GLOBAL WIND ENERGY OUTLOOK 2010

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GLOBAL WIND ENERGY COUNCIL

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CONTENTS

The Global Wind Energy Council and Greenpeace International are pleased to present this 3rd edition of the *Global Wind Energy Outlook* for 2010, the successor to the *Wind Force 10* and *Wind Force 12* series which began in 1999. What were once considered wild-eyed prognoses for a new technology have come to be recognised as an important planning tool for the future of the power sector.

Global wind power markets have been for the past several years dominated by three major markets: Europe, North America (US), and Asia (China and India). While these three markets still accounted for 86% of total installed capacity at the end of 2009, there are signs that this may be changing. Emerging markets in Latin America, Asia and Africa are reaching critical mass and we may be surprised to see one or more of them rise to challenge the three main markets in the coming years.

Commercial wind farms now operate in close to 80 countries, and present many benefits for both developed and developing countries: increased energy security; stable power prices; economic development which both attracts investment and creates jobs; reduced dependence on imported fuels; improved air quality; and, of course, CO_2 emissions reductions. Each of these factors is a driver in different measure in different locations, but in an increasing number of countries they combine to make wind power the generation technology of choice.

What role will wind power play in the coming two decades and beyond? How much of the global electricity demand will it cover? How much CO_2 will be saved by wind power in 2020 and in 2030? And what will it do for energy independence and economic growth? These are the questions that the GWEO seeks to answer. We present three scenarios for the development of the sector here, and play them off against two scenarios for electricity demand development to come up with a range of possible futures for the sector.

Our answers to these questions haven't changed dramatically since the 2008 edition, although the performance of the industry in the last two years tracked ahead of our Advanced scenario. What has changed is the IEA's Reference Scenario. In 2006, the Reference scenario projected 231 GW for 2020 – now that's up to 415 GW; and for 2030, the Reference scenario projected 415 GW – now that's up to 573GW. Of course, we still think those numbers are very low, but we were very pleased to see that the 2010 edition of the IEA's publication *Projected Costs of Generating Electricity* has onshore wind power replacing oil to join coal, gas and nuclear as the main technologies which will compete for market share in the power sector of the future.

But that future remains uncertain. The global climate negotiations have at least temporarily ground to a halt after the world's governments failed to come up with a successor treaty to the Kyoto Protocol in Copenhagen last year. In the absence of a clear international framework and without a clear prospect of a global price on carbon emissions, our focus has to be on the national and regional energy policies which drive local development. To quote the US President, 'The nation that leads the world in creating new sources of clean energy will be the nation that leads the 21st-century global economy.' An increasing number of governments around the world seem to have taken that message to heart.

Klaus Rave
Chairman –
Global Wind Energy Council

Sven Teske
Director, Renewable Energy
Greenpeace International

Steve Sawyer
Secretary General –
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THE GLOBAL WIND ENERGY OUTLOOK SCENARIOS

The Global Wind Energy Outlook scenarios examine the future potential of wind power up to 2020, 2030 and 2050.

Development of these scenarios was carried out as collaboration between the Global Wind Energy Council (GWEC), Greenpeace International and the German Aerospace Centre (DLR). Projections on the future of wind energy development have contributed to a larger study of global sustainable energy pathways up to 2050 conducted by DLR for Greenpeace and the European Renewable Energy Council (EREC)[1].

What will the growth of wind power look like? There are many variables that will determine its path, and we are presenting three different scenarios for each region, and for the world as a whole, looking first towards 2020, and then onwards to 2030 (see annex table for more long-term projections up to 2050). Each scenario starts with a range of assumptions which will influence expectations for the wind energy industry's development.

REFERENCE SCENARIO

The most conservative 'Reference' scenario is based on the projections in the 2009 World Energy Outlook from the International Energy Agency (IEA). This takes into account only existing policies and measures, but includes assumptions such as continuing electricity and gas market reform, the liberalisation of cross-border energy trade and recent policies aimed at combating pollution. The IEA's figures only go out to the year 2030, but based on these assumptions, DLR has extrapolated both the overall Reference scenario and the growth of wind power up to 2050.

MODERATE SCENARIO

The 'Moderate' scenario takes into account all policy measures to support renewable energy either already enacted or in the planning stages around the world. It also assumes that the targets set by many countries for either renewables, emissions reductions and/or wind energy are successfully implemented, as well as the modest implementation of new policies aimed at pollution and carbon emission reduction, and increased energy security. It also takes into account environmental and energy policy measures that were part of many government economic stimulus packages implemented since late 2008.

Up to 2014 the figures for installed capacity are closer to being forecasts than scenarios. This is because the data available from the wind energy industry shows the expected growth of worldwide markets over the next five years based on orders for wind turbines already committed, existing legislative programmes and targets, as well as known manufacturing capacity expansion plans. After 2014 the pattern of development is more difficult to anticipate.

ADVANCED SCENARIO

The most ambitious scenario, the 'Advanced' version examines the extent to which this industry could grow in a best case 'wind energy vision'. The assumption here is a clear and unambiguous commitment to renewable energy as per the industry's recommendations, along with the political will necessary to carry it forward.

While again, the development after 2014 is more difficult to predict, this scenario is designed to show what the wind energy sector could achieve if it were given the political commitment and encouragement it deserves in light of the twin crises of energy security and global climate change.

GLOBAL SCENARIO RESULTS

The GWEO scenarios show that even with the continuation of current policy measures to encourage wind power development and serious government efforts to meet existing targets, the resulting 'Moderate scenario' growth will put the development of wind power on a dramatically different trajectory from the IEA-based 'Reference' scenario.

With the political will to fully exploit each country's wind resource and reap the accompanying economic, environmental and energy security benefits, the 'Advanced scenario' could be reached, which would see substantial wind power growth in many regions of the world. Wind power would then be instrumental in achieving a genuine energy revolution, putting the world on the path to a sustainable energy future. We are now at a crossroads for making these decisions, which will determine the future of our energy systems as well as, to a great extent, the future of our planet.

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1 See http://www.energyblueprint.info

Capacity growth

ASSUMPTIONS ON GROWTH RATES

Market growth rates used in these scenarios are based on a mixture of historical figures, current policies and trends, new market development, discussions of future energy policy and other factors. While cumulative annual growth rates of more than 25% per year, as envisaged in the 'Advanced' scenario, are unusually high in most industries that manufacture heavy equipment, the wind industry has consistently experienced much higher growth. In fact, the global wind markets have grown by an average 28% per year in terms of total installed capacity during the last decade.

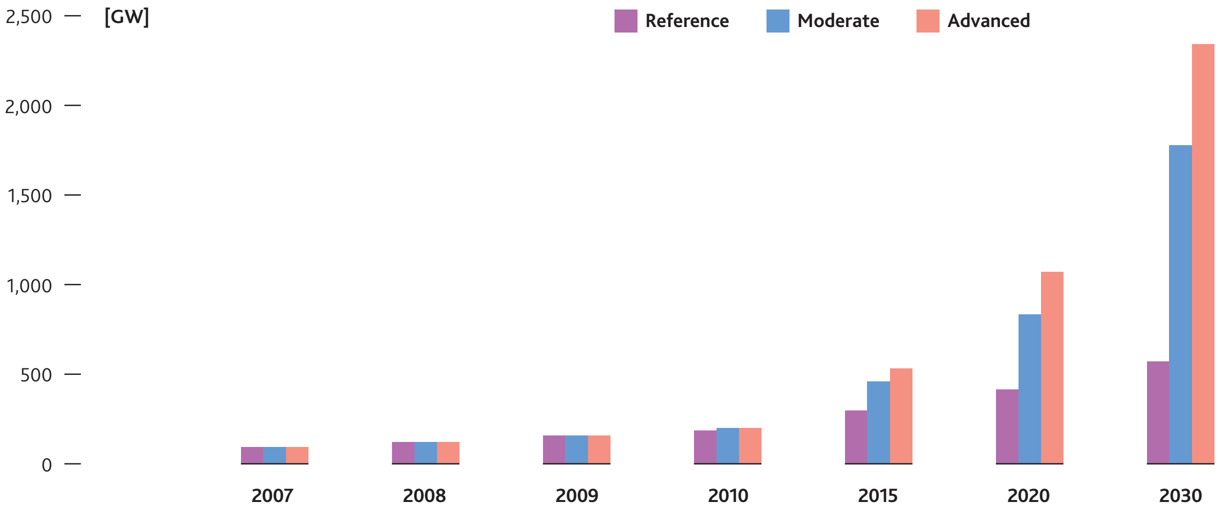
In the GWEO Advanced scenario, the average annual growth for cumulative installed capacity is assumed to start off at 27% in 2010, and then gradually decline to 9% by 2020. By 2030, they will have dropped to 4%. Growth rates as anticipated by the IEA in the Reference scenario start at 17% in 2010, drop to 3% by 2015, stabilising at that level. The growth rates for the Moderate scenario range from 26% in 2010 to 9% in 2020 and to 5% in 2030.

