure, which requires rather long spatial planning processes, grid capacity can considerably be increased by optimized operation.	Two examples for improving existing grid infrastructure are: □ Dynamic line rating to take into account weather conditions □ Rewiring with lower sag, high temperature wires Appendix B provides further information on both options.

[17] Large wind farms are usually directly connected to the transmission lines (i.e., to extra high voltage transmission “highways” to demand centers). Small and medium sized installation can be directly connected to the lower voltage distribution grid.

Provide Grid Access and System Integration (cont.)		
Policy	Description	Examples / Details
System and market integration: The task of reliably integrating increasing shares of fluctuating renewables into the power system becomes more significant as their share of total electricity production increases. Many options exist for improving system integration and are discussed below. An integrated, holistic power system management approach using all these options would provide significant advantages.		
Flexible power plants and storage technologies	Flexible power technologies and storage capacity can increase the ability of the power system to reliably balance larger shares of variable renewable energy. Such technologies will be operated for the benefit of the entire electricity system, and not only for a specific renewables installation.	By far the most important tool today is the use of ―flexible‖ power plants, such as gas turbines and hydropower, which can be quickly dispatched or turned off according to the output of wind energy. Advanced storage technologies may have the potential to reduce the need for flexible reserves, instead enabling excess wind power to be stored and dispatched later as needed. Options include pumped hydro storage; compressed air energy storage (CAES, undergoing testing, but relies on geology that is not found everywhere); electric vehicle batteries; and production of hydrogen for use in hydrogen cars. More information on the latter two can be found in Appendix B.
Wind power curtailment	Wind power curtailment entails the quick reduction of electricity fed into the grid to ensure system stability	Spain, Denmark, and Germany have had good experiences with wind power curtailment by providing that it be limited to disturbances or other situations where grid stability is threatened and other options, such storage or demand management, are inappropriate or not available. This would ensure the concept of guaranteed or priority dispatch. If firm network rights are allocated, operators of wind energy installations should receive compensation for being subject to curtailment. This creates an incentive to expand grid capacity and install additional flexible power plants or energy storage.
System (ancillary) services from wind installations	Wind turbines can provide important support for grid stability (e.g., voltage support.)	The role of wind turbines in this context has fundamentally changed in the past decade. While in the mid 1990s, system operators would require an immediate shut down of wind turbines in periods of short voltage drops, today they demand just the opposite. Experience has shown that the stability problem can be exacerbated when an outage at a large power plant automatically leads to an outage at a similarly scaled wind park. Today's grid codes demand sophisticated technology for wind turbines that allow them to remain in operation in cases of short voltage drops or grid outage, thus providing valuable system services.
Wide-area monitoring and improved weather forecasts	The integration of a wide variety of different power sources and the optimization of energy flows require a computer-based, wide-area monitoring approach for future and predictable congestion situations. Improved weather forecast models provide a necessary tool in this context that should be used by system operators.	Such systems are already applied in the United States and China. In Europe, neighboring TSO's have launched a collaborative security cooperation (TSC), whereby they share the results of the TSO's grid state prediction calculations and follow a joint strategy of counter measures in case of grid stability problems. The Spanish power systems operator Red Electrica started a control center in 2006 to control production and energy flow in the network for all renewable energies and to ensure system stability (CECRE).

Provide Grid Access and System Integration (cont.)		
Policy	Description	Examples / Details
Connection of adjacent power systems and markets	The more power systems that are linked with each other, the greater share of renewable electricity that can be integrated into the grid; interconnected power systems are more flexible as they can share dispatchable electricity and exchange excess supply of electricity from renewable sources. Sufficient interconnection capacities are needed between the grid infrastructures of different electricity markets. Consideration should be provided for the harmonization of converter and control standards (e.g., to allow a multi-terminal HVDC-system to be connected to different networks in different countries, which requires coordinated load flow control).	Interconnected power systems imply a need for collaboration among neighboring system operators and governments based on a transparent and advanced exchange of information to avoid the spread of faults throughout the entire region. A prime example is the Nordic power market, which covers the whole of Scandinavia. Based on strong interconnection and transmission capacities, large amounts of wind power can be integrated into the system. This system also benefits from the large Norwegian and Swedish share of hydropower and has supported Denmark in achieving a 20% wind share of the electricity market. Recently, the new European Network of Transmission System Operators body (ENTSO-E) has dedicated a special regional group to studying the feasibility of a North Sea super grid, also addressing the need for an international offshore system operator (see Figure 5). The North Sea super grid is a vision that would connect different offshore wind farms in the North Sea. Furthermore the European Commission has appointed a European Coordinator to facilitate concerted offshore interconnection in 2007 (IEA 2009c).
Demand-side management	A comprehensive system management approach should not only manage electricity supply but also electricity demand, a concept known as demand-side management (DSM).	Today, DSM tends to concentrate on large electricity consumers, such as large cooling houses, steel or aluminum plants, or waterworks. In this case, the short-term balancing potential is easier to control than for a large number of small consumers. Many future power system strategies including the European SmartGrids initiatives and the U.S. GridWise initiative highlight the need for increased end-user involvement. End users could potentially defer their demand to low load periods. Necessary policy conditions are needed, e.g., variable tariffs that set incentives for deferrable price-responsive demand. In concert with other innovations, such as smart household appliances, smart metering will be a key capability for consumer DSM. It allows analysis of consumer demand patterns and price signals and perhaps, control of individual household devices either through individualized programming or remote control.
Smart Grid	If fully implemented, a smart grid would intelligently connect all actors in the power market and thereby allow for integrated real-time, online visualization, analysis, and management of electricity supply and demand.	A number of demonstration, pilot, and deployment projects are underway, e.g., the German E-Energy project. The SmartGrids European Technology Platform for Electricity Networks of the Future began its work in 2005 aiming at developing a concept for the development of European electricity networks looking towards 2020 and beyond. For further detail on smart grids, please see the MEF Global Partnership Technology Action Plan: Smart Grids.

FIGURE 5: VISION FOR A NORTH SEA SUPER GRID

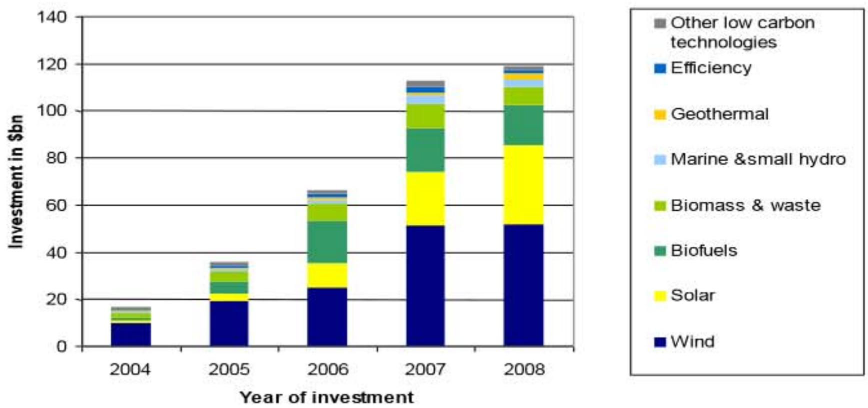


Source: Woyte et al. 2008, IEA 2009c

Sufficient, Affordable Financing

Increasing wind power capacity to address climate change and ensure energy security requires a number of financing instruments that foster predictable and sufficient investment conditions and create long-term price signals to the market. It is crucial to design and use financial instruments that are effective, efficient, and equitable. Investments in the wind energy sector have increased steadily in recent years (Figure 6). However, financing activities have stagnated during the current financial crisis (UNEP 2009). Fortunately, stable and effective support mechanisms have limited the impacts of the crisis.

FIGURE 6: GLOBAL NEW INVESTMENT IN RENEWABLE ENERGY TECHNOLOGIES, 2004-2008



Source: UNEP 2009

The financial flows and financing instruments for wind projects in developed countries differ markedly from those in developing countries. Entrepreneurial financing in industrialized countries does not appear to represent a major barrier to wind power development, or at least no more a barrier than other sectors are experiencing during the current financial crisis. By contrast, additional financing for wind power in developing countries constitutes a major hurdle. Current carbon prices and carbon-based financing measures have not significantly increased the financial viability of wind projects.

Concessional financing (soft loans, i.e., loans with less or free interest, and further relief regarding payback methods) can address these prevailing financing gaps in most developing countries and enable infrastructure projects. More generally, adequate financing instruments must be matched to project size. Critical financing gaps for wind projects occur during different periods of project development:

- At the beginning of the project, because of a lack of project development capital
- During the construction phase, because of issues that arise like debt-equity gaps and lack of risk management instruments (UNEP 2005).

The financial structure for wind energy projects generally includes equity, mezzanine, and debt capital.

Several best practice financing policies and instruments are summarized in the following table. See Appendix B for further detail.

Sufficient, Affordable Financing		
Policy	Description	Examples / Details
Public-driven financing mechanisms providing equity	Provision of capital support for projects that cannot obtain equity capital from corporate treasuries, strategic investors, private equity funds, or the capital markets	• Connecticut Clear Energy Fund (CCEF) provides capital support on a case-by-case basis for small-scale, decentralized renewable energy projects in Connecticut (U.S.) (UNEP 2005, CCEF)
Public funds providing mezzanine capital	By providing mezzanine capital to bridge the debt-equity gap, public funds can lower risks for investors and lenders or leverage private capital.	• FIDEME (Fonds d'Investissements de l'Environnement et de la Maîtrise de l'Energie) in France: a public-private mezzanine fund in which ADEME, the French Environment and Energy Management Agency, has invested € 15 million, providing a first loss guarantee to senior lenders in the fund. (UNEP 2005). • Sustainable Development Fund of Pennsylvania offers innovative financing for renewable energy projects (in Southeastern Pennsylvania) not easily financed on a commercial basis
National public sector loan instruments	Aimed at facilitating corporate and/or project financing to the wind energy sector, focusing on small to medium-sized projects	• Loan credit lines of the KfW (the German bank for reconstruction and development): Project developers contact partner banks, who assume the credit risk and then lend the funds provided by KfW. The loans offer attractive conditions for developers. • Netherland-Green Funds: offers individuals the possibility to receive a tax incentive of 2.5% and an earned interest of 1-1.5% on green savings accounts. Thus, banks offer soft loans to environmental projects and project developers. (UNEP 2005) • Bulgarian Energy Efficiency and Renewable Energy Credit Line: offers loans, technical assistance, and grant support to Bulgarian Sustainable Energy projects, capitalized by international financing institutions and bilateral donor agencies

SUFFICIENT, AFFORDABLE FINANCING (CONT.)		
Policy	Description	Examples / Details
Loans of international financial institutions	Loans with special conditions to renewable energy projects; banks offering those loans often have a specific share of renewable energy financing within their portfolio	- Loans of the World Bank - European Investment Bank (EIP) - Activities of individual countries, e.g., Germany has developed a strategic partnership with the Inter-American Development Bank (IDB)
Global partnerships	Interest-free loans, risk sharing, and co-funding options for renewable energy projects, focusing on support to developing and emerging countries. (CanREA 2006)	- Global Environmental Facility (GEF) - Global Village Energy Partnership (GVEP) - Global Energy Efficiency and Renewable Energy Fund (GEEREF) of the European Commission (European Commission 2006) - Renewable Energy and Energy Efficiency Partnership (REEEP)
Third-party financing	Another form of off-balance-sheet financing, instead of debt financing	- IDAE model in Spain: An investor provides 80-100% of the initial investment in addition to technical and management solutions. The investor owns the project up to the recovery of the investment, at which time ownership of the equipment is transferred to the user.
Financial risk management	Loan and partial risk guarantees to transfer project risks, usually implemented in conjunction with private financial institutions	- French FOGIME - Canadian GMIF - RE and EE Program of U.S. Department of Agriculture - Guarantee facilities of the World Bank in developing countries

Key areas to be considered when analyzing sufficient and affordable finance include:

- Incentives for private investments
- Risk mitigation
- Utility-scale project financing
- Pilot projects financing
- Carbon financing

Appendix B provides further detail on these areas.

Research, Development, & Demonstration

As a result of robust RD&D policies, tremendous technology progress and significant cost reductions have been achieved in the wind technology sector in recent years. Promising new technologies and novel concepts are providing further opportunities for generating economies of scale and greater cost reductions. Current research priorities include new offshore turbine designs, light-weight, high-strength materials, enhanced understanding of wind resources and engineering, improved weather forecast models, and improved grid compliance and network support.

Demonstration and Test Facilities

The gap between R&D success and market entrance for new technical solutions, sometimes called the ―valley of death,‖ can be bridged, at least partially, by demonstration projects and test facilities. Test facilities and demonstration projects help spur technology deployment. They provide prototype and component testing, supporting future R&D and serving as starting points for further technology refinement (e.g., improved materials, quality management, increased efficiency and reliability, extended service life).

In the wind sector, the size of modern wind turbines poses a challenge for test sites. Establishing test facilities is a lengthy and difficult process, as approval procedures are often based on wind farm permitting processes rather than those for a testing facility. Institutions have recently begun to pool their test facility efforts to tackle this issue more cost-effectively. Wind test sites can be found in several countries, most in Europe.

Current Best Practices in RD&D

RD&D efforts for wind energy technologies were driven initially by industry, with later involvement by universities and public and private research institutes. Analysis of successful RD&D policies indicates that the greatest technology progress could be achieved by a combined approach of constant RD&D and consequent deployment polices, thereby benefiting from synergies between laboratories and economies of scale. Experience shows the critical importance of an appropriate research environment that includes stable, consistent funding, protection of intellectual property rights, and the availability of suitable research facilities capable of pursuing a strategic research agenda.

The table below provides several examples of best practice RD&D efforts. See Appendix B for further details.

RD& D Gaps

Currently national R&D financing for wind energy is insufficient due, at least partially, to the perception that wind energy is ―mature,‖ as well as the tremendous progress made in reducing the costs of the technology. Moreover, overall government expenditures on energy RD&D have decreased (see Annex B). According to the IEA's findings in its analysis of Global Gaps in Clean Energy Research, Development, and Demonstration (GCERD, IEA 2009b), if the 2050 targets are to be met, then a global annual spending gap for RD&D in the wind sector of approximately US$1 billion must be filled.

RD&D PROJECTS	
Policy	Examples / Details
RD&D leadership	□ The Denmark Risø National Laboratory, Wind Atlas Analysis and Application Program (WASP) has developed a tool for wind assessment. □ The German Energy Research Program on Renewable Energy has been working on critical technologies such as grid integration, turbine components, and 5 MW technology. □ In China, the development of research and test facilities has been largely promoted by Danish and German development cooperation programs (DANIDA and GTZ). □ With foreign expertise, the China Electric Power Research Institute (CEPRI) now has basic services in wind energy research, testing, and consultancy. □ For two decades, wind research has been conducted through European programs (Joule and Thermie) by the Institutes and Universities in Europe (University of Oldenburg, Germany, Loughborough University, England, Risø, Denmark etc.). □ In the U.S., the National Renewable Energy Laboratory (NREL) conducts extensive wind research. □ For more than two decades, the European Research and Technology Development (RTD) programs have successfully facilitated wind technology development.
Cooperative industry RD&D	□ Under the IEA Wind Energy Systems Implementing Agreement, national technology experts and policy experts from 20 countries work together on an agreed R&D strategy. □ The European Wind Energy Technology Platform (TP Wind) was established in partnership with the European Commission to foster joint research by industry and the public sector. □ The German-Danish-Swedish-Norwegian Cooperation Agreement has a specific focus on offshore wind R&D (Joint Declaration 2007).
Demonstration and test facilities	□ In Germany, an offshore site (45km from shore) for 12 x 6 MW turbines will be used to test a new turbine class, study ecological and hydrological impacts, assess structural and foundational fatigue, and research turbine technology. □ Test sites for wind turbine testing are operated by Risø National Laboratory, Denmark Dutch ECN, in Germany by the German Wind Energy Institute and Windtest. □ Facilities for rotor blade testing are operated by Risøand by ECN, by NaREC in the United Kingdom, in Germany by Fraunhofer; a wind tunnel for blade profile testing is operated by Deutsche WindGuard. □ In Spain, the Institute CENER operates a site or ―experimental farm‖ to conduct tests on rotor blades, power train, and aerodynamics; the site also operates an electrical and nacelle test bench.

Improved Planning and a Reduced Administrative Burden

Streamlined and Harmonized Procedures

Potential investors in a wind energy project need an effective and stable policy framework with clear, rationale administrative procedures that minimize their transaction costs. Experience has shown that streamlining administrative procedures can significantly accelerate wind deployment.

Complex, bureaucratic approval and permitting processes can significantly increase investment risks since time a crucial factor, particularly for large scale projects. Moreover, differing requirements among regions and their application by multiple jurisdictions (local, state, federal), each with different methods of assessing costs, benefits, and environmental impacts, can mean increased efforts, longer delays, and added investor uncertainty. Countries with long experience in renewable energy projects, such as Denmark, Germany, Spain and the United Kingdom, recognize the value of a streamlined, integrated, and efficient process. Such process incorporate a combination of simplified approval procedures, grid access, and comprehensive information for all actors involved. In addition, a set of clear, transparent, and well-adapted requirements, harmonized among jurisdictions, could facilitate future investments significantly.

Permitting institutions can establish internal guidelines that promote fast-track approval procedures and set clear expectations (or obligations) for response periods. In this context, one approach has been to give permitting authorities ambitious targets for approval rates.

Integrated and Reliable Planning

The ability to rely on planning to foresee and preemptively address potential problems is a crucial factor, especially for large-scale investments. Public acceptance (e.g., regarding visual aesthetics or noise emission from rotor blades) and environmental concerns (e.g., impacts on wildlife and habitat) often present significant challenges to wind projects.[18] Similar problems exist for transmission infrastructure projects. Most countries have implemented rules and guidelines on environmental impact assessments during the planning period.

The high population densities of some emerging economies, many of which have an abundant wind resource and significant growth potential for wind energy, will likely complicate planning and permitting processes in these countries as well. Such concerns can be addressed through an integrated yet streamlined planning process that balances different land use and environmental conflicts and helps avoid delays during the permitting process.

One way to address these challenges is to ensure early participation by concerned stakeholders, including local residents. Another approach is privately-owned wind farms.[19] Government and industry information campaigns can also help increase public acceptance of wind energy and reduce the NIMBY phenomenon (―not in my backyard‖). Potential third-party concerns need to be addressed in an integrated and streamlined spatial planning procedure that balances different land use and environmental conflicts and helps avoiding delays during the permission procedure. To limit potential third party conflicts in the permitting procedure, planning could provide for appropriate distance of wind turbines to buildings.

A best practice to increase the predictability of the permitting process is pre-designation of priority and reserved areas for wind projects, enabling authorities to gather early information on potential conflicts. Wind installation operators could also be guaranteed legal claims to these sites, if they fulfill all necessary requirements (which should not discriminate against wind energy projects).

Facilitating Information Access

Challenges related to planning, permitting, and other administrative procedures increase exponentially when viewed in a global context. Differences in complex procedures and requirements among countries can hinder global investment in wind

[18] Transmission infrastructure projects, which are of particular important for wind energy, face similar challenges.

[19] In either case, to limit the potential of third party conflicts, planning should provide for appropriate distance between wind turbines and buildings and incorporate information regarding the impact of turbine heights on noise emissions.

energy even more than bureaucratic challenges at a national level, in part, because it can be much more difficult to gain access to needed information internationally.

A comprehensive global database that provides easy access to information on procedures, requirements, and framework conditions (e.g., support schemes and financing) could help mitigate this challenge. Such a database might also provide geo-specific information on technology-specific wind potentials, recognizing that accurate site assessment is one of the most important preconditions for investment.

IMPROVED PLANNING AND REDUCED ADMINISTRATIVE BURDEN	
Policy	Examples / Details
Environmental impact assessment	□ In the U.S., to evaluate issues associated with wind energy development on Western public lands, a Final Programmatic Environmental Impact Statement (EIS) applies (EWEA 2009e). □ In Europe, several Directives require project-based environmental impact assessment.
Streamlined permitting	□ Denmark has established a single permitting authority, or ―one stop shop,‖ for permitting procedures. □ The German Renewable Energy Source Act simplifies permitting procedures for small installations and guarantees grid access. □ The United Kingdom set ambitious approval rates for authorities in the permitting process
Public involvement	□ Offshore project planners in Denmark have established information centers and Internet platforms, which kept the public informed and significantly limited protests. □ In the German federal state Schleswig-Holstein, the local population has been directly included in many local wind energy projects, leading to fewer public conflicts. □ In an international context, the TERNA Program of the GTZ (German association for technical cooperation) initiates wind energy projects in developing countries and provides for sufficient communication between developing countries and interested external investors (WWEA 2009a).
Improve predictability of permitting procedures	□ One approach is to pre-designate wind sites. Some German federal states have required themselves to designate a minimum quota of priority and reserved areas for wind projects. □ Several countries provide for a claim for permitting if the necessary conditions are fulfilled □ An integrated spatial planning approach could early address and balance possible third-party conflicts, environmental and land-use conflicts. The European Directive on the assessment of the effects of certain plans and programs on the environment (2001/42/EC) encourages an integrated planning approach for large projects.
Transparency	□ The German guideline on repowering informs the public on necessary procedures and requirements regarding repowering projects. □ The EU has some general best practice guidelines for the planning phase of wind energy projects, which may reduce difficulties (EWEA 2002, DoEHLG, BWEA 1994).

Provide Greater Legal Certainty

Development in wind energy markets illustrate that deployment occurs where markets and support policies are sufficient. Investment decisions do not appear to depend on the quality of wind available as much as the prevailing framework conditions. A major factor in investment decisions is the degree of legal certainty, referring to the reliability and predictability of the judicial system and intellectual property rights frameworks. A lack of legal certainty can increase investment risk, and thus, poses a major obstacle to global investments in wind projects.

Support Human Resources: Training and Capacity Building

Wind power technologies are physically and technically complex, not only in their manufacture but also their planning, installation and operation and maintenance (O&M). Hence, to a large extent, the dynamics of wind energy development depend on the availability of highly qualified engineers. According to the wind industry (EWEA 2009c), the wind energy sector faces a significant lack of highly qualified staff. To avoid this becoming a severe obstacle for further market deployment, wind specific training, further education and technology know-how transfer is urgently required. This could create many new jobs.

To provide the necessary pool of skilled labor, comprehensive training programs are needed to train and further educate technicians and engineers. In addition, public relation programs are needed to inform technicians, engineers, and scientists at the secondary and university levels about the career opportunities in wind energy.

Capacity building can be viewed as one of the core components of a wind project and should therefore be addressed during the early planning stages. However, to develop significant and sustainable know-how, capacity building must go beyond the project-by-project approach. Strategic capacity building initiatives are needed that follow a more comprehensive approach with continuous development, improvement and update of capacity building and knowledge-base resources.

Public institutions and independent organizations should improve the transparency of ongoing capacity-building activities, including encouraging companies to join forces with them to improve information dissemination on wind technology. The private sector has a key role to play for training and capacity building as some best practices have already shown (e.g., Garrad-Hassan activities in developing countries) and could be encouraged to join forces with public institutions.

Specific areas of concern regarding capacity building in the wind sector include:

- **Operations and maintenance:** Wind turbines are expected to run for 20 years continuously, 24 hours a day – 7 days a week. Low quality in operations and maintenance will lower the technical availability of wind turbines. Each 1% reduction in technical availability means at least 1% loss in energy production.
- **Know-how transfer regarding effective offshore permitting procedures**: Permitting and planning procedures for offshore projects have not yet been firmly established in several countries. Long, bureaucratic and unpredictable administrative procedures put investments at risk. Best practice examples for streamlined procedures already gathered in leading offshore markets in Europe should be made to other countries.

Capacity building in developing and emerging countries needs to cover the whole set of key accelerators for the development of wind energy. This not only includes wind turbine installation and O&M, but also best practices for legal, economic, and other frameworks, including planning and permitting procedures, incentives and support schemes, grid infrastructure planning, management of public acceptance, technology assessments, etc.

Several examples of training and capacity building best practice efforts are listed in the table below. A relatively new initiative that may have significant impacts on capacity building, the International Renewable Energy Agency (IRENA), is described in a text box below.

SUPPORTING HUMAN RESOURCES	
Policy	Examples / Details
Promote careers in wind power	- The Masdar Institute in the United Arab Emirates is offering 20 full scholarships per class for IRENA-recommended students. - The "Transfer Renewable Energy & Efficiency" program (TREE) of the Renewable Academy (RENAC) in Berlin facilitates knowledge transfer to experts and decision makers from developing and emerging economies.
Knowledge transfer from developed to developing countries	- The CASINDO-program of Dutch-based SenterNovem cooperates with Indonesia to build and strengthen institutional and human capacity for energy policy formulation, development of renewable energy, and energy efficiency projects. - The German Technical Co-operation (GTZ) joined efforts with China to set up a joint wind energy training center with local partners, established a training program, and supported the foundation of an institute for broad services as well as a test center for wind energy in China (Sino-German cooperation) - Denmark has pursued similar efforts with China (Sino-Danish cooperation). - The private Garrad-Hassan activities provide technical training and capacity building in developing countries
Build a knowledge base	- Valuable knowledge base initiatives are active at the global level, including the Renewable Energy Policy Network for the 21st Century (REN21) and the Renewable Energy and Energy Efficiency Partnership (REEEP), which manages the reegle search engine for information on renewable energy and efficiency.

THE INTERNATIONAL RENEWABLE ENERGY AGENCY (IRENA)

Despite the many valuable capacity building initiatives underway today (e.g., REEEP, REN21, UNDP), no central authority currently exists to function as a ―one stop shop‖ for gathering and concentrating knowledge on renewable energy technologies and performing capacity building and technology and knowledge transfer.

The International Renewable Energy Agency (IRENA) aspires to provide such an international hub for all renewables. Founded in January 2009, IRENA plans to provide practical advice and support on renewable energy for both industrialized and developing countries, thereby helping to improve frameworks and build capacity. In addition, it intends to facilitate access to all relevant information, including reliable data on the potentials for renewable energy, best practices, effective financial mechanisms, and state-of-the-art technological expertise. Moreover, IRENA plans also to cooperate with and build networks of existing institutions in this field.

Currently, IRENA is being been built up. To date, 137 countries and the European Community have signed the Statute of IRENA, with seven having ratified it.

Encourage Technology Cooperation

Technology cooperation has the potential to accelerate technical development and foster the transfer of technology to places where prime wind sites remain untapped. In general, international collaboration is required among all regions of the globe. However, the situation in developing countries is complex and requires an integrated policy strategy—one that provides appropriate support from industrialized countries in technology, funding, and capacity building. Perspectives are needed on how to strengthen international cooperation on RD&D and specialized research centers. Moreover, cooperation is required not only in the development of new technology, but also in its deployment. Hence, the private sector should play a strong role in this effort.

Today, national and regional wind energy clusters exist in many countries. Cooperation between these centers of competence can be highly effective in advancing further development. However, the overall problem of such cooperation is that the decision to carry out cooperative activities depends heavily on the balance of economic interests and the desire to promote sharing of know-how.

In addition, consultation with industry representatives has suggested a continuing need for an improved, comprehensive, global discourse on wind technology progress. This ongoing discourse should encompass the full range of R&D, technology assessment, regulation, and deployment policies worldwide, reflecting the need to establish conditions that will attract sustained investment.

To accelerate significantly the development and deployment of low-carbon technologies will require further growth in scale and depth of international strategic cooperation. More public-private partnerships are needed across different developed and developing countries.

Please see the table below for several best practice examples of technology cooperation.

Technical Cooperation	
Policy	Examples / Details
National technology cooperation	▫ In Spain, RETECNA (network of technological centers in Navarra) fosters technology cooperation among the wind energy companies, energy suppliers, and research institutes active in the region (RETECNA 2009). ▫ The Spanish Wind Sector Technological Network, REOLTEC, brings together companies, laboratories, universities, research centers, and others involved in wind power. Its main purpose is to integrate and coordinate scientific and technological development and disseminate R&D results and experiences. All interest groups involved in the development of the sector are represented within REOLTEC (REOLTEC 2009). ▫ In the region around Esbjerg in Denmark, a wide range of companies and research institutes in the area collaborate to advance offshore wind energy technology in Denmark. The region is also engaged in the European project ―POWER Cluster‖ (South Denmark 2008), as described below. ▫ The UK Energy Technologies Institute (ETI) is a partnership between global industries and the UK Government, with both contributing funding towards a series of focused technology programs. The model harnesses the skills, capabilities and market access routes of the ETI Members. The ETI focus on developing offshore wind technology is achieving significant cost reduction and enhanced reliability. ▫ The UK's Offshore Wind Accelerator is a research, development and demonstration partnership between the Carbon Trust and leading offshore wind developers focused on bringing innovative technologies to market readiness and, in so doing, catalyze a 10% reduction in the cost of offshore wind power.
International technology cooperation	▫ The International Energy Agency (IEA) initiates international technology cooperation and has established an Implementing Agreement with various working tasks focused on wind energy. An international IEA working group with participants from universities, research institutions, and industry is analyzing deep water wind turbine concepts. This project has tested most of the modeling programs that analyze the dynamic response of offshore wind turbines (IEA Wind 2009, IEA 2008c). ▫ Denmark, Germany, Sweden, and Norway have joined in a ―Joint Declaration on Cooperation in the Field of Research on Offshore Wind Energy Deployment.‖ Key objectives are to exchange ideas, information, data, and experiences; collaborate on grid integration of offshore wind energy; develop offshore grids; strengthen cooperation; and support joint projects (Joint Declaration 2007). ▫ The European research framework program initiates joint research projects between institutions and companies across Europe. For example, the ―European Technology Platform for Wind Energy‖ is an initiative of the European Seventh Framework Programme for research and technological development to improve EU competitiveness wind energy. It has already developed a Strategic Research Agenda (TPWind 2008). ▫ The European project ―POWER Cluster‖ initiate working groups and cooperation among partner institutions, organizations, and research institutes in the North Sea region (POWER cluster). ▫ The German Association for Technical Cooperation (GTZ) program TERNA (Technical Expertise for Renewable Energy Application) helps developing and emerging countries evaluate their wind energy potential and initiate successful wind energy projects (GTZ 2004). GTZ supported cooperation between a Colombian energy supplier and a German service company to launch the first wind farm in Colombia in 2002. With the provided technical know-how and training offered to the Colombian partners, the project produced a very efficient wind farm that is running successfully today. ▫ The "China Wind Power Research and Training Project‖ (GTZ 2005) is implemented by the German GTZ in cooperation with Chinese partners (China Long Yuan Power Group – CLYPG and China Electric Power Research Institute – CEPRI). It provides training, applied research, operation/maintenance, wind power services and advice. ▫ The Danish-Chinese Wind Energy Development Program (WED) is a bilateral development program aimed at improving China's technological and management capacity in wind energy development. The program is an innovative approach to achieve bilateral technical assistance (CWPC). ▫ IRENA, in particular, might add value for technology cooperation on renewable energy between both developing and developed countries as soon as it becomes operational.

3. Actions to Accelerate Development and Deployment

This plan has outlined the potential for greatly reducing GHG emissions from the generation and use of electricity through deployment of wind energy technologies. Effective wind energy implementations are not based on –one size fits all‖ solutions. Specific country and regional factors will determine the appropriate set of technologies, applications and solutions for each geographic area and country that wishes to implement effective wind energy policies. Nonetheless, all countries seeking to catalyze progress on wind energy should consider similar categories of action. Countries can also work together to expedite their programs and develop standards that enable the wider dissemination of wind energy technology.

To achieve transformational gains in wind energy globally, MEF countries have developed a menu of opportunities to develop and deploy such technology. Many of these actions rely on, or can be effectively leveraged through, coordinated action among countries, including support for existing international forums on renewable energy. This chapter discusses both opportunities for individual country action as well as opportunities for cooperative action among MEF countries.

Menu of Opportunities for Individual and Collective Action

Chapter 2 illustrates multiple best practices that point to specific individual and collective country actions that can help to reduce market barriers and realize the full potential of wind energy.