It should also be borne in mind that while growth rates eventually decline to single figures across the range of scenarios, the level of wind power capacity envisaged in 20-40 years' time means that even small percentage growth rates will by then translate into large figures in terms of annually installed megawatts, especially in the advanced and Moderate scenarios.

SCENARIO RESULTS

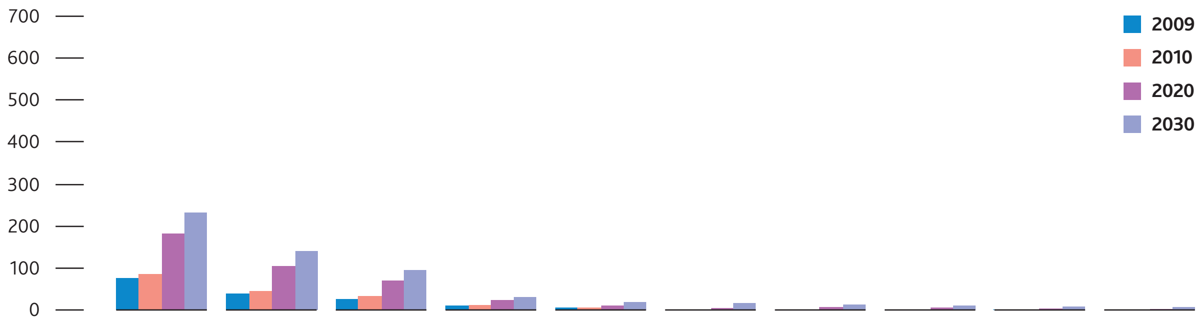
The IEA's **Reference scenario** suggests – contrary to the clear upwards trend we have witnessed in the past – that growth rates for wind power would decrease substantially in the coming years, and that 2010 would see an addition of only 26.8 GW, which would represent a decrease of the annual market by 30% in 2010 (compared to an increase of 41% in 2009). The annual market would then continue to shrink until 2015 and only recover to reach its 2009 levels again just before 2030. The cumulative wind power capacity accord-

GLOBAL CUMULATIVE WIND POWER CAPACITY



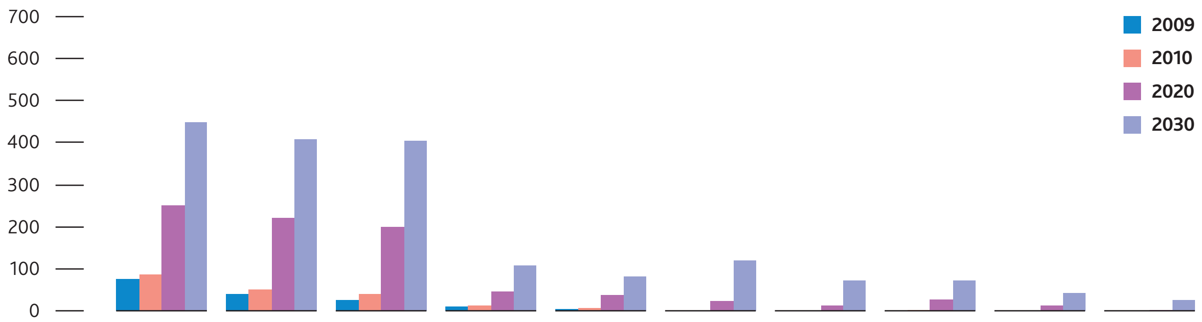
	2007	2008	2009	2010	2015	2020	2030
Reference [MW]	93,864	120,297	158,505	185,258	295,783	415,433	572,733
[TWh]	206	263	347	406	725	1,019	1,405
Moderate [MW]	93,864	120,297	158,505	198,717	460,364	832,251	1,777,550
[TWh]	206	263	347	435	1,129	2,041	4,360
Advanced [MW]	93,864	120,297	158,505	201,657	533,233	1,071,415	2,341,984
[TWh]	206	263	347	442	1,308	2,628	5,429

REGIONAL BREAKDOWN: REFERENCE SCENARIO



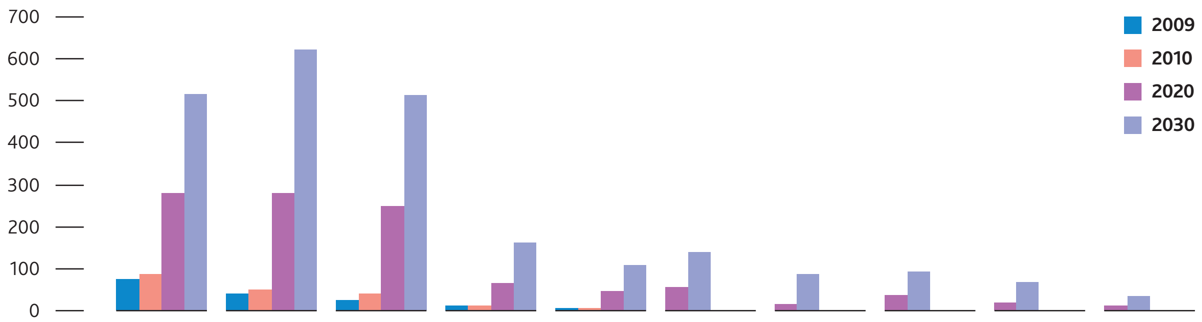
[GW]	OECD Europe	OECD North America	China	India	OECD Pacific	Non-OECD Asia	Eastern Europe/ Eurasia	Latin America	Africa	Middle East
2009	76	39	26	11	5	0,5	0,4	1	0,8	0,1
2010	86	45	33	12	5	0,6	0,9	2	1	0,1
2020	184	106	70	24	11	4	6	5	3	2
2030	234	141	95	31	19	16	13	11	8	6

REGIONAL BREAKDOWN: MODERATE SCENARIO



[GW]	OECD Europe	OECD North America	China	India	OECD Pacific	Non-OECD Asia	Eastern Europe/ Eurasia	Latin America	Africa	Middle East
2009	76	39	26	11	5	0,5	0,5	1	0,8	0,1
2010	87	50	40	13	6	0,7	0,9	2	1	0,1
2020	251	220	200	46	37	24	12	28	12	2
2030	447	407	404	108	81	120	71	72	42	25

REGIONAL BREAKDOWN: ADVANCED SCENARIO



[GW]	OECD Europe	OECD North America	China	India	OECD Pacific	Non-OECD Asia	Eastern Europe/ Eurasia	Latin America	Africa	Middle East
2009	76	39	26	11	5	0,5	0,5	1	0,8	0,1
2010	87	50	41	13	6	0,7	0,9	2	1	0,1
2020	279	279	250	65	48	55	16	37	19	11
2030	515	622	513	161	109	140	87	93	67	34

Dhule wind farm, India
© Suzlon

ing to this projection would stand at 415 GW in 2020 and 572 GW in 2030. For this to happen, annual additions would need to decline substantially, especially in China, although there is no indication of this happening at present. Overall, the Reference scenario seems disconnected from current developments, and curiously pessimistic.

While the Reference scenario suggests that between 20 and 26 GW of new capacity will be added each year between 2010 and 2020, reaching 41 GW/year only in 2030, the **Moderate scenario** envisages the addition of 40.2 GW two decades earlier (in 2010), followed by 63 GW/year by 2015, close to 90 GW/year by 2020, and almost 150 GW/year by 2030. This translates into 100 GW more installations per year than the Reference scenario by 2030, even though the annual market growth rate would by then have dropped off to a modest 4% per year. In terms of total installed wind power capacity, 830 GW would be reached in 2020 (twice as much as under the Reference scenario), and close to 1,800 GW by 2030 (more than three times as much).

In the **Advanced scenario**, the difference would be even more striking. Annual market growth rates here start at 27% for 2010, and then decrease to 17% by 2015, 9% by 2020 and finally 5% by 2030 – compared to an average cumulative market growth of 28% per year over the past decade. These growth rates would translate into annual markets of 120 GW by 2020, increasing and stabilising at around 185 GW by 2030. These projections would result in a total installed capacity of just over 1,000 GW by 2020 and 2,300 GW by 2030.