Key categories of action for consideration include the following:

- Supporting innovation:
  - Develop new technologies.
  - Demonstrate new technologies.
- Accelerating deployment:
  - Support stronger demand for wind power.
  - Improve grid and system integration.
  - Improve planning of wind plants and transmission, with reduced administrative burden.
  - Provide legal certainty.
  - Support training and knowledge management to ensure sufficient labor and intellectual resource.
  - Ensure sufficient, affordable financing.
  - Establish voluntary industry standards and otherwise reduce investment risk.
  - Build deployment capacity.
  - Improve relative economics between advanced clean energy technologies and conventional technologies to encourage market-based adoption.
  - Establish and strengthen regulation.

- Facilitate information sharing:
  - Share best practices and knowledge.
  - Enhance public awareness.

The following section outlines a menu of actions within each category, *generally listed in increasing order of ambition*. Interested countries should consider the actions in each category to identify those that may be appropriate to their unique circumstances.

Supporting Innovation

- Consider the benefits of possible joint RD&D projects between public institutions (e.g., laboratories, universities).
- Explore the possibility of international cooperative demonstration projects for small wind turbines at best wind sites.
- Strengthen the role of private sector in technology cooperation.
- Strengthen cooperation networks of wind energy research centers and further important players.
- Consider promoting demonstration projects for innovative technologies.
- Follow a combined approach of RD&D and consequent deployment policy benefiting from economies of scale and spillover effects between research and mass-scale testing.
- Follow a balanced set of instruments that ensure support of new, innovative concepts and all promising renewables technologies for a broad technology basket for future energy security.
- Provide as appropriate for sufficient test facilities and demonstration projects, particularly to address specific needs of new and emerging technologies.
- Establish appropriate RD&D framework conditions and environments, covering also legal certainty and intellectual property rights.
- Strengthen North-South collaboration and mutual exchange, and enhance South-South technology cooperation; also address the issue of rural electrification.
- Increase and coordinate public sector investments in RD&D in line with the L'Aquila declaration, while recognizing the importance of private investment, public-private partnerships, and international cooperation, including regional innovation centers.

Accelerating Deployment

- Encourage universities to initiate or further develop and deepen curricula in all relevant fields of renewable energy such as engineering, energy, environment, policy, economics, finance, urban planning, and natural resources management.
- Develop specific curricula in engineering disciplines at colleges and universities and set up technical schools to provide practical and theoretical training for mechanics, electricians, etc. in wind energy.
- Facilitate capacity building as one key element of wind projects.

- Develop and follow a strategic and sustainable capacity building approach, not only concentrating on project-by-project training.
- Continue to focus on technology cooperation during the deployment phase
- Promote strategic dialogue with investors to access untapped financing sources and establish public-private partnerships to accelerate investment in developing and emerging countries.
- Establish control centers that optimize flow, enable a wide-area monitoring approach, and improve weather forecasts (e.g., Spanish power systems operator Red Electric).
- Conduct detailed grid studies involving system operators, industry, and policymakers.
- Develop comprehensive grid studies that reflect a long term strategy for improving grid infrastructure.
- Ensure early start of grid infrastructure planning and provide for early involvement of stakeholders.
- Provide streamlined and concentrated administrative procedures; consider the benefits of a ―one stop shop‖ approval system.
- Introduce simplified approval procedures for small plants.
- Establish streamlined permitting and planning procedures for offshore projects.
- Accelerate appropriate permitting procedures and give clear time horizons to facilitate projects planning.
- Make international funding schemes more transparent.
- Follow an integrated spatial planning approach that settles rival claims, assesses environmental impacts, balances different land use interests and prevents third party claims during the permitting or construction periods.
- Follow a holistic approach[20] in planning activities to integrate renewable energy into the overall system and balance rival interests.
- Support efforts to cooperatively set or harmonize standards such as technical standards, labor and safety standards, and grid codes.
- Provide for clear, transparent, harmonized and sufficient regulations, requirements, and procedures to facilitate investments.
- Ensure sufficient grid capacity either through extending and upgrading the grid and/or through optimized grid operation (e.g., using demand side management).
- Make appropriate use of novel concepts and new technologies in grid infrastructure and operations.
- Ensure that permitting requirements are transparent and do not discriminate against wind projects.

[20] Such an approach would cover a flexible mix of power plans and advanced storage capabilities; advanced demand-side management; improved congestion management; connection of different power systems and market in order to enhance flexibility and grid adaptability; improved weather forecasting models and wide-area monitoring; and facilitation of new concepts, intelligent applications and devices (e.g., smart meters) to intelligently interconnect supply and demand side in a way that allows online-based real-time system management.

- Provide that wind farms are privileged, as appropriate, when balancing interests in the permitting process.
- Provide for pre-designation of priority and reserved areas.
- Provide legal claim for permitting, if requirements are fulfilled.
- Enact policies that provide for guaranteed connection and guaranteed or priority access to the grid for wind energy, with appropriate allocation of connection costs.
- Consider providing public funding to pay for grid connection (e.g., Denmark and Germany provide free grid connection for offshore installations).
- Interconnect power systems and neighboring markets to enable greater share of renewables (e.g., proposed North Sea grid).
- Establish stable and predictable legal frameworks.
- Set ambitious concerted targets to provide long-term investment security for wind energy; formulate these as minimum targets to achieve sustainable market development without –stop-and-goll cycles.
- Establish a predictable and reliable support scheme, taking into account unique national circumstances.
- Consider the use of tax and investment incentives, particularly during the early stages of market development. Soft loans can offer an additional incentive.
- Promote micro-financing in combination with technical assistance to reach rural populations and alleviate poverty, especially in developing countries.
- Implement, as appropriate, large-scale strategic financing programs with a sustainable impact.
- Consider leveraging more commercial financing through guarantee elements.
- Internalize external costs, e.g., through a cap-and-trade scheme or carbon tax.

Facilitating Information Sharing

- Facilitate best practice guidelines.
- Develop transparent and easily accessible information on requirements and procedures.
- Develop databases to make information more accessible.
- Improve consumer awareness of the benefits from electricity generation from renewables through appropriate public information campaigns and all other appropriate marketing options.
- Ensure transparent and cost-effective disclosure of renewable energy origin for consumers (e.g., via labeling).
- Support transparent information for consumers on the effect that their green power purchase agreements have on the deployment of additional renewables installations.
- Build up wind expertise in governments and in the private sector and keep decision makers informed.
- Provide training opportunities for wind energy technologies.

- Make information accessible and facilitate know-how transfer by training, workshops, and Internet libraries/databases.
- Support international institutions, such as IRENA, that focus on capacity building in cooperation with existing institutions (e.g., REEEP).
- Involve both public and private sectors to join forces in disseminating information about wind technology.
- Support strategic holistic capacity building on a global level, particularly focusing on countries with a need for wind energy capacity building.
- Develop jointly a global wind atlas with all relevant information to attract cross border investments (i.e., a comprehensive database on country specific economic, legal and administrative investment conditions combined with a global inventory of the potential of wind energy with a high spatial and temporal resolution to allow appropriate global, regional, and national renewable energy modeling).
- Coordinate development of a global wind plan that comprises demonstration and deployment projects, including a global roadmap for wind power projects, the necessary legal, political, and economic frameworks, a strategy for the necessary grid and infrastructure expansion, and identification of financing mechanisms.
- Establish an international technology platform (ITP) to address a deficit of consultation between policy, investors, and stakeholders and to promote an intensive dialogue between governments and industry. Moreover, such a platform can help to match the demand and the supply for specific technologies and to develop new and innovative concepts.

Actions by Individual Countries

To accelerate development and deployment of advanced wind energy technologies, countries should consider adopting some of the actions in each of the categories outlined above as appropriate to their goals and unique national circumstances.

More generally, MEF countries may wish to start by developing a national wind energy roadmap (or updating an existing roadmap) that identifies and appropriately sequences high-impact actions from each category as appropriate to their unique circumstances. These roadmaps may include resource assessments, targets for deployment, reliable support schemes and timelines, and would define the key stages for how wind technologies, associated market changes, and enabling legislation should be implemented in order to meet those targets. Moreover, they might be integrated with roadmaps for other technologies that would enable broader uptake of wind energy (e.g., smart grid).

Periodically, countries should assess progress against their own action plan and correct their course as desired. At the very least, they may want to ensure that they are establishing policies or taking other enabling actions on the schedule envisioned in their road map. To that end, they may wish to consider, as appropriate, that ambitious minimum renewable targets, reliable support schemes and internalization of external costs appear to be the most significant policies for wind technology deployment and progress.

Similarly, they may establish a matrix of demonstration projects categorized by solution type of solution to ensure they are addressing the full range of promising wind energy technology improvements.

These individual actions could then feed into coordinated or cooperative international initiatives, to the extent appropriate or desired, in accordance with national circumstances.

Accelerated global deployment of wind technology, combined with a RD&D strategy, could realize economies of scale effects, facilitate technology progress and improve technology efficiency. Thereby, investment costs as well as electricity generation costs could be driven down along the technology learning curve. All countries could benefit from this technology progress in the long run.

Coordinated or Cooperative Action

Beyond the individual efforts described above, countries should consider the vital role of international coordination and cooperation for the deployment of wind energy technologies. The Global Partnership can play an active role in overcoming common barriers faced by all countries to accelerate development and deployment of advanced wind technologies. Global Partnership initiatives would not replace ongoing work in existing forums but rather enhance cooperation globally.

Several attached proposals for technology coordination and cooperation seek to add value to ongoing discussions in various forums on the contribution of wind energy technologies for mitigation. They offer an outlook of possible technology cooperation and know-how exchange between developing and developed countries on wind energy. Illustrative calculations on potential benefits, based on different studies, are provided. Individual MEF countries may wish to consider participating in one or more of these proposed initiatives.

Joining Forces: A Global Wind Energy Plan

MEF countries could start an initiative to evaluate their abilities to join efforts with developing countries to implement large-scale wind deployment projects at sites where very high wind resources have not been explored yet.

Toward this end, joint efforts could be established to develop a global wind plan illustrating a comprehensive strategy for such favorable joint, large-scale wind projects in regions and along coastlines with very high wind speeds. This global wind plan should:

- Include a global roadmap for joint wind power projects in developing and emerging countries
- Address the necessary legal, political, and economic frameworks
- Develop a strategy for the necessary grid and infrastructure expansion
- Reflect adequate financing

The global wind energy plan could be implemented through several subordinate regional wind plans offering greater specificity.

This global wind plan could provide a win-win-situation for all countries involved due to the following:

- Large-scale wind projects could cover the growing electricity demand of developing and emerging countries.
- In the long-term, all countries could benefit from the reduction of wind investment costs and electricity generation costs, induced by economies of scale and technological progress along the learning curve.
- Exporting wind power to neighboring countries could benefit those countries and be an additional option to attract investments.
- Large-scale projects would have to be accompanied by capacity-building initiatives in order to ensure sustainable, comprehensive know-how for the necessary operation and maintenance services.
- A considerable share of investments could be local investments.
- Joining forces for developing and implementing a global wind plan strategy would constitute a unique technology cooperation and know-how exchange and could set free cross-border synergies and spillover effects for the potential benefits of all participating countries.

Background

The world's best wind resources, particularly in the developing and emerging parts of the world, remain untapped. The five leading wind energy markets (United States, Germany, Spain, China, and India) account for approximately 75% of the global installed wind capacity of 121 GW (IEA 2009c). Large-scale wind power deployment led by a global wind plan could provide a major share of the electricity needed to cover the increasing global demand at reasonable and predictable costs.

For example, feasibility studies for large-scale wind deployment projects along Northwest Africa's coastline estimate electricity generation cost to be about US$0.45/kWh (Risø/ISET 2003).[21] A global wind plan is needed to guide efforts in conducting and further verifying studies like this and in evaluating additional costs, such as operational costs for extreme wind sites or costs of grid connection and system integration. This information is critical to the appropriate and successful deployment of large-scale wind power.

Key regions for evaluation could include the Caribbean, South America, North and West Africa, and the Middle East. At these locations, significant wind resources have been measured and capacity factors of 40% are achievable (e.g., (Risø/ISET 2003).[22]

The possible benefits of large-scale wind power deployment guided by a global wind plan could include the following:

- As an illustrative example, 20 GW of new capacity additions induced by possible projects under a global wind plan would increase the current global wind capacity by about 20%, thus giving significant investment signals to the market and providing impetus for economies of scale and cost reduction along the learning curves.

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[21] Exchange rate 15 October 2009.

[22] This means that due to better wind conditions, 40% of the maximum capacity of the wind turbine can be utilized (for comparison: capacity factor average in Europe is 25%).

- Continuing the example, 20 GW of new capacity at locations with the highest wind resources and capacity factors of about 40% could generate about 70 TWh per year of electricity.[23] Taking into account the global energy mix, this would correspond to about 43 Mt of CO_2 emissions reduction per year.[24] (Note: this is only a rough estimate because exact emission reduction figures depend on the energy mix of the host country).
- As a rough estimate, this level of wind power deployment could support 300,000 jobs, based on moderate calculations of the wind industry, which figures a ratio of 15 jobs per MWof installed wind capacity (falling to 11 jobs per MW by 2030; see EWEA 2009d).
- It would be foreseeable that a large share of the triggered investments would be local investments. Consultation with industry indicates that the local content of large wind projects amounts up to 50% of the total investments and maintenance costs. Local services, particularly local operations and maintenance services, are of particular importance because use of local production chains avoids complex logistics, provided adequate legal framework conditions for such local chains are in place.

  Current wind project investment costs depend very much on the location and vary between about US$1 million per installed MW in China and India to about to US$2.6 million in Switzerland (including costs for the turbine, grid connection, foundations, infrastructure, etc.; see IEA 2009c). Where appropriate, exports of any excess electricity remaining after meeting local demand could constitute an additional incentive to attract investments.

- Where appropriate, electricity exports may provide particular advantages if the load curves of export and import countries complement each other. This export option can be further incentivized by establishing regional renewables targets for several countries that can be partially fulfilled by imports. However, to avoid overlapping with Clean Development Mechanism (CDM) incentives and to facilitate the transition to a low-carbon economy in the importing state as well, only physically imported electricity amounts should be taken into account for compliance with renewable targets in the importing country. The new European Directive on the promotion of the use of energy from renewable sources (2009/28/EC) provides for such an opportunity of physical imports from countries outside of the EU to match Member States' renewables targets.

  To achieve deployment, a number of advanced challenges must be addressed step by step, including the following:

  - The installation of large, high-voltage, direct-current transmission (HVDC) to the receiving country.
  - The establishment of appropriate framework conditions that ensure secure and reliable transmission through transit countries.
  - The integration of the electricity into the renewable and overall energy strategy of the receiving country.

[23] 8780 hours per year * 0.4 = 3504 full load hours * 20 GW.

[24] IEA figures of total electricity generation and CO_2 emissions caused by the current global energy mix (cp. WEO 2008) lead to avoided emissions of about 0.6 t per MWh renewable electricity generation.

Nevertheless, if managed soundly, energy exports remain a promising option.

Implementation

A comprehensive, holistic approach would be needed to evaluate, verify, and address the various aspects and challenges of a global wind plan.

A global wind plan should build on the knowledge gathered in the course of the implementation of the recent *Mediterranean Solar Plan* (MSP) within the Union of the Mediterranean. The MSP focuses on establishing the necessary infrastructure and legal framework conditions for large-scale CSP projects and wind energy projects in the Middle East and North Africa (MENA) Region. Close cooperation with the secretariat of the Union for the Mediterranean should be taken into consideration; value may be added by joining forces. Existing institutions could also provide value for implementation of this global wind plan. For instance, the recently founded International Renewable Energy Agency (IRENA) could contribute, with a view to capacity building, know-how transfer, and policy advice, including projects-related technology assessment, as soon as it comes operational and in cooperation with other existing institutions as appropriate.

This initiative would have to evaluate access to existing and new and innovative finance instruments to attract investments.

Demonstration of Small- and Medium-Sized Wind Turbines: Paving the Way for Rural Electrification and "Grid Parity"

Small wind power generation systems represent a promising opportunity that should be developed more intensively. MEF countries could start an initiative to evaluate their abilities to join forces for demonstration projects of small wind turbines in developing and emerging countries at sites with very high wind resources.