Production and share of global electricity supply

ASSUMPTIONS ON TURBINE CAPACITY...

Individual wind turbines have been steadily growing in terms of their nameplate capacity – the maximum electricity output they achieve when operating at full power. While the average size of turbines still differs dramatically from country to country, there has been a market trend towards bigger turbines across all markets. For the purposes of the GWEO scenarios, this trend is expected to continue over the next few decades.

It is also assumed that each turbine will have an operational lifetime of 20 years, after which it will need to be replaced. This 'repowering' or replacement of older turbines has been taken into account in the scenarios.

...AND CAPACITY FACTORS

A wind turbine's 'capacity factor' refers to the percentage of the nameplate capacity that a turbine installed in a particular location will deliver over the course of a year. This is primarily an assessment of the wind resource at a given site, but capacity factors are also affected by the efficiency of the turbine and its suitability for the particular location. For example, a 1 MW turbine operating at a 25% capacity factor will deliver 2,190 MWh of electricity in one year.

From an estimated average capacity factor today of 25%, the scenario assumes that improvements in both wind turbine technology and the siting of wind farms will result in a steady increase. Capacity factors are also much higher at sea, where winds are stronger and more constant. The growing size of the offshore wind market, especially in Europe, will therefore contribute to an increase in the average. As a result, across all three scenarios, we assume that the average global capacity factor will increase to 28% by 2015 and then 30% by 2036. Although capacity factors will vary from region to region, we have assumed these same global averages for the regional scenarios as outlined below.

PROJECTIONS FOR ELECTRICITY DEMAND DEVELOPMENTS

While it is of interest to calculate how much power would actually be generated by wind energy in the three scenarios,

Maranchón wind farm, Guadalajara, Spain
© Wind Power Works

putting this into the context of global electricity demand is even more relevant, as it will give us an idea of the share that wind power can have in satisfying the world's increasing hunger for power. The three GWEO scenarios are therefore set against two projections for the future growth of electricity demand: a 'Reference Demand Projection'; and an 'Energy Efficiency Demand Projection'.

Reference demand projection

The more conservative of the two global electricity demand projections is again based on data from the IEA's 2009 World Energy Outlook, including its assumptions on population and GDP growth, extrapolated forwards to 2050. It takes account of policies and measures that were enacted or adopted by mid-2009, but does not include possible or likely future policy initiatives.

The IEA's estimation is that in the absence of new government policies, the world's electricity demand will rise inexorably. Global demand would therefore almost double from the baseline 15,000 TWh in 2005 to reach nearly 29,000 TWh by 2030.

Energy efficiency demand projection

The IEA's expectations on rising energy demand are then set against the outcome of a study on the potential effect of energy efficiency savings developed by DLR and the Ecofys consultancy[2]. This study describes an ambitious development path for the exploitation of energy efficiency measures, based on current best practice technologies, emerging technologies that are currently under development and continuous innovation in the field of energy efficiency.

In reality, of course, constraints in terms of costs and other barriers, such as resistance to replacing existing equipment and capital stock before the end of its useful life, will prevent this 'technical' energy efficiency potential to be fully realised. In order to reflect these limitations, we have used the more moderate Energy Efficiency demand projection from the study, which is based on implementing around 80% of the technical potential.

This scenario results in global demand increasing by much less than under the Reference projection, i.e., to 25,000 TWh in 2030, which is 14% (or 4,000 TWh) lower.

SCENARIO RESULTS

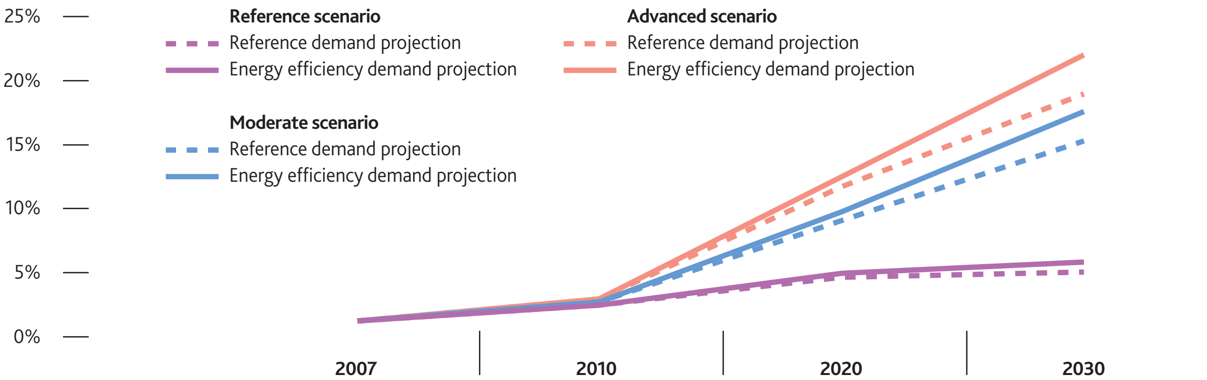
On the basis of these energy demand projections, the share of wind power in the global electricity demand can be calculated.

In the Reference scenario, wind power would produce 1,000 TWh of electricity by 2020, a trebling from the estimated 350 TWh produced by the 158.5 GW of wind capacity in 2009. Depending on the demand projection, this would cover between 4.5-4.8% of the world's electricity needs, about the same share as is currently achieved in Europe. By 2030, 1,400 TWh would account for 4.9% to 5.6%. Overall, the contribution of wind power to the global electricity supply would remain small.

2 *www.energyblueprint.info/1211.0.html*

Cerro Becerril wind farm, Spain

WIND POWER SHARE OF GLOBAL ELECTRICITY DEMAND

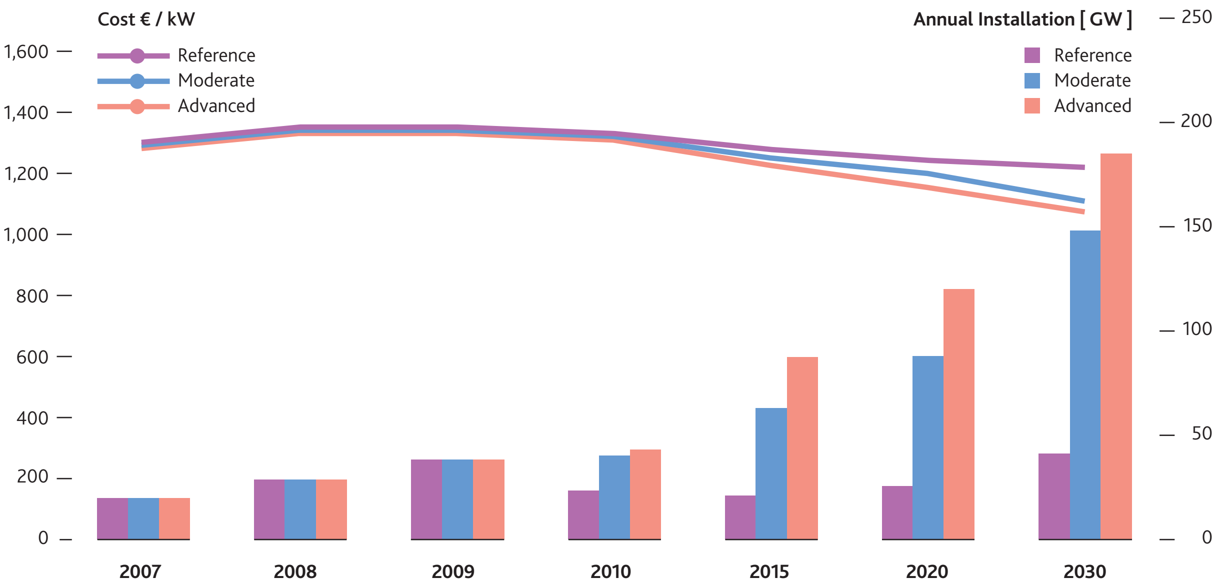


	2007	2010	2020	2030
Reference scenario				
Reference demand projection	1.1%	2.3%	4.5%	4.9%
Energy efficiency demand projection	1.1%	2.3%	4.8%	5.6%
Moderate scenario				
Reference demand projection	1.1%	2.4%	8.9%	15.1%
Energy efficiency demand projection	1.1%	2.5%	9.5%	17.5%
Advanced scenario				
Reference demand projection	1.1%	2.5%	11.5%	18.8%
Energy efficiency demand projection	1.1%	2.5%	12.3%	21.8%

Under the Moderate scenario, the situation would look considerably different. In 2020, wind energy would produce 2,000 TWh, twice as much as under the Reference scenario, and this would meet 8.9%-9.5% of the world's power demand – already a substantial contribution. By 2030, 4,300 TWh would be produced by wind energy, taking the share up to 15%-17.5%, depending on how demand develops over the next two decades.

The Advanced scenario paints a picture in which wind power would become a central player in global power generation. By 2020, the world's combined installed wind fleet would produce 2,600 TWh of clean power, which would account for 11.5%-12.3% of global electricity supply. This would rise to 5,400 TWh by 2030 and a share of 18.8%-21.8% – a fifth of the world's power needs could thus be satisfied by wind power alone.

COSTS AND CAPACITIES



INVESTMENT AND EMPLOYMENT

	2007	2008	2009	2010	2015	2020	2030
Reference							
Annual Installation [MW]	19,865	28,700	38,343	26,735	20,887	25,712	41,219
Cost [€ / kW]	1,300	1,350	1,350	1,327	1,276	1,240	1,216
Investment [€ million /year]	25,824	38,745	51,763	35,507	26,649	31,894	50,136
Employment [job year]	329,232	470,559	627,927	462,982	411,801	524,027	809,006
Moderate							
Annual Installation [MW]	19,865	28,700	38,343	40,212	62,887	88,133	148,416
Cost [€ / kW]	1,300	1,350	1,350	1,329	1,258	1,208	1,116
Investment [€ million /year]	25,824	38,745	51,763	53,459	79,109	106,504	165,691
Employment [job year]	329,232	470,559	627,927	629,137	1,033,721	1,422,874	2,372,911
Advanced							
Annual Installation [MW]	19,865	28,700	38,343	43,263	87,641	120,135	185,350
Cost [€ / kW]	1,300	1,350	1,350	1,328	1,245	1,172	1,093
Investment [€ million /year]	25,824	38,745	51,763	57,450	109,072	140,762	202,600
Employment [job year]	329,232	470,559	627,927	672,827	1,404,546	1,918,530	3,004,081

Investment

Producing increased volumes of wind-generated electricity will attract considerable levels of investment.

The capital cost of producing wind turbines has fallen steadily over the past 20 years as turbine design has been largely concentrated on the three-bladed upwind model with variable speed and pitch blade regulation. Manufacturing techniques have been optimised, and mass production and automation have resulted in economies of scale.

The cost developments in the GWEO scenarios are based on the assumption of a gradually decreasing capital cost per kilowatt of installed capacity, due to increased deployment, which accelerates technological progress and increases economies of scale in manufacturing, which in turn results in lower equipment costs. Since this progress will be faster the more units are produced, the cost of wind turbines is

Production Yinchuan, China
© Nordex

projected to decrease most quickly in the Advanced and least quickly in the Reference scenario.

Capital costs per kilowatt of installed capacity are taken as an average of €1,350 per kW in 2009. In the Reference scenario, these costs fall gradually to €1,240 per kW by 2020 and €1,216 by 2030. In the Advanced scenario, costs will fall more rapidly to reach €1,093 per kW in 2030.[3]

Given the high up-front costs of wind power projects, large investments of predominantly private but also public funds are expected to flow into the growing wind power markets. This investment will directly benefit regional development by creating jobs in manufacturing, transportation, construction, project development and operation and maintenance; providing new revenue sources to local landowners such as a farmers or communities; and increasing the local tax base. The investment value in the future wind energy market envisaged in this scenario has been assessed on an annual basis.

In the Reference scenario the annual value of global investment in wind power equipment drops by nearly half from €51.8 billion in 2009 to only €26.6 billion by 2015, and then rises again to reach current levels after 2030.

In the Moderate scenario the annual value of global investment in the wind power industry rises from €53.5 billion in 2010 to €79.1 billion in 2015 and €106.5 billion by 2020. Investment rises rapidly during the next 10 years to reach €166 billion by 2030.

In the Advanced scenario the annual value of global investment rises rapidly from €57.5 billion in 2010 to €109.1 billion by 2015, and peaks at €202 billion in 2030.

Although these figures are large, they should be seen in the context of the total level of investment in the global power industry. During the 1990s, for example, annual investment in the power sector was running at some €158–186 billion each year.

3 All figures are in 2009 €

Employment

The employment effect of this scenario is a crucial factor to weigh alongside its other costs and benefits. High unemployment rates continue to be a drain on the social systems of many countries in the world. Any technology which demands a substantial level of both skilled and unskilled labour is therefore of considerable economic importance, and likely to feature strongly in any political decision-making over different energy options.

A number of assessments of the employment effects of wind power have been carried out in Germany, Denmark, Spain and the Netherlands. The assumption made in this scenario is that for every megawatt of new capacity, the annual market for wind energy will, as of 2010, create employment at the rate of 14 jobs (person years) per MW installed in that year through manufacture, component supply, wind farm development, installation, transportation, as well as indirect employment. As production processes are optimised, this level will decrease, falling to 13 jobs per MW by 2020 and 12 by 2025. In addition, employment in regular operations and maintenance work at wind farms will contribute a further 0.33 jobs for every megawatt of cumulative capacity.

Under these assumptions, more than 600,000 people would have been employed in the wind energy sector in 2009. Under the Reference scenario, this figure would decrease to just 463,000 jobs in 2010, then slowly recover to reach 524,000 jobs by 2020 and 809,000 by 2030.

In the Moderate scenario, the wind sector would become a powerful jobs motor, providing 'green collar' employment to more than a million people by 2015 and 1.3 million five years later. By 2030 the wind industry would employ 2.6 million people worldwide.

The Advanced scenario would see the employment level rise rapidly to 1.4 million as early as 2015, almost reaching close to 2 million jobs in wind energy by 2020 and going beyond 3 million by 2030.

Carbon dioxide savings

A reduction in the levels of carbon dioxide being emitted into the global atmosphere is the most important environmental

Zafarana wind farm, Egypt
© Wind Power Works

benefit from wind power generation. Carbon dioxide is the gas largely responsible for exacerbating the greenhouse effect, leading to the disastrous consequences of global climate change.

Modern wind technology has an extremely good energy balance. The CO_2 emissions related to the manufacture, installation and servicing over the average 20 year lifecycle of a wind turbine are generally 'paid back' after the first three to nine months of operation. Beyond this, wind power produces no CO_2 emissions.

The benefit to be obtained from carbon dioxide reductions is dependent on the fuel, or fuels, that wind power displaces; for example, emissions from coal for a kilowatt hour of electricity produced are higher than from natural gas. Calculations by the World Energy Council show a range of carbon dioxide emission levels for different fossil fuels. Working on the assumption that coal and gas will still account for the majority of electricity generation in 20 years' time – with a continued trend for gas to take over from coal – it makes sense to use a figure of 600 kg/MWh as an average value for the carbon dioxide reduction to be obtained from wind generation. Although this will vary from region to region, we have assumed these same average global CO2 reduction value for the regional scenarios as outlined below

This assumption is further justified by the fact that more than half of the cumulative wind generation capacity expected by 2020 will be installed in the OECD regions (North America, Europe and the Pacific), where there is a strong trend for a shift from coal to gas for electricity generation. Outside of the OECD, the CO_2 reduction will generally be higher due to the widespread use of coal-fired power stations.

The expected annual CO_2 savings from wind energy under the Reference scenario is 243 million tonnes in 2010, passing 500 million tonnes per year between 2015 and 2020, gradually climbing to 843 million tonnes per year of CO_2 savings by 2030. This is small compared with the 18.7 billion tonnes of CO_2 that the IEA expects the global power sector will emit every year by 2030.

Under the Moderate scenario, wind power would save the emission of a more significant 1.2 billion tons of CO_2 per year by 2020, rising to 2.6 billion tonnes by 2030.

Under the Advanced scenario, by 2020 1.6 billion tons of CO_2 would be saved every year, and this would grow to a considerable 3.3 billion tonnes per year by 2030– thereby saving a sixth of all CO_2 emitted by the electricity sector compared with the IEA's projections.

However, it is the cumulative effect of these yearly CO_2 savings that really matters to the atmosphere.

The slow growth of wind energy as envisaged by the Reference scenario would mean that by 2020, wind power would have saved just 5.5 billion tonnes of CO_2 globally, and this would rise to 13 billion tonnes by 2030.