Such demonstration projects could lead to a win-win situation for the following reasons:

- Small wind turbines have considerable potential for rural electrification.
- Small turbines are promising for tapping unused onshore wind in industrialized countries.
- Small turbines could facilitate ―grid parity‖ when built in tandem with building-integrated PV applications and storage technology.
- Combining demonstration projects with capacity building initiatives would ensure constant high-level know-how for O&M services.
- Joint evaluation and implementation would lead to intensified joint technology assessment and technology cooperation, as well as exchange of expertise and know-how.

Background

Rural electrification

Today, 1.5 billion people in the world have no access to electricity. In 2009, the IEA estimated that this figure will only decrease slightly to 1.4 billion by 2030 if there are no ambitious electrification efforts taken (IEA WEO 2009).

In the context of rural electrification, small- and medium-sized wind turbines, with a rated power of 10–600 kW, could compete with diesel generators and would realize competitive advantages. Compared to diesel generators, wind turbines have higher upfront investment costs; however, operation costs are very low because wind turbines do not need fuel for operation. The cost situation for diesel generators is the opposite. Estimates on behalf of the German Federal Ministry for the Environment indicate that diesel generators operate at levelized electricity generation costs of US$0.20–0.30 per kWh (depending on local fuel prices, Prognos 2009[25]). Due to the large influence of oil prices, the cost of diesel generation may vary even more.

This initiative would need to address several challenges, including the following:

- A backbone network of a stiff medium- or high-voltage grid, which connects local small and separated grids, would likely need to be installed.
- Modern small wind turbines capable of network support services would have to be used in order to allow for high wind power penetration in a potentially weak local grid.
- Appropriate balancing storage capacity would be needed. The need for battery tanks as storage media could possibly be reduced by excess electricity production, which could be achieved through a respective rotor diameter setup. Excess electricity could be fed into a heating system. The combination with solar systems could support balancing wind power.

***Exploration of untapped onshore p**otentials and the way for "grid parity"*

Small- and medium-sized wind turbine installations show promise in areas that are difficult to access for larger megawatt turbines, such as isolated areas or areas where land use conflicts would prevent permitting. Small or medium turbines could be installed in areas with high, untapped wind resources in industrialized countries.

Though small- and medium-sized wind turbines have been in operation in many countries for quite a period of time, they often do not reflect state-of-the-art technology standards for large-megawatt turbines. They particularly lack modern network support technology, which is needed to integrate large shares of fluctuating wind power into the grid. Some companies produce small- and medium-sized wind turbines with integrated modern network service technology today, but the majority of companies concentrate on technology progress for large-megawatt turbines. Industrialized countries could benefit from a large-scale demonstration project for small- and medium-sized wind turbines to encourage integration of modern turbine technology. Such a pilot project would also allow small- and medium-sized wind turbines to be tested, as appropriate, in complex terrains and at sites where the wind resources are very high.

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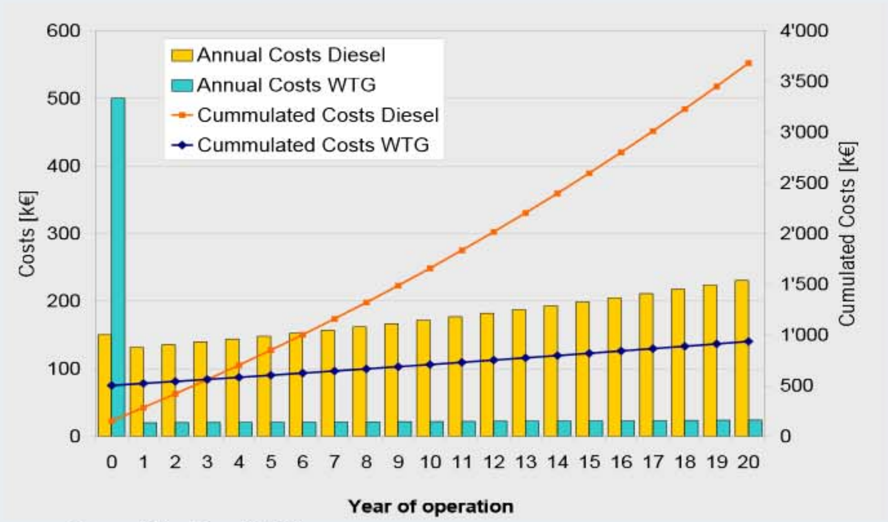
[25] Based on current Chinese diesel prices according to the IEA Energy statistics (http://data.iea.org).

Case Study: East Indonesia

For example, in a site-specific feasibility study for East-Indonesia, the German WindGuard concluded in 2005 that assessed wind speeds in East-Indonesia are sufficient to cover local demand. Currently, electricity in Indonesia is produced almost entirely from diesel generators (WindGuard 2004). The study concludes that after several years of operation, cumulative costs of diesel generators would exceed those of wind turbines (after 20 years by four times for the site under consideration).

Moreover, the study concluded that electricity generation costs of diesel generators amounted to US$0.32/kWh in East Indonesia in 2005. Public subsidies cut the selling price for electricity generated from diesel generators to US$0.053/kWh. It was calculated that, in a start-up project, electricity generation costs from small wind turbines would already be 20% lower than the electricity generation costs from diesel. Start-up costs for a demonstration project for small wind turbines are specifically higher and include, for example, costs of establishing appropriate logistics, installation infrastructures (cranes, grid connection), spares inventory, etc. However, the study assumes that these specific costs would be significantly lower if small wind turbines were installed on a massive scale. The German WindGuard Study estimated investment costs of about US$6 million for a first pilot project covering a total capacity of 2.6 MW.

Figure 7: Example for the Comparison of Costs for a Diesel Generator and a Wind Turbine at a Remote Site in Indonesia



Source: WindGuard 2004

Well-proven small- and medium-sized wind turbines could also help encourage grid parity. Grid parity refers to the point in time when building-integrated PV is less expensive than household electricity prices. In many countries, this may be reached by 2020. Small wind turbines, if well-tested, could be competitive with household electricity prices today if applied, for example, on a farm or on large private premises. The IEA estimates today's electricity generation costs from standard wind turbines to be in a range between US$0.06/kWh at the best wind sites, and US$0.13/kWh at sites with low average wind speeds (IEA 2008c, see also Appendix B). Even taking into account the specifically higher investment costs for smaller wind turbines, estimates by the German WindGuard in support of this *Technology Action Plan* indicate that electricity generation costs today could be significantly below US$0.20/kWh in areas which are difficult to access, and therefore below household electricity prices.

Further verification and evaluation would be needed in the course of this joint initiative by MEF countries.

Implementation

A comprehensive, holistic approach would be needed to evaluate, verify, and address step by step the various aspects and challenges of this initiative.

Existing institutions could support implementation of this initiative. For instance, IRENA could provide value, with a view to offer capacity building, know-how transfer, and policy advice, including project-related technology assessment, as soon as it becomes sufficiently operational and in cooperation with other existing institutions active in this field.

This initiative would have to evaluate access to existing and new and innovative finance instruments to attract investments.

Joint Standard Setting

Proposed Technology Cooperation

Uncertainty in the level of required quality, performance, and safety of products and services constitute market barriers to technology cooperation. Common rules and standards could help overcome this barrier.

MEF countries could consider launching an initiative on joint standard setting regarding:

- Technical standards
- Labor and safety standards
- Grid codes

Joint standard setting will offer a valuable opportunity for technology cooperation, know-how transfer, and joint technology assessment.

Background

Technical Standards
Technical standards in wind energy, like in any other industry, are set on a national and international level (Appendix A), for example, for testing of rotor blades, power performance, power quality of wind turbines, etc. These existing standards need to be improved as technology develops further and new techniques emerge (e.g., wind resource assessment, new wind measurement techniques, offshore applications).

Labor and Safety Standards
The level of harmonization is low regarding international labor and safety standards. This often constitutes a market barrier and limits access to qualified staff. For example, qualification certificates for critical skills—such as welding or safety training, like offshore rescue, helicopter or underwater escape, and height rescue—are different in each country and consequently not accepted in others. Employees from one country may have difficulties working on wind turbines in other countries. This problem multiplies with respect to large international offshore wind farms.

Grid Codes
Grid codes establish minimum security requirements for wind installations to be connected to the grid. Whereas in the United Kingdom, one general grid code regulates all technical terms of generation and demand, in Germany, each transmission system operator determines its own grid code. With increasing market penetration of wind energy, different grid codes may constitute a market barrier.

Technical Standards for HVDC (High Voltage Direct Current) Transmission
Harmonized technical standards for HVDC transmission lines would be vital to ensure that grid connection between different countries on the HVDC transmission level will be possible.

Implementation

MEF countries could consider launching a joint discourse on harmonizing standards. This joint effort would facilitate technology cooperation and knowledge exchange in the spirit of the global partnership.

Establishing a Global Wind Atlas

Background

Consultation with industry and experts in the field of wind energy illuminates the fact that global investments are often hampered by insufficient information on investment conditions, potentials, legal and economical conditions, and administrative hurdles in other countries. Moreover, improvement of wind modeling is needed in order to further improve the comparability of data on global and regional wind energy potential. Currently, existing analyses are hard to compare because they differ with respect to their underlying assumptions. There is a lack of a comprehensive analysis that compares the global and regional potential based on a consistent and integrated methodology.

Proposed Technology Cooperation

It is proposed that MEF countries jointly develop a global wind atlas that could comprise:

- **A global wind map** on the inventory of the wind energy potential with a high spatial and temporal resolution to allow most accurate global, regional, and national renewable energy modeling. This model should follow a comprehensive, holistic approach taking into account all regions and all renewable technologies.
- **A global wind database** on all relevant site-specific investment information, including regional potential economic framework conditions and legal, technical, and administrative information, such as local know-how and needs for capacity building.
- **A region-specific technology assessment** indicating which onshore and offshore wind energy projects and which specific turbine classes could achieve most valuable benefits under region-specific conditions.
- **Improved wind modeling based on a comprehensive, holistic approach,** which should illustrate future wind technology development based on an enhanced understanding of the basic science and engineering of wind turbine technology and of the complexity of wind resource on many different levels

(e.g., temporal, spatial, turbulences, wake effects, forecasting). This is important to give first indications on the value of possible wind project investments but could not, however, substitute a detailed anemometric site study, i.e., the wind measurement on site.

By jointly analyzing potentials, collecting policies and strategies, and assessing technologies, enormous impetus can be triggered for knowledge transfer, spill-over innovation, technology transfer, and best-practice synergies. The cooperation output between collaborating countries could be deepened through continuous updating.

Implementation

This initiative can be started immediately. The initiative should identify existing measurement and reanalysis data which could, as appropriate, assist the local and regional adaptation of the model.

As soon as it is operational, IRENA could help implement this initiative by providing and further developing renewable energy resource data and by developing renewable energy modeling, in close cooperation with all relevant institutions in this field and, in particular, the IEA.

Establishing an International Wind Technology Platform

Proposed Technology Cooperation

Consultations with the industry indicate that information deficits and a lack of constant consultation between policy, industry investors, and other stakeholders are still main barriers for the global distribution of wind technology.

Establishing an international technology platform (ITP) can help to systematically address this deficit and to promote an intensive dialogue between governments and industry. Moreover, such a platform can help to match the demand and the supply for specific technologies. Consultations during the course of drafting this *Technology Action Plan* have illustrated that industry often has different needs than those addressed by policy.

The ITP would be a valuable tool for constant technology cooperation. Through the ITP, information about technology needs can be communicated to interested parties at every level of detail required. Experienced stakeholders should be involved to deliver meaningful input and to enrich dialogue and cooperation. Large cooperation networks can be created to trigger the dissemination of information about wind technology and to link stakeholders all over the world. The ITP will thereby foster accelerated wind technology deployment as an important part of a broad basket of energy technology options for future energy security.

In particular, the ITP could hold collaborative workshops targeting a range of R&D and industry-wide issues such as:

- Quality/reliability of wind turbines
- Issues/strategies for systems/grid integration
- Public acceptance, environmental impacts, and sustainability of production chain
- New trends and novel concepts

- Repowering
- Support policies and financing instruments

Implementation

Existing institutions and initiatives such as IRENA, IEA implementing agreements, and the European Technology Platform could join forces and establish a constant dialogue in close cooperation with the global partnership.

Joint Capacity Building, Knowledge Transfer, and a Global Wind Energy Training Center

Proposed Technology Cooperation

Qualified staff and local knowledge on wind turbine operation is a prerequisite for massive global wind technology deployment.

Therefore MEF countries should foster a comprehensive, long-term strategy for capacity-building and knowledge transfer on a global level, covering the development of all wind technologies, and permanently gathering, concentrating, and updating all relevant information. Examples for concrete capacity building needs indentified in the wind sector include:

- **A joint capacity building initiative on advanced O&M services**, because advanced O&M strategies enhance technical availability of wind turbines, thereby reducing variable costs.
- **A knowledge transfer initiative on offshore planning**. Appropriate know-how for streamlined and integrated planning and permitting procedures is of significant importance to attract investments. The experience gathered by leading offshore countries could be made available to other countries.

MEF countries could consider supporting the establishment of a Global Wind Energy Training Center. There is a significant need for wind-specific training in several fast growing wind markets. Wind energy training could include:

- Training on wind turbine testing according to international standards
- Training on wind farm power output-forecast systems
- Training on wind resource analyzing and micro-siting

Background

Joint efforts for capacity building and knowledge transfer are of utmost importance to foster investments in wind technology. Qualified professionals and stakeholders are needed all along the value chain: officials need to be well-skilled as they are responsible for favorable legal framework conditions; engineers and technicians need expertise on the proper design, construction, operation, and maintenance of turbines; lawyers have to be familiar with the national and international legal implications; and financing institutions need specific background to adequately evaluate the bankability of wind energy projects.

Training is most effective when accompanied by practical implementation, e.g., applied technology cooperation. However, there is a variety of capacity building needs that are broad and should always be adapted to the technology and local conditions, starting earlier than the practical implementation and going beyond it. Therefore, a strategic and long-term approach for capacity building and knowledge transfer on a global level is needed, covering the development of all wind technologies and permanently gathering, concentrating, and updating all relevant information in the wind sector.

One concrete example for capacity building needs would be a joint capacity building initiative on advanced O&M services. During their potentially 20 years of lifetime, wind turbines have to be operated 24 hours per day with a maximum availability. Low quality in operation and maintenance results in low technical availability of wind turbines. Each 1% reduction in availability means 1% or more loss in energy production. Several wind farms around the world do not operate at maximum availability. To put this into perspective, technical availability of only 70% results in more than 30% losses in energy and thus in economic revenues. This is due to a lack of qualified O&M services. To remedy this situation, a significant and sustainable program for training and further education for technicians and engineers is required. Therefore, countries with long-term experience in wind energy should launch a joint capacity building initiative on advanced O&M services (e.g., wind farm management procedures and systems, condition-oriented operation). This would create many new qualified jobs.

Another example concerns knowledge transfer for offshore planning. In several countries newly entering the offshore sector, permitting and planning procedures are not well-adapted to offshore projects. Procedures must slowly emerge, as they did over several years in leading offshore markets in Europe. Appropriate know-how for streamlined and integrated planning and permitting procedures is of significant importance to attract investments. Long, bureaucratic, and unpredictable administrative procedures put investments at risk, as time and planning predictability is a critical factor for investments in large offshore projects.

In the leading offshore countries in Europe, a large amount of work has been performed regarding approval procedures. In Germany, for example, standards were derived from the recent approval procedures describing subsoil investigations on sea ground, constructive design of offshore wind turbines, and investigations of the impact of offshore wind turbines on the marine environment. In Denmark, a so-called ―one-stop-shop‖ procedure exists to ease the approval procedure, particularly for offshore wind farms. In the UK, strategies for public relations showed positive results; when local residents were informed early and comprehensively, consent for the offshore project did improve.

The experience of the European countries could be made available to other countries. Possible measures could include international training workshops, practical training programs, and the provision of procedure documents in an Internet-accessible database.