A much faster growth such as the one outlined in the Moderate scenario would substantially increase the cumulative CO_2 savings, by achieving reductions of 8.5 billion tonnes by 2020 and 28 billion tonnes by 2030. Under the Advanced scenario, these savings would be as high as 10 billion tonnes by 2020 and 34 billion tonnes of CO_2 by 2030.

What will make a significant difference to the climate is the speed at which cuts are made. So it is not only the total emissions reductions that are of value, but it is the timing of them. Wind power's scalability and speed of deployment is a critical part of any plan to get global emissions to peak and begin to decline by 2020, which is essential to put us on a pathway where global mean temperature rise can be kept below 2°C, the most positive part of the agreement in the Copenhagen Accord.

ANNUAL AND CUMULATIVE CO_2 EMISSIONS REDUCTIONS

Reference

Year	CO_2 reduction (with 600gCO_2/kWh) [annual mil tCO_2]	Avoided CO_2 since 2003 [cumulative mil tCO_2]
2009	208	772
2010	243	1,016
2015	435	2,834
2020	611	5,539
2025	727	8,944
2030	843	12,928
2035	960	17,495
2040	1,155	23,017
2045	1,272	29,143
2050	1,387	35,854

Moderate

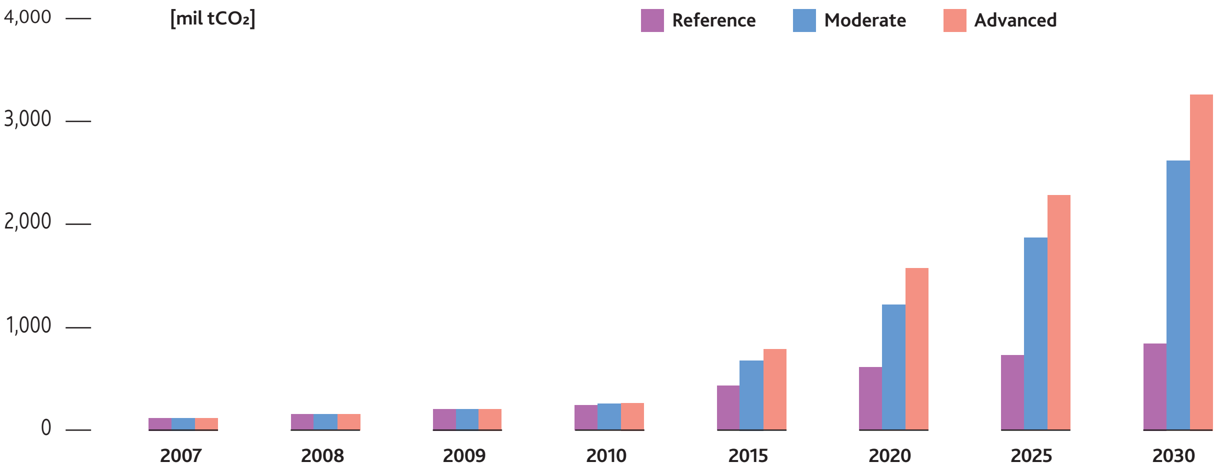
Year	CO_2 reduction (with 600gCO_2/kWh) [annual mil tCO_2]	Avoided CO_2 since 2003 [cumulative mil tCO_2]
2009	208	772
2010	261	1,033
2015	678	3,550
2020	1,225	8,510
2025	1,875	16,556
2030	2,616	28,104
2035	3,348	43,415
2040	4,322	63,559
2045	5,066	87,394
2050	5,838	115,026

Advanced

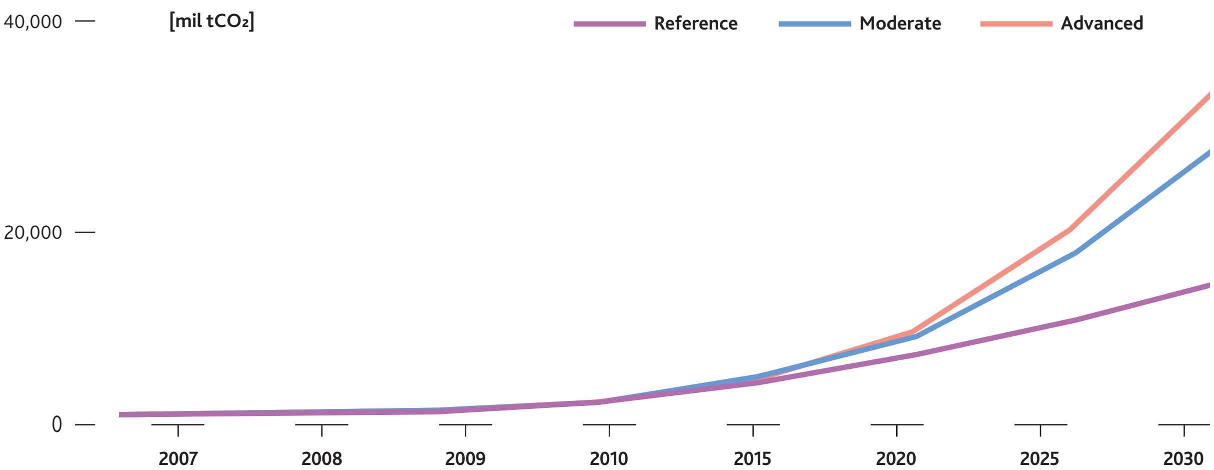
Year	CO_2 reduction (with 600gCO_2/kWh) [annual mil tCO_2]	Avoided CO_2 since 2003 [cumulative mil tCO_2]
2009	208	772
2010	265	1,037
2015	785	3,812
2020	1,577	9,953
2025	2,283	19,667
2030	3,257	34,027
2035	4,094	52,926
2040	5,084	77,001
2045	5,686	104,256
2050	6,242	134,363

Wind farm in Spain
© Alstom

ANNUAL CO_2 EMISSIONS REDUCTIONS



CUMULATIVE CO_2 EMISSIONS REDUCTIONS



Research Background

THE GERMAN AEROSPACE CENTRE

The German Aerospace Centre (DLR) is the largest engineering research organisation in Germany. Among its specialities are the development of solar thermal power station technologies, the utilisation of low and high temperature fuel cells, particularly for electricity generation, and research into the development of high efficiency gas and steam turbine power plants.

The Institute of Technical Thermodynamics at DLR (DLR-ITT) is active in the field of renewable energy research and technology development for efficient and low emission energy conversion and utilisation. Working in co-operation with other DLR institutes, industry and universities, research is focused on solving key problems in electrochemical energy technology and solar energy conversion. This encompasses application oriented research, development of laboratory and prototype models as well as design and operation of demonstration plants. System analysis and technology assessment supports the preparation of strategic decisions in the field of research and energy policy.

Within DLR-ITT, the System Analysis and Technology Assessment Division has long term experience in the assessment of renewable energy technologies. Its main research activities are in the field of techno-economic utilisation and system analysis, leading to the development of strategies for the market introduction and dissemination of new technologies, mainly in the energy and transport sectors.

SCENARIO BACKGROUND

DLR was commissioned by the European Renewable Energy Council and Greenpeace International to conduct the study 'Energy [R]evolution: A sustainable global energy outlook', developing global sustainable energy pathways up to 2050[1]. This study, first published in January 2007 and the 3rd edition published in June 2010, lays out energy scenarios with emissions that are significantly lower than current levels.

Part of the study examined the future potential for renewable energy sources; together with input from the wind energy industry and analysis of regional projections for wind power around the world, this forms the basis of the Global Wind Energy Outlook scenario.

The energy supply scenarios adopted in this report, which both extend beyond and enhance projections by the International Energy Agency, have been calculated using the MESAP/PlaNet simulation model by DLR covering all 10 world regions. This model has then been developed in cooperation with Ecofys consultancy to take into account the future potential for energy efficiency measures.

ENERGY EFFICIENCY STUDY[2]

The aim of the Ecofys study was to develop low energy demand scenarios for the period 2007 to 2050 on a sectoral level for the IEA regions as defined in the World Energy Outlook report series. Energy demand was split up into electricity and fuels. The sectors which were taken into account were industry, transport and other consumers, including households and services.

The Ecofys study envisages an ambitious overall development path for the exploitation of energy efficiency potential, focused on current best practice as well as technologies available in the future, and assuming continuous innovation in the field. The result is that worldwide final energy demand is reduced by 35% in 2050 in comparison to the Reference scenario. Energy savings are fairly equally distributed over the three sectors. The most important energy saving options are the implementation of more efficient passenger and freight transport, improved heat insulation and building design, and technical efficiency standards for consumer applications, stand-by modes and IT equipment.

While the Ecofys study develops two energy efficiency scenarios, only the more moderate of these has been used in this report.

1 Krewitt W, Simon S, Graus W, Teske S, Zervos A, Schaefer O, 'The 2 degrees C scenario - A sustainable world energy perspective'; Energy Policy, Vol.35, No.10, 4969-4980, 2007; and www.energyblueprint.info

2 www.energyblueprint.info/1211.0.html

Xioa Yan Kou wind farm, Rudong, China
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OECD NORTH AMERICA

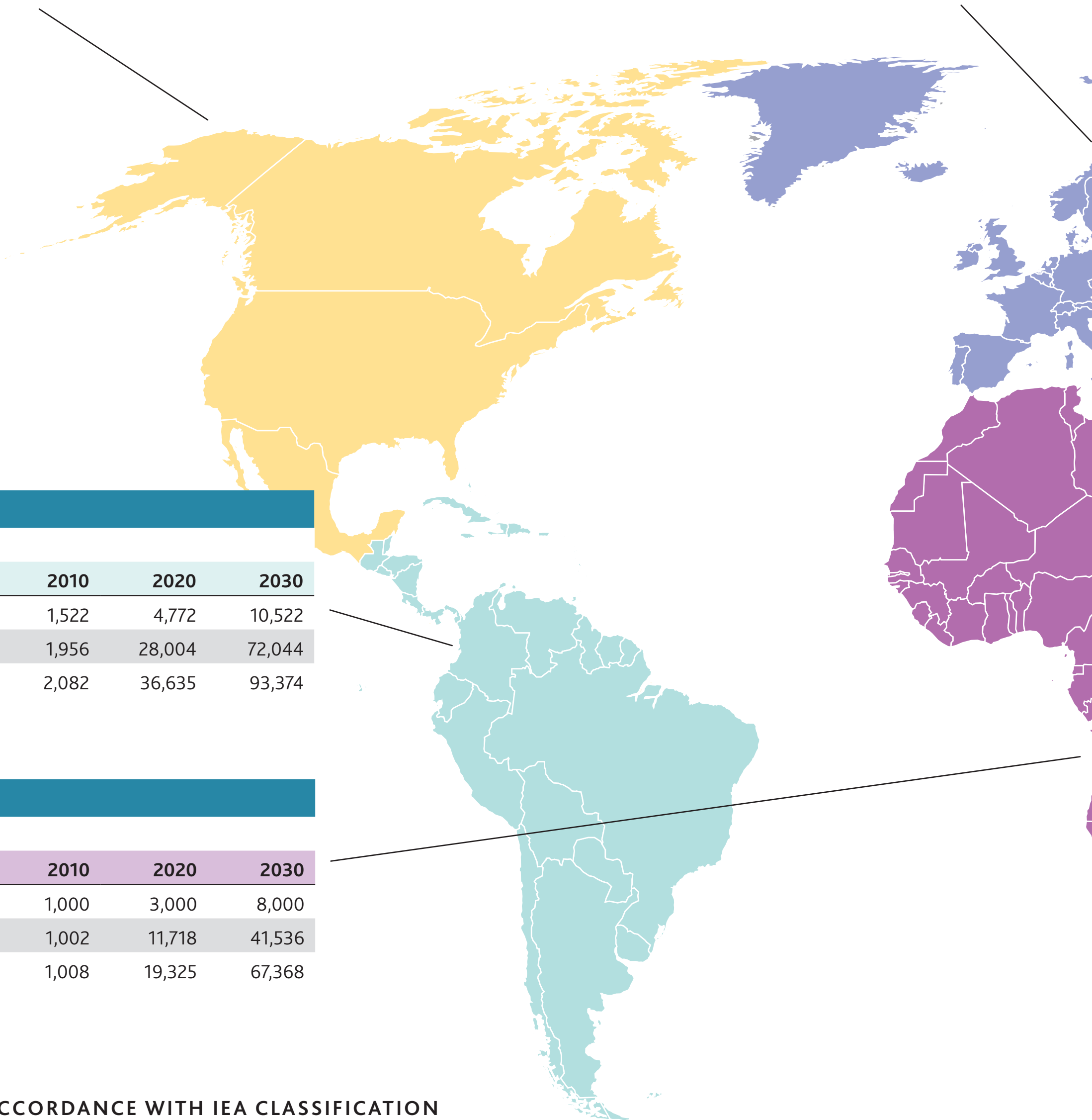
Total capacity in MW

	2009	2010	2020	2030
Reference scenario	38,585	45,085	106,085	141,085
Moderate scenario	38,585	49,869	220,002	407,445
Advanced scenario	38,585	49,925	278,570	621,680

OECD EUROPE

Total capacity in MW

	2009	2010	2020	2030
Reference scenario	75,565	85,696	183,996	233,796
Moderate scenario	75,565	86,175	250,824	447,432
Advanced scenario	75,565	87,140	293,963	514,806



LATIN AMERICA

Total capacity in MW

	2009	2010	2020	2030
Reference scenario	1,072	1,522	4,772	10,522
Moderate scenario	1,072	1,956	28,004	72,044
Advanced scenario	1,072	2,082	36,635	93,374

AFRICA

Total capacity in MW

	2009	2010	2020	2030
Reference scenario	763	1,000	3,000	8,000
Moderate scenario	763	1,002	11,718	41,536
Advanced scenario	763	1,008	19,325	67,368

DEFINITIONS OF REGIONS IN ACCORDANCE WITH IEA CLASSIFICATION

OECD Europe: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom

OECD North America: Canada, Mexico, United States

OECD Pacific: Australia, Japan, Korea (South), New Zealand

Eastern Europe/Eurasia: Albania, Armenia, Azerbaijan, Belarus, Bosnia-Herzegovina, Bulgaria, Croatia, Estonia, Serbia and Montenegro, the former Republic of Macedonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Romania, Russia, Slovenia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan, Cyprus[1], Malta[1]

India

Non-OECD Asia: Afghanistan, Bangladesh, Bhutan, Brunei, Cambodia, Chinese Taipei, Cook Islands, East Timor, Fiji, French Polynesia, Indonesia, Kiribati, Democratic People's Republic of Korea, Laos, Macao, Malaysia, Maldives, Mongolia, Myanmar, Nepal, New Caledonia, Pakistan, Papua New Guinea, Philippines, Samoa, Singapore, Solomon Islands, Sri Lanka, Thailand, Tonga, Vietnam, Vanuatu

Latin America: Antigua and Barbuda, Aruba, Argentina, Bahamas, Barbados, Belize, Bermuda, Bolivia, Brazil, the British Virgin Islands, the Cayman Islands, Chile, Colombia, Costa Rica, Cuba, Dominica, the Dominican Republic, Ecuador, El Salvador, the Falkland Islands, French Guyana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Montserrat, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, St. Kitts and Nevis, Saint Lucia, Saint Pierre et Miquelon, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago, the Turks and Caicos Islands, Uruguay and Venezuela

Africa: Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Democratic Republic of Congo, Cote d'Ivoire, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Reunion, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, United Republic of Tanzania, Togo, Tunisia, Uganda, Zambia, Zimbabwe

Middle East: Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates, Yemen

China: People's Republic of China including Hong Kong

1 *Cyprus and Malta are allocated to Eastern Europe/Eurasia for statistical reasons*