In several fast-growing markets—such as China, which doubled its overall installed capacity in 2008 for the fourth time in a row (GWEC 2008a)—knowledge increase could not keep up with growing rates. These boosting markets need to make up for knowledge leaps on advanced questions of wind technology operation and integration in a very short period of time. Joint training measures on specific questions could add significant value.

Implementation

As soon as IRENA is operative, it could add value by implementing this joint capacity-building initiative in cooperation with other existing institutions active in this field, e.g., the Renewable Energy and Energy Efficiency Partnership (REEEP), which applies the reegle search engine[26] for information on renewable energy and efficiency.

26 www.reegle.info

APPENDIX A. WIND ENERGY TODAY AND TOMORROW

In the last three decades, the wind energy market has experienced vibrant growth. This growth can be attributed to the ambitious support policies in several leading markets, which have triggered rapid progress in technology development. This technological progress has brought down the cost of generating electricity from wind enormously, making wind technology competitive today—particularly in areas with a high-quality wind resource situated near the grid and in which energy prices (to some extent) reflect carbon costs.

Technology Development and Perspectives

History

The first wind turbines for electricity generation were invented as early as the end of the 19th century. Earlier applications served mostly for milling corn and pumping water. The first broadly applied wind turbine for pumping water was the American windmill, which was self-regulating and had a rotor diameter of up to 5 meters. Similar types of windmills can still be found in operation today in rural areas around the world. Serial production of wind turbines for electricity generation started only after the two oil price shocks in the 1970s. More than 15,000 small wind turbines with a rated power of about 50 kW and a 15 m rotor diameter were then produced and installed (e.g., in Denmark and California, USA). This marked the beginning of enormous technical development in wind turbines. The first megawatt (MW) wind turbines entered the market at the end of the 1990s.

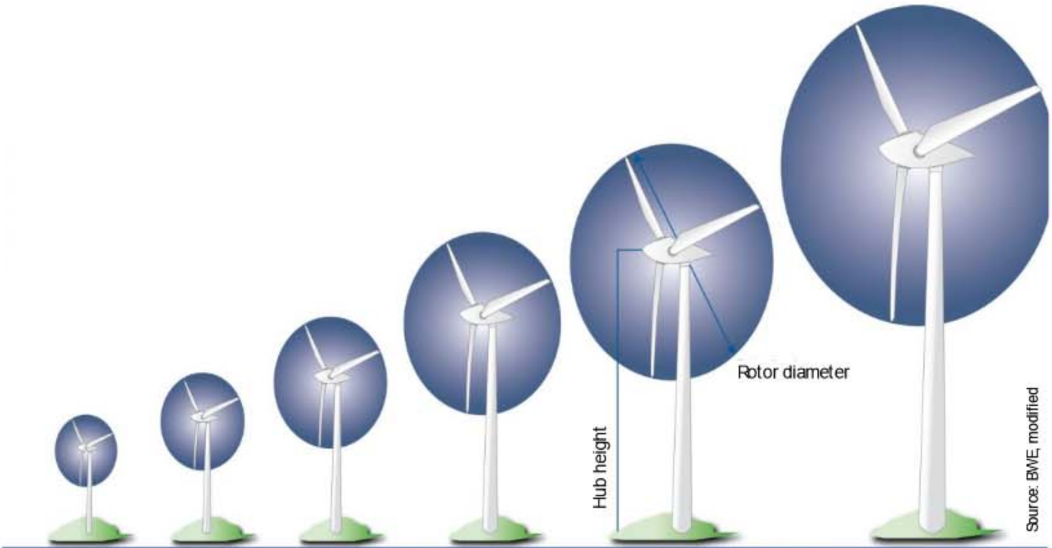
Standard Wind Turbines Today

Standard wind turbines today have a three-bladed, upwind rotor that operates on a horizontal axis. The rotor blades are made of glass and/or carbon fiber-reinforced plastics and have high-performance, aerodynamic profiles. This high-efficiency, lightweight design has proven cost-effective, despite high material costs.

These modern turbines, which have a rated power ranging between 1.0–3.0 MW, are normally connected to the power grid. The specific power ratings of installed wind turbines depend on the wind resource available, the topography, and the local infrastructure. Larger turbines with a rated power of 5–6 MW are currently produced on a small scale. Although they are still being tested, they promise leaps in efficiency. These larger turbines typically target the offshore market, but they are also being used in on-shore markets where repowering strategies are in effect. Such strategies involve replacing lower-power turbines with higher-power turbines to increase efficiency in regions that already have a high density of wind power utilization, as in Germany.

The rated power of commercially available wind turbines increased from 30 kW in 1980 to 6 MW in 2008 (see Figure 8). This rapid increase is attributed to the turbine's increased ability to intercept the wind resource, as affected by the height of the hub and the square of the diameter of the rotor. Growth rates have slowed slightly in recent years, reflecting the increasing maturity of wind turbine technology.

FIGURE 8. INCREASE OF COMMERCIAL WIND TURBINE SIZE



	1980	1985	1990	1995	2000	2005	2008
Rated power :	30 kW	80 kW	250 kW	600 kW	1,500 kW	3,000 kW	6,000 kW
Rotor diameter :	15 m	20 m	30 m	46 m	70 m	90 m	126 m
Hub height :	30 m	40 m	50 m	78 m	100 m	105 m	135 m
Annual energy yield :	35,000 kWh	95,000 kWh	400,000 kWh	1,250,000 kWh	3,500,000 kWh	6,900,000 kWh	~ 20,000,000 kWh

Source: BWE 2009b, modified

Today's megawatt turbines account for more than 99% of global installed wind capacity. A significant number of small and medium-sized wind systems with a capacity of less than 1 MW are also installed worldwide, mostly in off-grid applications. Although these small and medium-sized turbines account for only 80 MW of global wind capacity (IEA Wind 2009), they play important roles in providing electricity to remote areas of industrialized countries and in the rural electrification of developing countries.

For very small wind systems (i.e., wind turbines with a rated power below 10 kW), a wider range of design concepts is available on the market. For instance, two-blade systems are common, as are vertical-axis rotor types, like Darrieur and Savonius rotors. Although not well proven today, they may play a significant role as stand-alone home systems in the context of rural electrification in the future.

Today's Technology Efficiency Rates

Today's standard wind turbines achieve a maximum wind-to-electricity-conversion efficiency rate of up to 50% (BWE 2009c).[2/] This rate is close to the theoretical maximum practical conversion efficiency rate of 59.3% (Gasch/Twele 2007). Conversion efficiency has increased by approximately 25% over the past decades, largely as a result of improved turbine technology and more sophisticated operations and maintenance (O&M).

[2/] Efficiency of wind turbines with rated capacity of 1.5 MW to 2.5 MW.

Operational Availability of Wind Turbines

Today's highly skilled staff and advanced O&M concepts have increased the reliability of modern wind turbines. Modern on-shore wind turbines operate with a technical availability of up to 97% (i.e., wind turbines are ready for use 97% of the time and do not suffer from technical faults). Off-shore wind turbines operate with a technical availability of 80–95%, reflecting the relatively less mature technology (IEA 2009c). Of course, these high-end availability rates can only be achieved with highly skilled staff and advanced O&M strategies, which are not always in use, leading to lower technical availability rates in some systems.

Main Aspects of Technology Progress So Far

The following characteristics of modern wind turbines reflect key areas of technological progress:

- The **rated power** of wind turbines has grown by a factor of 200. The largest wind turbines today have a capacity of 5 to 6 MW and a rotor diameter of up to 126 meters.
- The change from fixed speed to **variable speed** improves exploitation of the wind resource and reduces mechanical stress. Until the mid-1990s, stall-controlled rotors working at two fixed speeds were common. This power-limiting concept has been replaced by optic-controlled rotors, which are able to work at variable speeds, thus adapting to wind speeds and optimizing both turbine efficiency and integration into the grid.
- **Decoupling and grid stabilization:** Electronic conversion systems allow decoupling the rotor and generator speed from grid frequency, which helps to achieve higher conversion efficiency rates and also provides network system stability. In case of a grid disturbance, wind turbines can remain in service and thereby facilitate restoration of stable grid operation.
- **Improvements in rotor blade aerodynamics** increase the efficiency rates of modern, variable-speed turbines by more than 10%, thereby reducing noise pollution and causing only minimal increase in production costs.
- **Weight reduction of rotor and drive train.** Construction of today's 5 MW-class turbines with rotor diameters in excess of 120 m is possible only with the reductions achieved in the weight of rotors and drive trains.
- **Standards:** The introduction of technical standards has reduced market barriers. So far, the International Electrotechnical Commission (IEC) has published 14 international standards for wind turbines (IEC 61400); additional standards are under development.
- **Advanced operation and maintenance strategies (O&M)** avoid expensive, long-term repairs and standstills of wind turbines, leading to lower operational costs. Early repair measures on main components, such as the gear box and generator, can avoid sequential failures and more than 90% of repair costs. Since wind farms have grown in size and are installed in more remote areas (including offshore), remote supervision and control have become important technical tools for O&M. Improved condition monitoring enables preventive O&M measures, such as replacement of certain bearings, to be scheduled and performed before major components become damaged.

- **Improved wind assessment methods** are of primary importance in stimulating investment. An accurate estimate of a wind project's annual energy production is critical to ascertaining its profitability. Accurate wind assessment is also essential for achieving optimal conversion efficiency rates, since it enables selection of equipment with the optimal rated power. Enormous efforts have been taken to improve the accuracy of meteorological measurements, wind forecasting, and simulation (e.g., 50-years meteorological reanalysis data and sophisticated flow-modeling tools).

Trends, Needs, and Emerging Technologies

Despite the remarkable progress in wind technology, further improvements are required to drive down costs, enable competitive operation in locations with lower wind speeds, and improve technology efficiency in sites with complex terrain (e.g., cold climate, offshore, deserts). Some examples of current trends in technology development are described below.

Further Growth in Size

To improve the capability to exploit promising wind sites, it will be necessary to further increase the rated power of wind turbines. This improvement will require new concepts and improved, light-weight, high-strength materials to reduce the turbine weight and to ensure resource efficiency. Advanced logistic strategies will also be needed.

Advanced Remote Control and Real-time, Online Monitoring

The largest wind farm in operation today, with a total capacity of 780 MW, is located in Texas, USA, and comprises 627 wind turbines (E.ON 2009). Efficient wind farm operation requires remote control of each turbine. Modern wind turbines are equipped with sophisticated controllers with full remote control, enabling fault messaging. There is a clear trend toward real-time, online monitoring and remote intervention to enable immediate response to malfunction messages. A further enhancement concept could be the development of self-diagnostic systems to minimize the escalation of minor faults into serious failures (IEA 2009c). While condition-monitoring systems have been developed to detect potential wear and damage on the drive trains of multi-MW wind turbines, similar monitoring of the rotor requires further R&D.

Improved Wind Assessment, Energy Yield Prediction, and Wind Forecast Models

Current wind assessment methods still suffer from uncertainties. An accurate wind assessment and forecast is critical to calculate return on investment and efficiently integrate large shares of fluctuating wind power into the system. An enhanced understanding of the wind resource is needed on many levels, including temporal, spatial, shear, turbulence, wake effects, and more.

New Turbine Design Concepts

Future development will require the design of even more robust turbines for reliable operation in harsh environments and complex terrains, such as offshore, cold climate, or typhoon areas. New design concepts aim to improve reliability by reducing the number of components subject to possible failure and enhancing system redundancy (e.g., by using electronic components and auxiliary drives).

New concepts for driving generators could minimize electrical losses and reduce weight and maintenance. Such concepts could include, for example, the self-excitation of synchronous generators using permanent magnets or hybrid gearbox generator systems.

Currently, progressive new offshore concepts are under discussion. These include two-bladed, downwind turbines and floating foundations for deep, offshore projects. The one-bladed rotor concept with teetering hub and nacelle could re-emerge and offer new concepts for dynamic loads. Some of these new technologies will be tested in the near future. If proven economically and technically feasible, they might open the door to tap new wind resources and increase the competitiveness of wind power.

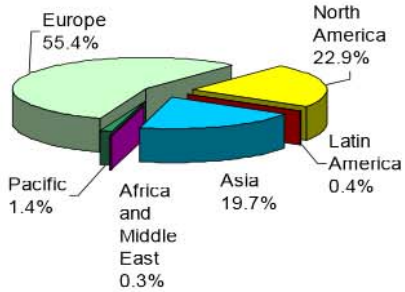
Market Development and Perspectives

Current global installed wind capacities amount to approximately 121 GW, reducing CO_2 emissions annually by 163 Mt. The five leading markets, the United States, Germany, Spain, China and India account for approximately 75% of the global installed wind capacity due, in large part, to their ambitious support policies.

Regional Wind Energy Markets Today

By 2008, more than half of global wind capacity was installed in Europe. The other two principal shares, each representing approximately one fifth of the global capacity, were installed in North America and Asia. The Pacific region, mainly Australia and New Zealand, accounted for approximately 1.4% of total installed capacity (see Figure 9, GWEC 2008a).

FIGURE 9. TOTALLY INSTALLED CAPACITY IN 2008 BY REGIONS



Source: GWEC 2008a.

European countries started early in establishing appropriate framework conditions for wind development and deployment, including supportive policies and ambitious R&D efforts. Thus, most European countries have experienced a steady increase in wind capacity and resulting wind shares of total electricity production.

Until 2008, Germany led the market in cumulative installed capacity. Driven by vibrant growth in the wind energy market, the United States has now taken over that lead. With growth rates of approximately 50% per year, the United States has held the record in annual wind power capacity installation for the past two years, nearly doubling its cumulative installed wind capacity (IEA 2009c). The United States recently achieved a cumulative installed capacity of more than 25 GW, soon followed by Germany as a close second.

In offshore wind capacity, Denmark has long been the world leader and has more than 650 MW capacity installed. However, the United Kingdom is becoming the next world leader by reaching a cumulative installed capacity of 566 MW in 2008 (GWEC 2008a) and impressive growth rates in view. The UK government published a Renewable Energy Strategy in June 2008, proposing 14 GW of onshore and 14 GW of offshore wind by 2020. Achieving this goal would increase the UK's current installed capacity by eight times in 12 years (GWEC 2008a).

France achieved 3.4 GW of installed capacity in 2008 and enjoys an annual growth rate of 38%. In 2008, wind energy became the fastest growing energy source in France with 950 MW newly installed (GEWC 2008).

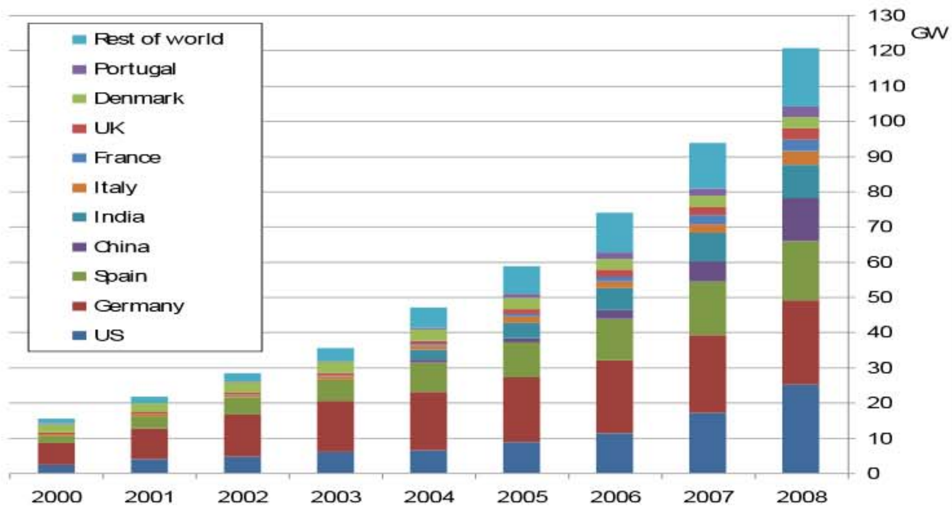
About 78% of the global installed capacity is in Europe and North America, while wind resources in the rest of the world are still largely untapped. For example, in Asia, North Africa, and the Caribbean region, wind energy deployment is largely at an early stage (see Figure 10). Nevertheless, the perspective for future dynamic growth in these regions is promising, given their tremendous local wind resources.

For example, China's wind market is growing at an extraordinary pace, doubling in 2008 for the fourth year in a row. Given this dynamic growth stimulated by ambitious national targets and governmental support, China is likely to challenge the United States and Germany for the top spot. Other Asian countries also witnessed significant and steady annual wind capacity growth rates; India and Japan's annual growth rates of about 23% in 2008 are particularly impressive. In sum, Asia doubled its cumulative installed capacity within the last five years.

Australia possesses spectacular wind resources and is leading the wind market in the Pacific (see Table 2). After several years of stagnation, development has again picked up. In 2007, the government released a 2020 renewables target of 20%, expanding the national Renewable Energy Target (RET) for wind by four times, and essentially setting an electricity quota of 45 GWh in 2020. Australia experienced the strongest growth ever in 2008, resulting in 482 MW of new installations—a 58% jump in total installed capacity (GWEC 2008a).

Looking at wind power as a share of domestic electricity supply, the five countries with the highest shares are all European (see Table 2). The front-runner, Denmark, supplied approximately 20% of its electricity demand from wind power in 2008, followed by Spain, Portugal, and Ireland, all of which supplied an estimated 10%, and Germany, which could supply about 7% of its electricity demand with wind power in 2008. On days with very high wind speeds, wind power today can reach up to 100% of grid penetration in some areas, such as Denmark.

FIGURE 10. GLOBAL CUMULATIVE INSTALLED WIND CAPACITY, SHOWING TOP TEN COUNTRIES 1990 – 2008



Source: IEA 2009c, modified

TABLE 2. WIND POWER SHARE OF DOMESTIC ELECTRICITY DEMAND OF SELECTED COUNTRIES

Country	Wind Power Share of Electricity Demand	Reference Year / Remarks
Denmark (integrated in the Nordic Market)	19.3%	2008
Spain	11.7%	2008
Portugal	11.3%	2008
Ireland	8.8%	2008, estimated
Germany	6.5%	2008
Europe (EU)	4.2%	2008
India	1.6%	2006
USA	1.9%	2008
Australia	1.3%	2008
China	0.4%	2007, estimate based on 2007 wind production & 2006 electricity consumption

Source: IEA Wind 2009 and GWEC 2008a

Wind farms installed in the EU by the end of 2008 are estimated to produce a total of 142 TWh per year (GWEC 2008a). This equals approximately 4.2% of the EU's total electricity demand and amounts to a reduction in CO_2 emissions of 108 million metric tons per year.[28]

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[28] Calculated as energy-related CO_2 savings relative to the mix of conventional power generation in the *ETP* Baseline scenario.

Perspectives of Market Development

Given that currently installed global wind power represents only about 0.19–0.21% of the estimated overall technical potential (DLR 2009, Greenpeace 2008), future growth rates for wind energy remain highly promising. To put this into perspective, studies state that 30,400 TWh of wind energy are economically available in the EU alone, which is seven times the projected electricity demand in 2030 (EEA, 2009, IEA 2009c). The largest growth is expected in onshore wind projects, since much of the wind potential on land remains untapped and investment costs are significantly lower in comparison to offshore projects (IEA 2008c).

Offshore Wind Energy is about to Take Off

A total of only 28 offshore wind farms have been commissioned worldwide, even though the first offshore wind farms were erected in 1991 (e.g., Vindeby, Denmark), and large-scale wind farms followed in 2002 and 2003 (e.g., 160 MW + 290 MW at Horns Reef and 166 MW at Nysted, Denmark). Today's offshore installations are mainly located in the north of Europe, representing about 1.5 GW of installed wind capacity.

In 2009, the offshore market seems ready to take off. Several countries have undertaken enormous R&D efforts to establish appropriate framework conditions, including advanced support incentives and infrastructure projects, to pave the way for dynamic growth in the offshore market. As a consequence, several offshore wind farms are planned, including the following projects:

- Great Britain is planning the offshore wind farm London Array, the first phase of which consists of 175 turbines to be installed more than 20 km (12 miles) off the Kent and Essex coasts. A total of 341 turbines are planned.
- In Denmark, construction for the offshore wind farm Roedsand II has started and the farm will be commissioned in 2010. Rodesand II will become one of the largest offshore wind parks—only Horns Reef II with 209 MW is bigger. It will consist of 90 turbines south of Lolland Island, providing a total installed capacity of 207 MW.
- The first offshore wind farm in Germany will be Alpha Ventus in the Nordic Sea. Alpha Ventus will be installed at a distance of 45 km from shore and provide a total capacity of 60 MW. This recently launched project is characterized as the starting signal for increased offshore development in Germany.
- In China, construction on the country's first offshore wind farm, the Shanghai Donghai Bridge, started in 2009. This offshore project will consist of 34 turbines with a total installed capacity of 102 MW (EWEA 2009b).
- ANEV, the Italian Wind Energy Association, estimates that Italy will have 200 MW of offshore wind power capacity installed by 2020.

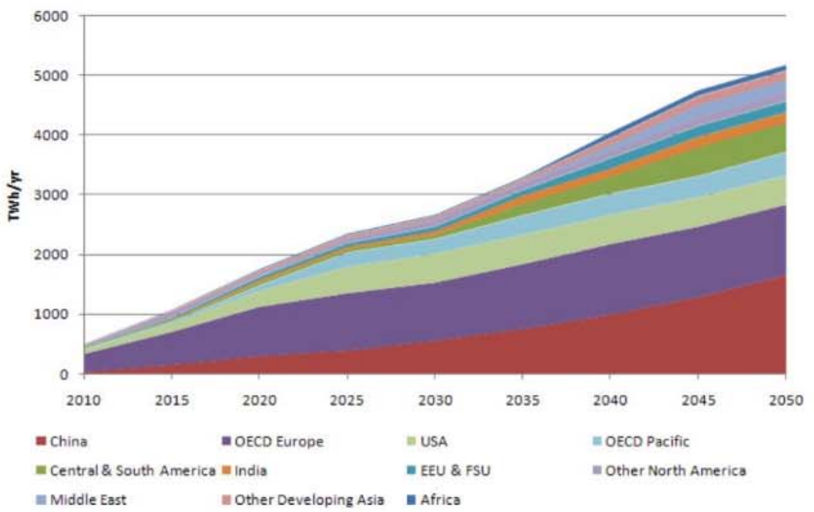
The wind industry estimates that 40 GW of offshore wind capacity will be installed in Europe by 2020. This target implies an average annual market growth of 28% over the next 12 years (EWEA 2009b).

Regional Market Perspective

In Europe, a stable market with slight growth is expected. Countries with a high density of onshore wind power utilization, such as Germany and Spain, might face somewhat lower growth rates, but steady growth nevertheless. Repowering initiatives (i.e., replacing existing small and medium-power turbines with larger MW turbines) will become a critical factor in further dynamic growth for these regions.

As shown in Figure 11, North and South America, Asia, and the rest of the world are expected to exhibit rapid growth (BTM 2009). India and China represent particularly important growth markets for wind power. China and Europe together are likely to generate wind power equal to more than 50% of global electricity generation (BTM 2009).

FIGURE 11. REGIONAL PRODUCTION OF WIND ELECTRICITY IN THE ETP 2008 BLUE MAP SCENARIO



Source: IEA 2009c

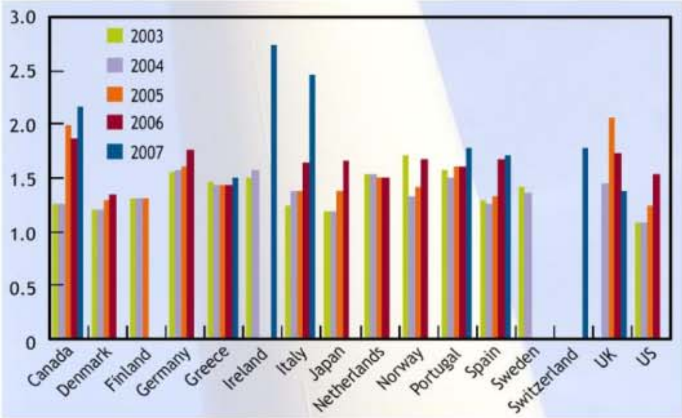
Economics of Wind Energy

Current Status of Development Costs

Investment Costs

Investment costs for wind energy projects vary widely (see Figure 12) depending on grid requirements, external conditions (e.g., complex terrain), infrastructure, and turbine prices (IEA 2008c). In 2008, reported investment costs (including turbine, grid connection, foundations, infrastructure, etc.) for European onshore projects ranged from US$1.45-2.6 million per MW installed (€1-1.9 million). In North America, investment costs ranged from US$1.4-1.9 million per MW (€ 0.98-1.3 million); in India and China, investment costs were about US$1 million per MW (€1.45) (IEA 2009c).

FIGURE 12. INVESTMENT COSTS IN SELECTED COUNTRIES: 2003 TO 2007 IN USD MILLIONS PER MW



Source: IEA 2008d

The steady cost reductions achieved through economies of scale since the late 1980s helped investment costs remain relatively stagnant until 2004, when they rose considerably. This increase was driven by the limited supply of turbines and components (including gear-boxes, blades and bearings) available to meet increasing demand; to a lesser extent, increased commodity prices (particularly for steel and copper [IEA 2009c, IEA 2008c]) also contributed. Commodity prices are critical, since turbine costs make up the lion's share of overall wind project investment costs. During the current recession, the turbine market has loosened, offering a window of opportunity to invest at lower costs.

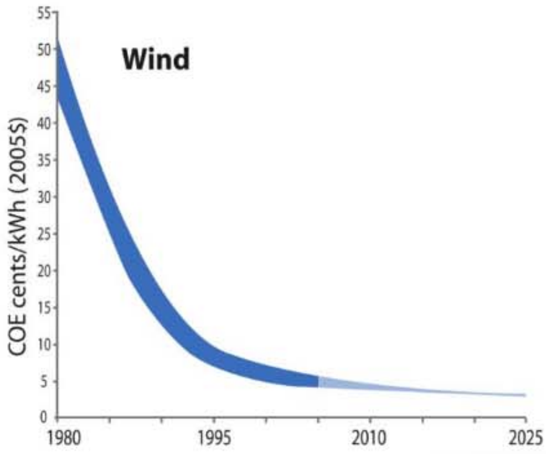
Offshore investment costs are difficult to assess, particularly as data is sparse and projects vary widely in nature. For example, investment costs depend to a significant extent on the water depth, the grid infrastructure needed, and whether financing will be provided by the operator of the wind farm. The IEA estimates that offshore investment costs could be more than double the cost on land. For instance, 2008 investment costs ranged from US$3.1 million (€2.1 million) per MW in the UK to US$4.7 million (€3.2 million) per MW in Germany and the Netherlands, as estimated by the IEA (IEA Wind 2009, IEA 2009c).

Electricity Generation Costs

Although overall investment costs have remained virtually unchanged, investments in wind energy projects have become far more attractive due to the increased efficiency of wind turbine technology. Onshore production costs decreased over the last two decades by approximately 80%. Levelized wind electricity generation costs are estimated today to be in the range of US$0.06–0.09/kWh at sites with high average wind speeds and US$0.09–0.13/kWh at sites with low average wind speeds (IEA 2008c).

The exact electricity generation costs depend on various factors, including investment costs, costs for operation and maintenance, full-load-hours, wind speed, and turbine efficiency. For offshore projects, reliable cost estimates are difficult due to the relative immaturity of the technology. In 2008, electricity generation costs are estimated by the European Wind Energy Association to range from US$0.11–0.13/kWh (€0.75–0.90/kWh) (EWEA 2009e, IEA 2009c).

FIGURE 13: WIND ENERGY COST TRENDS. LEVELIZED COST OF WIND ENERGY IN CONSTANT (2005) US$[29]



Source: NREL 2005

Tomorrow's Cost Reductions

Onshore

Further decreases in the cost of wind energy projects are expected on the basis of promising technology learning curves (see Figure 14). Past experience shows learning rates of 8%, i.e., every doubling of cumulative wind power capacity lowered investment costs by 8%. The IEA's *ETP* BLUE Map scenario assumes future learning rates for investment costs of 7%. This would lead to a 23% decrease in investment costs for onshore wind energy projects by 2050 (IEA 2009c). Other studies predict even lower costs, such as a 27.5% decrease in onshore investment costs until 2050 (Greenpeace 2008, AT: DLR 2009).

Learning curves for electricity generation have been even higher in the past (between 18 and 32%). To put these figures in perspective, future learning curves for fossil-powered systems, such as IGCC (integrated gasification combined cycle) or CCS technologies, are so far assumed to equal only about 3% (IEA 2008c).

Future electricity generation costs for onshore wind power are expected to come down to about US$0.05–0.06/kWh in 2015, depending on the region of the world (IEA 2008c).

Offshore

An even larger potential for cost reduction is assumed for offshore wind energy. Overall, project costs are likely to remain high due to the complex process of wind site selection, logistics, challenging weather conditions, and increasing demand for offshore turbines. Nevertheless, significant reductions in investment costs are likely to be achieved. The IEA *ETP* BLUE Map scenario assumes learning curves of 9% for offshore wind energy. As a consequence, the IEA estimates that investment costs for offshore wind energy projects will decrease about 38% by 2050 (IEA 2009c).

Other studies assume even greater cost reductions for offshore wind energy—up to 50% by 2050 compared to today's investment costs (Greenpeace 2008, DLR 2009). The German-led study by the Federal Ministry of Environment estimates an impressive 57% decrease by 2050 (BMU 2008, DLR 2009).

In terms of electricity generation costs, estimates indicate that about US$0.10 (€0.071) per kWh can be achieved in 2020 and US$0.088 (€0.061) per kWh in 2030 (EWA 2009a).

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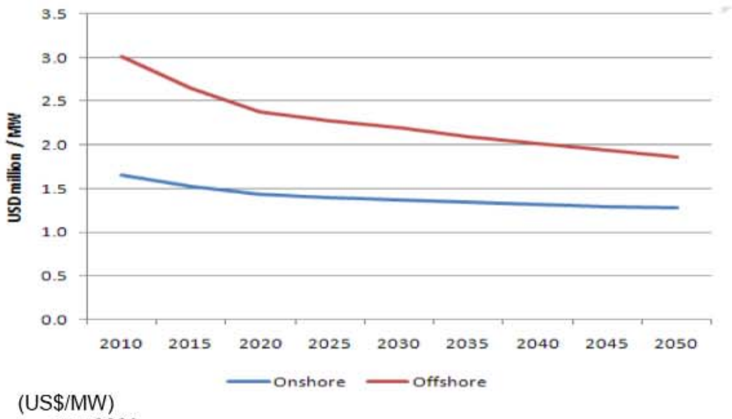
[29] These graphs are reflections of historical cost trends, and not precise annual historical data.

FIGURE 14. ETP BLUE MAP PROJECTIONS FOR ONSHORE AND OFFSHORE WIND INVESTMENT COSTS



(US$/MW)
Source: IEA 2009c

Competitiveness

Onshore wind farms today can already be cost-competitive with newly built conventional power plants if the wind farms are located with high wind resources, have close access to the grid, and the cost of carbon is reflected to some extent (IEA 2008d, IEA 2009c). Offshore wind is supposed to reach commercialization between 2035 and 2040.

The competitiveness of wind electricity could be further strengthened by a variety of measures that add flexibility to the power system. Examples include mechanisms for sharing reliability responsibilities over larger regions, growth of demand response, transmission expansion, and affordable storage.

Small wind turbines may realize a particular competitive advantage in the context of rural electrification. Even though small wind turbines have higher specific production costs than larger wind turbines, in the context of rural electrification they compete with diesel generators, which are estimated to generate electricity at levelized costs of US$0.20-0.30 based on local fuel prices (Prognos 2009).[30] These small wind-turbines require further cost reduction and reliability improvement.

Prospect of Very Low Variable Costs

Wind electricity generation from re-financed wind installations raises the prospect of costs considerably lower than those for conventional electricity generation. Since wind power, like other renewables, does not require fuel for its operation nor does it produce residues, it has the strong competitive advantage of very low variable costs, the potential of which could be fully realize once installation costs are re-financed. Within the last decade, wind turbines have proven their reliability.