EASTERN EUROPE/EURASIA

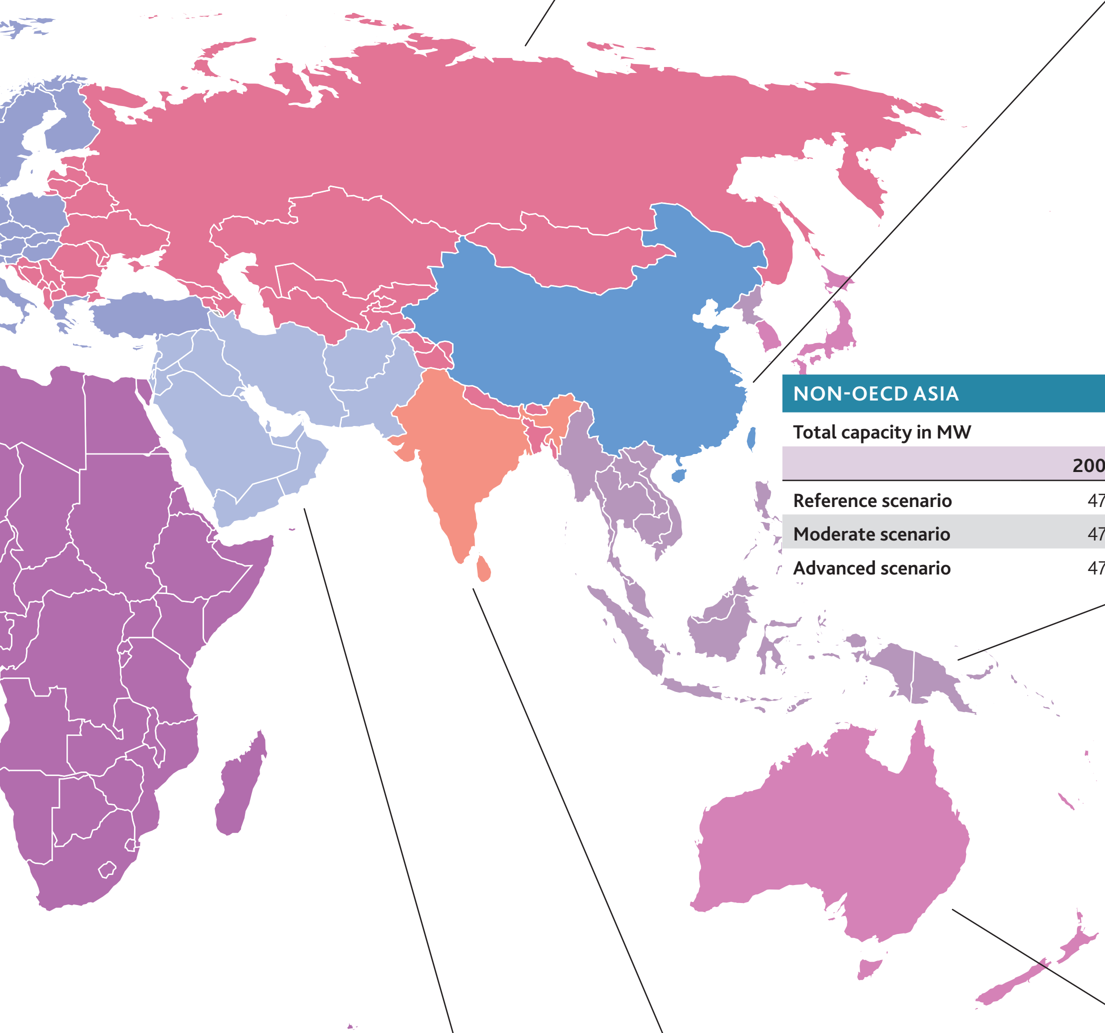
Total capacity in MW

	2009	2010	2020	2030
Reference scenario	484	869	5,869	13,369
Moderate scenario	484	910	12,083	71,011
Advanced scenario	484	938	15,784	86,815

CHINA

Total capacity in MW

	2009	2010	2020	2030
Reference scenario	25,805	32,805	70,305	95,305
Moderate scenario	25,805	39,608	200,026	403,741
Advanced scenario	25,805	41,030	250,397	513,246



NON-OECD ASIA

Total capacity in MW

	2009	2010	2020	2030
Reference scenario	475	575	4,325	15,575
Moderate scenario	475	709	24,204	120,313
Advanced scenario	475	709	54,813	140,426

OECD PACIFIC

Total capacity in MW

	2009	2010	2020	2030
Reference scenario	4,613	5,318	10,568	18,568
Moderate scenario	4,613	5,740	37,259	81,159
Advanced scenario	4,613	5,870	47,876	109,367

MIDDLE EAST

Total capacity in MW

	2009	2010	2020	2030
Reference scenario	102	112	2,027	5,987
Moderate scenario	102	119	2,487	24,791
Advanced scenario	102	123	10,523	34,159

INDIA

Total capacity in MW

	2009	2010	2020	2030
Reference scenario	10,926	12,276	24,026	30,526
Moderate scenario	10,926	12,629	46,104	108,079
Advanced scenario	10,926	12,833	65,181	160,741

REGIONAL SCENARIO RESULTS

Africa

About a quarter of the world's population has no access to electricity, and the problem is especially acute in peri-urban and rural areas in Sub-Saharan Africa. In many African countries, the electricity that is available is likely to be generated by means of diesel generators or other small-scale plant, very often using expensive imported fuel. More small generators keep individual businesses, hospitals and households running. The high cost of relying on imported fuels has a great impact on some African countries' economies, and some of them spend a considerable share of their scarce foreign exchange reserves on energy imports.

Local, national or regional grids – where they do exist – are challenged by the increasing demand from consumer equipment such as refrigerators, lighting, mobile phones, TVs and computers; and outages are often a regular feature. In many countries, it seems that the provision of a stable supply of electric power is either not a government priority, or is a priority that conflicts with other pressing issues such as provision of clean water, education and health care.

Large-scale power production in Africa, where it exists, is likely to mean large hydro (as found in Egypt) or the coal-based generation that characterizes South Africa's power system. Given Africa's vast land mass and relatively low population density, it seems likely that a broad mix of decentralized technologies will have the flexibility to meet the needs of many of its countries. Wind power, because of its scalability, can play a key role in both decentralized and in centralized systems.

Africa's wind resource is best around the coasts and in the eastern highlands, and it is in Mediterranean North Africa that wind power has been developed at scale. This, too, is where current national policies are set to grow the sector further. At the end of 2009, about 96% of the continent's total wind installations of 763 MW were to be found in Egypt (430 MW), Morocco (253 MW) and Tunisia (54 MW).

EGYPT

In February 2008, Egypt's Supreme Council of Energy approved a plan to produce 20% of its electric power from renewable sources by 2020. This target includes a 12% contribution from wind energy, which translates into more than 7,200 MW of grid-connected wind farms. Egypt's best developed wind region so far is the Zafarana district, with some 430 MW that have been put in place during recent years, and a further 120 MW due to come online by the end of 2010. There are also plans to construct four 250 MW plants on the Red Sea coast at Gabal el-Zeit. Tendering takes place in September 2010, open to ten companies shortlisted from earlier applications, and the project is expected to start operations in 2014 or 2015. Over 7 GW of wind power could potentially be developed by 2020 in this area of Egypt alone.

Zafarana wind farm, Egypt
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MOROCCO

Morocco has excellent wind resources along nearly its entire coastline, as well as inland near the Atlas Mountains.[1]

The Moroccan government has set a target of raising the contribution of renewable energy to 18% of the national electricity consumption (up from 7.9%) by 2012. Wind power is poised to play a key role for reaching this goal with a targeted 1,500 MW of capacity, up from the existing 253 MW at the end of 2009. This target is likely to be met through both a 300 MW grid connected wind farm currently planned in Tarfaya, and plans by industrial companies to install around 1,000 MW of wind energy for their own consumption.

1 For wind resource map of Morocco, please see http://www.wind-energie.de/fileadmin/dokumente/Themen_A-Z/Entwicklungsdialog/GTZ_terna-haddouch-2006.pdf (slide 15)

SOUTH AFRICA

South Africa's electricity market is at a cross roads, and facing numerous challenges. The current electricity system, which is primarily based on coal, suffers from low reserve margins. Current power generation infrastructure is now barely adequate to meet demand, and state utility Eskom estimates that South Africa needs to construct 40 GW of new generating capacity by 2025, about 12.5 GW of which is already under construction.

South Africa is ideally suited for wind power development, given its abundant wind resources, ample suitable sites and modern high voltage electrical infrastructure.

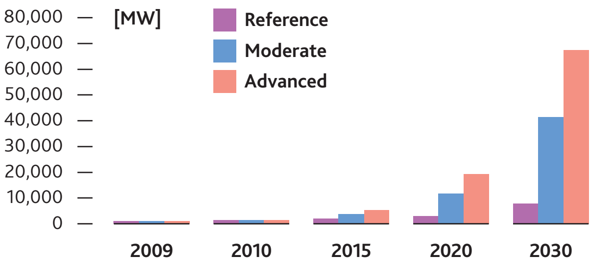
While so far, only one commercial-scale wind farm (the 7 MW Darling wind farm) is in operation, the South African Wind Energy Association (SAWEA) estimates that with the right policy framework, wind power could provide as much as 20% of the country's energy demand by 2025, translating into 30,000 MW of installed wind capacity. According to SAWEA, 7,000 MW of this wind capacity are already at various stages of development, and many projects will be ready for construction within the next 12-18 months, assuming that they get confirmation of a grid connection and a Power Purchase Agreement (PPA).