[30] Based on current Chinese diesel prices according to the IEA.

Benefits of Investing in Renewables

Economic Growth and New Markets

Renewable support policies attract considerable private investment. In the EU for example, the total value added by investments in *renewable* projects in 2005 was worth more than US$80 billion (€58 billion). Global financial investments in *wind* technology in 2008 reached US$51.8 billion, which represents an equivalent 51% average annual growth for wind technology investments during the period 2004-2008 (UNEP 2009).

The continuing prosperity of the European renewable market, driven by the EU 2020 renewable energy targets, is estimated to induce investments amounting to approximately €130 billion of gross value added, which would induce up to a 0.25% net increase in the EU GDP of in 2020 (Ragwitz et al., 2009).

In leading wind energy countries, total revenue from wind energy had a notable impact on national GDP in the last few years. In Spain, for example, the wind sector provided 0.35% of the GDP in 2007 (AEE 2008a). In Germany, wind energy contributed a 0.23% share to the national GDP in 2008 (BMU 2009a), and the Danish wind turbine manufacturing industry alone contributed approximately 1.8% of Denmark's GDP in 2006 (Moneyweek 2006).

Employment in the Wind Power Industry Current

Investments in renewables are investments in jobs and lead to future markets with high growth rates. Qualified personnel are needed all along the value chain. The wind industry estimates that the wind sector provided employment for 400,000 people in 2008 (GWEC 2008a).

According to the European Wind Energy Association, 154,000 people were employed in the European wind sector in 2007 (EWEA 2009c). The German wind sector has created about 90,000 jobs. Spain employed 37,730 people in 2007 in the wind sector. In Spain, each 1% growth of GDP in the wind sector creates 0.42 jobs (this ratio being 0.34 in the whole energy sector) (AEE 2008b). The United States had 85,000 jobs in the wind sector in 2008, and Italy, 15,000 jobs (GWEC 2008a).

Employment in the Wind Power Industry Future

The growth of the wind power industry in the future is likely to require a steep increase in employment. The wind industry moderately assumes that one MW of installed capacity could support 15 jobs (falling to 11 jobs per MW by 2030). This means that wind energy development could support 535,000 to 2.2 million jobs by 2020 (EWEA 2009d). The U.S. Department of Energy published a report in 2008 predicting that wind energy would support 500,000 jobs by the year 2030 (DOE 2008). In the EU alone, direct employment in the wind industry is expected to more than double from 154,000 in 2007 to almost 330,000 in 2020 (EWEA 2009d). ANEV, the Italian Wind Energy Association, estimates 66,000 will be employed by its wind sector in 2020, mainly in rural areas.

Local Investments

Investments in wind technology generate local added value. For one, existing component suppliers tend to set up production lines in proximity to existing markets.

Locating close to established markets enhances their market presence and can reduce logistical or legal obstacles to market entry. So far, only a few suppliers have expanded into major global markets, but this trend is expected to gain momentum (BTM Consult 2009, IEA 2008c).

Consultation with industry indicates that the decision to set up local production chains depends on market size and other appropriate framework conditions for investment, such as legal certainty, protection of intellectual property rights, and the availability of qualified staff. Even without local production chains, local jobs are created to install the wind turbines and provide the other local services required for operation and maintenance of wind farms. Other services, such as local equipment manufacturing, project planning, logistics, financing, and craft services play an important role as well. O&M of wind turbines is already an important economic factor in certain regions. As wind turbine operations need no fuel, O&M costs are mostly labor. This creates jobs for skilled staff in rural areas. Estimates indicate that up to about half of the investment in a wind energy project is likely to consist of local investment and services.

Save Climate Change Costs and Other External Costs

As indicated above, renewables will presumably be available at lower energy costs in the future. If one takes into account the relative carbon costs, wind energy would be even more competitive today. Taking into account long-term macroeconomic factors, it becomes clear that the most relevant costs are the comparative costs of inaction.

Wind technology saves climate change costs, costs for energy imports, and other external costs, such as environmental or long-term health-care costs from pollution. The Stern Report impressively demonstrates that the costs of inaction by far exceed the costs of action. Unchecked climate change would cost between 5 and 20% of global GDP; active climate policy, on the other hand, will cost only approximately 1% (Stern 2006).

Energy Security

Investments in wind technology improve energy security in the long run by enhancing independence from energy imports and by providing stable and predictable wind energy prices. Avoided fossil fuel imports can improve a country's balance of trade considerably, depending on the amount avoided and the price for fossil fuels. Wind energy replaces energy produced through fossil fuels. For the EU, renewables are estimated to help save a total of about €100 billion in 2020 by avoiding fossil fuel imports (Ragwitz et al., 2009). In Spain, the Renewable Energy Plan 2005-2010 aims to avoid fossil fuel imports totaling €3,500 million (assuming US$50 per barrel of oil).

Future Competitiveness

Investing in clean energy technologies is a question of long-term competitiveness. To achieve the 2°C target requires phasing out the use of fossil energies. The transition toward a low-carbon economy is of utmost complexity for the energy system. New challenges will only become clear in practice. For example, balancing fluctuating energy supplies from renewables will require a comprehensive energy policy that provides larger balancing areas, smart grids, flexible and easily controllable power plants, and efficient storage technologies.

Spillover Effects and Synergies

Investing in renewable energy technologies accelerates market dynamics, facilitates a high level of innovation and synergy, and increases knowledge, which could have spill-over effects in the renewables sector (e.g., storage technology, system integration) and in the broader economy (e.g., electric vehicles, smart grids, smart domestic appliances, new technology concepts).

Know-how Transfer

Implementing wind projects requires capacity building to assure the availability of qualified service and technology-specific know-how. Capturing the vast, untapped wind potential in developing regions may initiate a global transfer of know-how, investments, and technologies through cooperation and capacity building.

Window of Opportunity

The current global and financial crisis has lead to lower investment costs for renewable energy projects. This coincides with the current need to stimulate the economy and create recovery programs. Currently, a unique window of opportunity has opened for low-cost investments in green technology for tomorrow's energy security and sustainable growth. Green recovery programs in many countries reflect this opportunity to a considerable content. Furthermore, countries that begin investing in renewables today can benefit from the technological progress and enhanced cost-efficiencies achieved over the last several years. By doing so, they could contribute to the further progress of technology and reduced costs.

APPENDIX B. FURTHER DETAIL ON BEST PRACTICE POLICIES AND GAPS

Increasing Demand for Wind Power

Green Power Purchase Agreements, Labeling of Additionality, and Improving Customer Awareness

According to global evaluations, green power markets grew strongly over the last few years in several countries. The worldwide number of green power consumers grew to 5 million households and businesses. In Germany, more than 1 million households purchased 2.8 TWh of green electricity; in the United States, 850,000 green power consumers purchased 18 TWh of green electricity; in Australia almost 950,000 green consumer purchases 1.8 TWh; and in Switzerland 600,000 green power consumers purchased about 4.7 GWh (REN21 2009).

Nevertheless, the market pull for new renewables deployment remains inadequate. One major hurdle is the lack of transparent consumer information on the origin of the energy mix (disclosure). The EU has launched the electricity labeling directive to tackle this issue with some progress. But the system does not work at full effectiveness yet due to the complexity of disclosure-related issues. Since renewable electricity, once fed into the grid, cannot be tracked physically toward the consumer, a certificate needs to be used as proof of electricity origin (guarantees of origin). Since the amount of electricity produced by old and already re-financed hydropower installations exceeds the overall consumer demand for renewables, these guarantees of origin can be achieved today at very low costs (in the EU currently a guarantee of origin costs significantly less than €0.01). This leads to a considerable drawback for marketing renewables since consumers pay higher prices for renewable contracts motivated by supporting renewables deployment, but do not set off additional deployment effects. This hinders market pull and could considerably affect consumer confidence.

Private eco-labeling initiatives attempt to overcome this gap by requiring that suppliers that want to sell an eco-labeled renewable contract have to invest a set amount of their margins into new renewable installations.

Grid Access and System Integration

New Transmission Infrastructure and Connecting Power Systems

High voltage direct current (HVDC)

High voltage direct current (HVDC) transmission is a promising solution particularly for bulk power transport of wind power over long distances. It reduces transmission losses and undesired load flows. For example, a feasibility study of the German Aerospace Centre (DLR 2009) has shown that for a HVDC transmission line from Africa to Europe only 10% loss would likely occur. In addition, HVDC transmission has a smaller land print than the alternating current system (AC) because it only needs two power lines instead of three. For example, a pylon construction for transferring 10 GW of electric capacity needs about 60% less space with HVDC than with AC (DLR 2009). However, this system is more complex than the alternating current system (AC) and requires more advanced communication between all terminals and power flow has to be actively regulated. Good examples for HVDC connections that have been or are being built can be found in China, India, the United States, Brazil, and Europe (e.g., the HVDC connection between the Netherlands and Norway).

Underground transmission cabling

The use of underground transmission cabling can enhance public acceptance of grid installations and therefore speed-up the permitting process. Even though they are rather costly at the moment, prices have come down over the last years and further cost reduction is envisaged through economies of scale. The German grid expansion act provided for four demonstration projects for ground cabling on the transmission level.

Power electronic devices for load flow control

Power electronic devices for load flow control, so-called FACTS (Flexible AC Transmission Systems) enhance the grid performance by responding to fast-changing network conditions by influencing the AC transmission parameters. The first installation was put into service 20 years ago. The full potential of this innovative technology can only be realized once a coordinated control scheme is implemented.

Improving Existing Grid Infrastructure

Dynamic line rating (vs. fixed line rating)

Today, the power carrying capacity of overhead lines is determined by their sag. The line sag depends on the conductor temperature and therefore on the ambient weather conditions such as air temperature and irradiation. The responsible transmission system operator (TSO) normally bases its calculations of the maximum power capacity according to international standards (IEC /CENELEC) on fixed weather conditions which reflect the worst case scenario. A dynamic line rating, which takes into account the current weather terms, such as wind cooling, could increase the transmission capacity by up to 50%.

Rewiring with low sag, high temperature wires

Another approach to overcoming the line sag problem is to rewire existing overhead transmission lines with low sag, high temperature wires. This is an easy and simplified approach since rewiring does not require complicated spatial planning procedures and therefore allow for quick permitting. The exchange of wires has already been approved, e.g., in Canada, USA, Switzerland and Italy.

Sufficient, Affordable Financing

Incentives for private investment

Cost of wind energy projects are determined by up-front capital costs, because wind turbines have only very small variable costs as they need no fuel for their operation. Wind energy projects typically require long-term financing, primarily from private investors. The financial sector prefers that policy frameworks to incentivize this funding are ―loud, long, and legal.‖ In other words, market signals, through incentive structures or other means, need to be sufficiently ―loud‖ and clear to attract capital into the sector. Rules and incentives need to be stable and sustained for a sufficiently ―long‖ duration to reflect the financing horizons of the projects. A ―legal,‖ established regulatory framework based around binding targets or implementation mechanisms is needed to provide the basis for long-life, capital-intensive investments (UNEP 2004).

With few exceptions, there is no ongoing discourse with the financial sector regarding the opportunities, technical risks, and mitigation mechanisms specific to wind energy. Risk-averse, large-scale, long-term financiers, such as pension funds, could be an attractive partner to wind investments. In addition, specialized renewable energy financiers – developers of closed funds for example – can access private investors who want to put small amounts of money into ethical investments, and might be open for facilitation of global cooperation.

Nevertheless, wind energy projects in industrialized countries mainly are financed by private capital. During the past decade, national banks gained sound experience with this type of project-finance and built up knowledge in wind energy business. Financing instruments from national or regional development banks, generally aimed at broad infrastructure support measures in industrial and developing countries, provide loans with favorable interest rates and payback conditions. Prior to the global financial crisis, financing of wind energy projects has not typically been a problem for developers in industrialized countries. However, during the current financial crisis, a decrease in project finance has been observed. Recognizing that onshore wind energy projects range from small- to large-scale projects, the challenge is to keep up and enhance possibilities for project finance to sustain dynamic growth and development of wind energy.

The financing situation for offshore wind energy is more problematic, as experience with this technology and the related risks are comparatively low. Moreover, the financial crisis has had a greater impact on offshore wind energy. Project finance has stagnated over the last years. New solutions are needed, particularly to keep up offshore project financing.

In developing countries the situation may differ. In some countries, where only few wind projects have been realized so far, project developers and financing institutions may lack the required experience to evaluate the financing aspects of wind energy projects. In addition, a lack of clear political support and, if the technology is imported, exchange rates could carry additional risks. To mitigate these risks, development banks can play a crucial role. Several development banks, such as the World Bank, the Turkish Clean Technology Fund (CTF), the German KfW, the European Bank for Reconstruction and Development (EBRD), the Inter-American Developing Bank (IDB), the African Developing Bank (AFDB) and the Brazilian Developing Bank (BNDES) offer loans and guarantees to renewable energy projects. Some institutions also actively address risks related to exchange rates. For instance, in Turkey, energy remuneration paid in Turkish Lira is guaranteed by a fixed minimum price, which is expressed in European currency (€0.050–0.055/kWh).

The United Nations Environment Programme (UNEP) has been working to bring the public and private sectors together on the best ways to use public monies to catalyze private investment through public finance mechanisms (PFMs). Estimates suggest that $1 of public investment spent through a well-designed PFM can leverage between $3–15 of private sector money (UNEP 2008).

Financial commitments made by the public sector should ideally bring down market barriers, bridge gaps, and share risks with the private sector. In addition, any effective financing mechanism for wind development in developing countries will consider financial institutions' capacity to use funds supplied by industrialized countries to mobilize commercial financing and build commercially sustainable low-carbon markets.

Clear, easily available information on existing financing mechanisms is also needed. The Sustainable Energy Finance Initiative (SEFI) and, in the future, IRENA can add value in this area.

Risk Mitigation

Financial instruments can be designed to transfer specific risks from project sponsors and lenders to insurance companies or other parties. A publicly funded portion covers high risks that may impede commercial credit or asset financing. The public sector loan guarantee is another risk mitigation instrument. A guarantee given for a specific project can motivate banks to invest, even if the project is perceived as risky. These innovative financing instruments may provide global risk capital through private investments. In contrast to end-user lump-sum investments or tax subsidies, these instruments result in less significant market distortion. In the past, ongoing investment subsidies have helped some markets develop but have negatively impacted others. If not applied properly, they can lead to higher margins in the supply chain and less efficient delivery of wind technology to the consumer. Examples of small to medium-sized guarantee instruments include the French FOGIME, the Canadian GMIF, and the RE and EE Program of the United States Department of Agriculture (USDA) (UNEP 2005). In developing countries, the World Bank offers some guarantees for specific project and risk types. In the UK, the Euler Hermes Guarantee provides a full range of bonds and guarantees to every size of company.

Utility-scale Project Financing

A large number of mechanisms have been used on both national and international levels for utility-scale project financing. They include funding by the World Bank Climate Investment Fund, European Investment Bank (EIB), Development bank of the Federal Republic and federal states (KfW), Global Energy Efficiency and Renewable Energy Fund (GEEREF), Global Environment Facility (GEF) / International Finance Cooperation (IFC), and Overseas Private Investment Corporation (OPIC) funding for equity funds. The World Bank's Climate Investment Funds (CIF) has particularly displayed an effective and promising model. Under this scheme, established in 2008, a total of US$6 billion was pledged by ten donor countries (World Bank 2009a). The fund supports the dissemination of experience to other key players. It also can place renewable energy firmly in the minds of a larger number of lending institutions.

Pilot Projects Financing

An alternative approach can be to set up funds for supporting pilot projects. These funds, by their very nature, have a limited impact in terms of replication and multiplication. A number of initiatives such as GEEREF and US OPIC are based on equity funds. They operate in regions where there is a lack of equity investment available to the market for these types of projects. In this way, they create a finance platform to accelerate the transfer, development, and deployment of environmental technologies. The "closed fund model," originally conceived in the 1990s for the German wind power industry, is one such example. Innovative public-private partnerships can also be used to raise the financial resources needed. Such efforts to support pilot projects can also be linked to the expanding global carbon markets. The

German Climate Protection Initiative (CPI) uses parts of the revenues generated from the emissions allowance auctions to support the development of innovative project approaches.

Carbon-Based Financing, CDM

The CDM under the United Nations Framework Convention on Climate Change (UNFCCC) boosts developing wind projects. China and India currently dominate among CDM wind projects, which today account for about 16% of all CDM projects (IEA 2009c). A reformed CDM may offer further incentives for financing wind energy projects. However, current carbon prices or carbon-based financing measures like CDM or emissions trading schemes do not significantly increase the financial viability of wind projects.

Incremental rates of return due to carbon finance revenues can be on the order of 0.5%–2.0% for wind power projects. Selling Certified Emission Reduction certificates (CERs) may lead to an increase of €0.004–0.01/ kWh, depending both on CERs price (€0–30) and on country emission factor. The impact of carbon revenues on project profitability typically depends on the technology, the investment cost, the price of the emission reduction (carbon credits), the ―global warming potential‖ of the fossil fuel being reduced, and, for renewables and energy efficiency projects, the carbon intensity of the fuel being displaced.

Carbon revenues alone, however, are unlikely to make a difference in a renewable energy project sponsor's decision whether to pursue a project, because of several reasons:

- Carbon revenues from these projects are small relative to investment costs.
- Although the CDM allows for a 21-year crediting period, the Kyoto protocol expires in 2012.
- Using risk-adjusted rates of return, the higher upfront cost of renewables makes some of them uncompetitive relative to conventional sources despite their relatively low operating cost.
- The relatively small size of most renewables and the high fixed cost of implementing CDM projects imply a minimum project size of about 5 MW.

In other cases, carbon finance does help to reach financial closure of wind power CDM projects by leveraging project financing, thanks to the monetization of future carbon finance receivables. Carbon finance can improve the viability and profitability of clean infrastructure projects by defraying their cost and improving their ¨bankability¨.

In developing and transition countries with capital constraints, the hard-currency revenues from selling carbon credits can help these projects achieve financial closure, notably through financial engineering of the future flows from forward carbon contracts. To address the financing gaps prevailing in most of the developing countries, concessional financing is one key approach to enable infrastructure projects. Also, CERs can be associated with other support schemes (feed-in, green certificates, investment subsidies etc.). More generally, adequate financing instruments must be matched to project size.

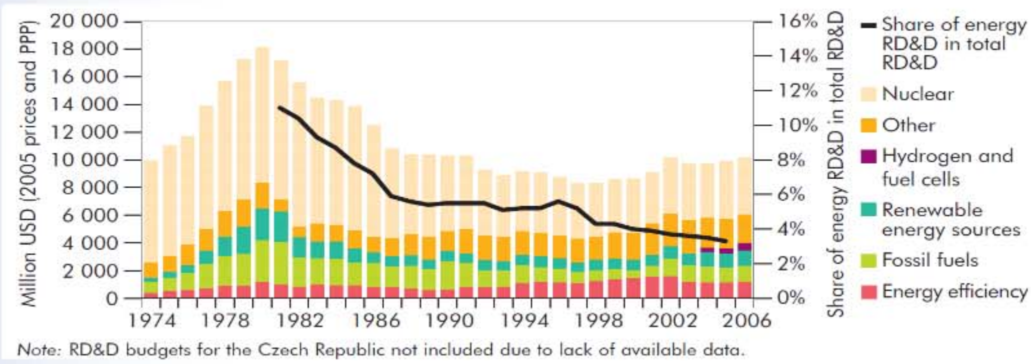
Research, Development & Demonstration Projects

RD&D Investment Trends

Currently national R&D financing for wind energy is insufficient due, at least partially, to the perception that wind energy is ―mature‖ and the tremendous progress made in reducing the costs of the technology. Moreover, overall government expenditures on energy RD&D have decreased (Figure 15).

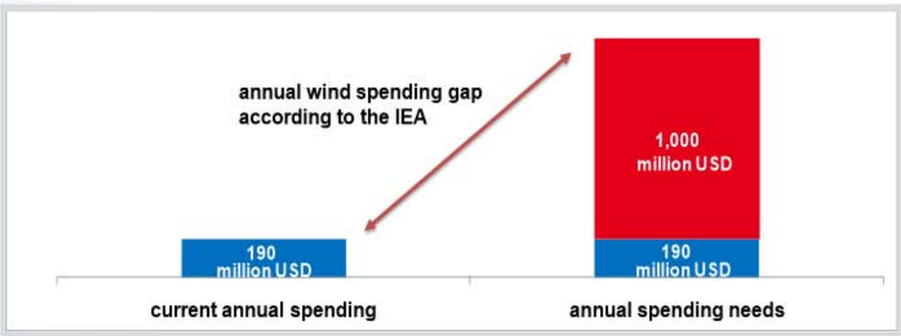
Although the remaining challenges of cost reduction, system integration, and offshore projects have brought a slight increase to RD&D funds in recent years, remaining RD&D investment needs have likely been underestimated. According to the IEA findings in the its analysis of Global Gaps in Clean Energy Research, Development, and Demonstration for the Major Economies Forum (GCERD; IEA 2009b), global RD&D investments are insufficient to achieve the needed advances in wind energy technologies. The IEA estimates the overall investment required in MEF countries from now until 2050 is between US$60-70 billion to achieve the 2050 wind energy goals (IEA 2009b, which refers to the IEA ETP study [2008]). According to that roadmapping exercise only about US$190 million is currently spent annually on wind energy R&D globally. The global annual spending gap based on this figure is about US$1 billion (Figure 16) (IEA 2009b).

FIGURE 15. GOVERNMENT BUDGETS ON ENERGY RESEARCH, DEVELOPMENT & DEMONSTRATION IN IEA COUNTRIES



Source: IEA 2008d

FIGURE 16. ANNUAL MEF-WIDE SPENDING NEEDS FOR WIND ENERGY TECHNOLOGIES



Source: IEA 2009b

Joint International Research

Joint international research efforts could lead to synergies and accelerated research dynamics. However, industry-based research cooperation has proven to be a rather complex challenge, hindered by a number of legal uncertainties, such as policies on intellectual property rights. Therefore, public institutions, such as laboratories or universities, may be better positioned for joint research and development programs.

Despite increasing government representation at meetings of international wind technology platforms, consultations with industry have suggested there is a further need for an international wind energy technology platform that ensures effective participation of policy makers.

Over the past decade, significant efforts have gone into improving the power quality of wind turbines and developing technologies for supporting network stability and grid reliability. These efforts were supported by the development of unique international standards for power quality and grid compliance testing (IEC 64000-21). Test facilities with a capability of testing wind turbines in the multi-megawatt range exist today in countries that manufacture turbines.

Support Human Resources: Training and Capacity Building

Examples for implementing training and education programs in wind energy can be found in universities and technical colleges around the world. However, additional comprehensive training programs are needed to meet the enormous demand for skilled personnel. Public authorities and private companies should be encouraged to undertake joint training programs adapted to the specific wind technology needs.

Public relations programs should promote the possibilities of wind energy as a career for technicians, engineers, and scientists at the secondary school and university level. Some institutions offer professional training programs in advanced topics for the renewables sector.

Experience has taught that capacity building efforts require continuous development and improvement. Therefore a comprehensive, strategic approach is needed, covering the development of all renewables, and permanently gathering, concentrating and updating all relevant information. Public institutions and independent organizations should improve transparency of ongoing capacity-building activities. To this end, developed countries should encourage companies to join forces with public institutions and independent organizations to improve information dissemination on wind technology.

Building Capacity in Operations and Maintenance

Wind turbines are highly advanced technologies that must run continuously 24 hours per day, 7 days per week, for 20 years. Capacity building is important for operation and maintenance (O&M) services. Low quality in operation and maintenance will lower the technical availability of wind turbines. Each 1% reduction in technical availability means at least 1% loss in energy production. To put this into perspective, if a wind turbine runs only 70% of the time, as is known to be the case in some wind farms, greater than 30% losses in energy generation may result.

To ensure a high quality of wind farm operation, sufficient knowledge in maintenance, repair and management is required. According to the wind industry

(EWEA 2009c) the wind energy sector faces a significant lack of highly qualified staff. To avoid this becoming a severe obstacle for further market deployment, wind specific training, further education and technology know-how transfer is urgently required. This could create many new jobs. Several companies have already started professional training programs for O&M services on the company level.

Know-how Transfer Regarding Effective Offshore Permitting Procedures

In several countries that have recently entered the offshore sector, permitting and planning procedures are not elaborated for offshore projects. They will have to emerge, as they emerged over several years in leading offshore markets in Europe. Appropriate know-how for streamlined and integrated planning and permitting procedures is of significant importance to attract investments. Long, bureaucratic and unpredictable administrative procedures put investments at risk since time and planning predictability is a critical factor for investments in large offshore projects.

Appendix C. Further Specification of Options for Fostering Wind Energy

Goals and Support Schemes for Wind Technologies	
Barrier / Gap	Options
Lack of confidence for investments	□ Set ambitious targets to provide long-term investment security for wind energy. Targets should be formulated as minimum targets to achieve sustainable market development without -stop-and-goll cycles.
Lack of predictable and reliable demand	Establish a predictable and reliable support scheme, which should ideally comprise the following characteristics, as appropriate to unique national circumstances: □ Provide predictable, reliable and transparent support over period sufficient for re-financing of investment costs. □ Promote technology-specific support that aims at a broad renewable energy technology basket for future energy security. □ Provide transitional incentives that decrease over time in order to further drive innovation. □ Provide incentives for electricity fed into the grid rather than installed capacity therefore promoting efficient production over the project lifetime. □ Recognize the increasing need for grid and market integration to ensure system reliability and overall cost efficiency due to the growing market share and increased technological maturity of renewables. □ Promote ease of application and enforcement to attract as many private investors as possible. □ Ensure efficient interactions with other schemes and other national policy frameworks
Additional stimulus	□ Consider the use of tax and investment incentives, particularly during the early stages of market development. Soft loans can offer an additional incentive.

Improving Marketing Conditions	
Barrier / Gap	Options
Lack of consumer information	□ Take into account the benefits of labeling and consider ensuring transparent and cost-effective disclosure of renewable energy origin for consumers (e.g., labeling). □ Support transparent consumer information on the effect consumers' green power purchase agreements have on the deployment of additional renewables installations.
Lack of awareness	□ Improve consumer awareness of the benefits from electricity generation from renewables through appropriate public information campaigns and all other appropriate marketing options.

Grid Access and System Integration	
Barrier / Gap	Options
Grid access	- Enact policies that provide for guaranteed connection and guaranteed or priority access to the grid for wind energy
Grid capacity	- Ensure sufficient grid capacity either through extending and upgrading the grid and/or through optimized grid operation. - Make appropriate use of novel concepts and new technologies in the field of grid infrastructure and grid operation.
Lack of predictability of grid access and capacity	- Ensure early start of grid infrastructure planning. - Follow an integrated spatial planning approach that balances different land use interests and prevents third party claims during the permitting or construction periods. - Develop comprehensive grid studies that reflect a long term strategy for improving grid infrastructure.
System integration	Follow a holistic approach to integrate renewable energy into the system, which should cover in particular: - A flexible power plants mix and advanced storage capacity - Advanced demand-side management. - Improved congestion management that only rarely negatively affects renewables integration. - Connecting, as appropriate, different power systems and markets in order to enhance flexibility of the power system, leading to increased adaptability to fluctuating electricity generated from intermittent renewable sources. - Improved weather forecasts models and wide-area monitoring. - Facilitation of new concepts, intelligent applications and devices (e.g., smart meters) to intelligently interconnect supply and demand side in a way that allows online based real-time system management in a smart grid.

Sufficient, Affordable Financing	
Barrier / Gap	Options
Utility-scale financing	- Implement, as appropriate, large-scale strategic financing programs with a sustainable impact.
Investment risks	- Consider leveraging more commercial financing through guarantee elements.
Knowledge gap	- Consider promoting micro-financing in combination with technical assistance to reach rural populations and alleviate poverty, especially in developing countries
Untapped sources	- Promote strategic dialogue with investors to access untapped financing sources and establish public-private partnerships to accelerate investment in developing and emerging countries.
Financing gaps	- Promote increased transparency of international funding schemes

RESEARCH, DEVELOPMENT AND DEMONSTRATION PROJECTS	
Barrier / Gap	Options
Funding reliability	☐ Increase and coordinate public sector investments in RD&D in line with the L'Aquila declaration, while recognizing the importance of private investment, public-private partnerships, and international cooperation, including regional innovation centers.
RD&D framework conditions	☐ Establish appropriate RD&D framework conditions and environments, covering also legal certainty and intellectual property rights.
Lack of synergies and RD&D dynamics	☐ Follow a combined approach of RD&D and consequent deployment policy benefiting from economies of scale and spillover effects between research and mass-scale testing.
Lack of forecast of technology development	☐ Follow a balanced set of instruments that ensures support of new and innovative concepts as well as all promising renewables technologies for a broad technology basket for future energy security.
International cooperation	☐ Consider the benefits of possible joint RD&D projects between public institutions (e.g., laboratories, universities).
Gap between RD&D progress and market entrance for new and emerging technologies	☐ Provide, as appropriate, for sufficient test facilities and demonstration projects, particularly to address specific needs of new and emerging technologies. ☐ Promote demonstration projects for innovative technologies.

GREATER LEGAL CERTAINTY	
Barrier / Gap	Options
Frequent change in support schemes/ weak judicial system	☐ Establish stable and predictable legal frameworks.

Improved Planning and Reduced Administrative Burden	
Barrier / Gap	Options
Large number of required procedures and authorities involved	Provide streamlined and concentrated administrative procedures; consider the benefits of a ―one-stop-shop‖ approval system Introduce simplified approval processes for small plants.
Different requirements in different regions	Provide for an appropriate harmonization of requirements and procedures in order to facilitate investments.
Huddle of techno-administrative requirements	Provide for ―better regulation,‖ i.e., clear, transparent, harmonized and sufficient set of regulations.
Lengthy permitting process	Accelerate appropriately permitting procedures and give clear time horizons to facilitate project planning.
Unclear planning requirements	Provide for appropriate environmental impact procedures (e.g., impacts on wildlife, habitat, land use, etc.).
Lack of planning predictability	Use an integrated planning approach with a holistic approach that settles rival claims and balances land use interests and possible environmental impacts. Start as soon as possible with the planning procedure; provide for early involvement of stakeholders. Provide for pre-designation of priority and reserved areas. Provide legal claim for permitting if requirements are fulfilled. Ensure that permitting requirements are transparent and do not discriminate against wind projects. Provide that wind farms are privileged, as appropriate, when balancing interests in the permitting process.
Lack of transparency and lack of information	Develop transparent and easily accessible information on requirements and procedures. Facilitate best practice guidelines.

Human Resources: Training and Capacity Building	
Barrier / Gap	Options
Knowledge gaps	Build up wind expertise in governments and the private sector and keep decision makers informed.
Lack of education	Develop specific curricula in engineering disciplines at colleges and universities. Set up technical schools to provide practical and theoretical training for mechanics, electricians etc. in wind energy.
Lack of information exchange	Involve both the public and private sectors to join forces in disseminating information about wind technology. Create databases to make information easy to access. Facilitate know-how transfer, e.g., through workshops and training.
Lack of project specific know-how	Facilitate capacity building as one key element of wind projects.
Fading knowledge	Follow a strategic and sustainable capacity building approach, not only concentrating on project-by-project training.
Lack of effectiveness due to lack of coordinated approach	Support strategic holistic capacity building on a global level, particularly focusing on countries with a need for wind energy capacity building. Support international institutions, such as IRENA, that focus on capacity building in cooperation with existing institutions (e.g., REEEP).

Technology Cooperation	
Barrier / Gap	Options
Involvement of developing countries	Strengthen North-South collaboration and mutual exchange, and enhance South-South technology cooperation; also address the issue of rural electrification.
Deployment gap	Focus on technology cooperation in the deployment phase.
International cooperation over RD&D	Strengthen cooperation networks of wind energy research centers and other important players.
Private sector participation	Strengthen the role of the private sector in technology cooperation.
International collaboration	Support international institutions aiming at facilitating technology cooperation in the field of renewables

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