Unfortunately, however, the current framework conditions (both in terms of policy and market structure) are not conducive to such fast wind power development. A feed-in tariff for wind power was announced in 2009, but it is yet unclear if there will be a long-term government commitment to wind power, and several issues remain unsolved. One of these concerns the fact that the vertically integrated state utility Eskom controls generation (which is primarily based on coal), transmission and supply of electricity across the country, making it difficult for independent power producers to access the market.

EAST AFRICA

Interestingly there have recently been developments in East Africa – with a 300 MW project under construction in Kenya and other wind projects well advanced in Ethiopia and Tanzania. Hopefully these early projects, which will in and of themselves make a substantial contribution to the total generating capacity in each of these countries, are a harbinger of a much broader uptake of wind on the continent in the coming years.

AFRICA: CUMULATIVE WIND POWER CAPACITY 2009-2030



Year	Reference	Moderate	Advanced
2009	763	763	763
2010	1,000	1,002	1,008
2015	2,000	3,807	5,284
2020	3,000	11,718	19,325
2030	8,000	41,536	67,368

THE GWEO SCENARIOS FOR AFRICA

Given Africa's vast potential for wind power development, especially in the North, along the coasts, and in South Africa, the GWEO scenarios differ substantially from those presented by the IEA.

Under the IEA's Reference scenario, only 200 MW of new wind power capacity would be added every year until 2020 (less than in 2009), and this would increase to 500 MW by 2030. This would result in 3,000 MW of wind power installed on the entire African continent by 2020 and 8,000 by 2030, producing 7.3 TWh in 2020 and close to 20 TWh in 2030. This would trigger an annual investment of €250 million and €600 million respectively, and create between 4,000 and 8,000 jobs.

The GWEO scenarios, however, are considerably more optimistic, taking into account existing policy measures and government targets.

Under the Moderate scenario, wind power would deliver more than four times as much power by 2020 as the IEA forecasts, with an installed capacity of 11,700 MW generating 28.4 TWh every year. This would then grow by 2,000 - 3,000 MW every year up to 2030, when more than 40 GW would be installed, producing over 100 TWh of clean electricity for Africa. This would not only help the continent's elec-

Tan Jing wind farm, China
© Nordex

trification and energy independence, but also its economies; more than €2.2 billion would be invested in wind power every year by 2020, and this would increase to 3.5 billion annually by 2030; and 30,000-50,000 jobs would be created.

The Advanced scenario assumes that even more effort will be taken to exploit Africa's wind resources. It shows how, by 2020, close to 20 GW of wind power capacity could produce 47 TWh of electricity, growing to 165 TWh by 2030. Wind power would then be able to play a key role in developing a sustainable energy future, by displacing 28 million tons of CO_2 every year by 2020 and close to a billion tons by 2030, cleaning the air and increasing energy security at the same time.

Economically, too, this development could have a substantial impact in Africa's wind rich nations. With annual investments in the order of €4.6 billion in 2020 and €5.6 billion in 2030, wind power could grow to become a considerable industry in Africa. The development of local manufacturing facilities would provide jobs for 60,000-80,000 people across the continent, and the avoided costs of imported fuel would have a very positive effect on these nations' foreign exchange.

China

The performance of China's wind sector in 2009 managed to surprise even many optimists in the industry. China added a record-breaking 13.8 GW of new wind power capacity (compared with 6.3 GW the previous year), making it a world leader in terms of new installations in 2009. Notably, 2009 also saw Chinese turbine manufacturers take a quarter share of the global market, confirming the solidity of the home-grown industry.

China's expansion in the wind industry is worth viewing against the background of this growing economy's broader electric power sector, where heavy investments are also being made in new coal, gas, hydro and nuclear generation. China's total power generating capacity grew by some 11% in 2008 (2009 figure not yet available), while wind power more than doubled in that year. In 2009 alone, more wind power was added to the Chinese power grid than the total amount of operating nuclear power stations (13.8 vs 9 GW). However, despite this tremendous growth, wind power still only covers less than 1% of China's total electricity demand.

POLICY

The growth experienced by China's wind industry over the past five years has been driven mainly by national renewable energy policies, as well as very active participation in the UNFCCC's Clean Development Mechanism.

The start of the government's active engagement in renewable energy development dates back to 2004, when the nation was drafting its first Renewable Energy Law. This law, which was passed in 2005 and entered into force in 2006, marked a shift in energy policy by requiring grid companies to purchase all the electricity that is produced from renewable sources. The wind industry has grown rapidly since its introduction: the market grew by 60% in the year the law was passed, followed by four consecutive years of more than 100% growth (2006-2009).

The Chinese government clarified its long-term commitment to renewable energy through its 'Medium and Long-term Development Plan for Renewable Energy in China', released in September 2007. The plan set a target for a mandatory market share (MMS) of electricity from renewable sources – by 2010 and 2020, electricity production from non-hydro

Xioa Yan Kou wind farm, Rudong, China
© *Wind Power Works*

renewable sources should account for 1% and 3% of total electricity in the grid (indicating a target of about 18-20 GW of installed capacity by 2010 and 80-100 GW by 2020). The plan also requires larger power producers to generate 3% of their electricity from non hydro renewable energy sources by 2010, and 8% by 2020. In 2008 the government identified six locations in provinces with the country's best wind resources, and set each of them a target – ranging between 10 GW and 23 GW – to reach by 2020.

ECONOMICS OF WIND DEVELOPMENT

Until the introduction of new feed-in tariffs for wind power in 2009, China had a dual track system for wind projects, with a concession tendering process on the one hand, and the project-by-project 'government approval' process on the other. The 2009 feed-in tariff now replaces both these processes, except for the 'wind-base' projects and the new offshore development. Now, there are four different categories of tariff depending on a region's wind resources, ranging from 0.51 RMB/kWh to 0.61 RMB/kWh[1]. Not only is the feed-in tariff comparable to that of the government approved tariffs over the past several years in most regions; and substantially higher than most tariffs granted under the old concession system; it is set considerably higher than the tariff paid for coal-fired electricity, which helps rebalance the attractiveness of investments in these two technologies. Further, the feed-in tariff applies for the whole operational period of a wind farm – providing investors with a much clearer long-term perspective.

TURBINE MANUFACTURING

Two ways China has addressed the economics of wind power plants are economy of scale, by developing large-scale projects, and local manufacture of wind turbines and other equipment. In the past, turbines manufactured by international players dominated the market, but this changed rapidly as the growing market and clear policy direction have encouraged the establishment of domestic players.

2009 was something of a turning point for the rapidly growing domestic industry, in the sense that it has completed its localization and is now gearing up for the international market. Yet it seems unlikely that all manufacturers can survive in this toughly competitive market. By the end of 2009, China had almost 80 wind turbine manufacturing businesses, about 30 of which had already sold their products into the market.

However, in spite of these numbers, three top Chinese manufacturers currently dominate the wind energy sector in China. Goldwind, Sinovel and Dongfang all earned a place in the world's top ten manufacturers in 2009, and United Power and Mingyang made the top 15. Yet, unless the export market for Chinese wind equipment increases considerably or the home market expands further than predicted, there will be little room for the remaining 60 Chinese manufacturers alongside the established Chinese players and the international companies that manufacture in China.

Chinese turbine manufacturers are also readying themselves to enter the international market, albeit from modest beginnings. Only 21 Chinese-made wind turbines were exported in 2009 (to the US, India and Thailand), according to the Chinese Wind Energy Association (CWEA).

TRANSMISSION

It is by no means uncommon for a growing wind sector to run up against the constraints of a limited power transmission system. In China, which is experiencing rapid economic growth and an unprecedented expansion of its power sector, the grid infrastructure is proving to be a serious issue, especially in areas with high wind speeds, such as the Northwest, the North and the Northeast of China. This problem has both institutional and technological aspects.

1 Equivalent to €5.9 - 7.1 cents/kWh in September 2010

Politically, the low official target for wind power development in China (30 GW by 2020, a figure that should in reality already have been reached in mid-2010) provides a welcome excuse for delays in infrastructure upgrades. The lack of suitable power grids in turn discourages grid operators from accepting more wind power into the grid. While under the existing legislation, grid companies are obliged to buy power generated from renewable sources, there are no penalties for non-compliance with this provision, and no compensation is paid to wind farm operators for the losses they incur when failing to sell their power. Although this issue was addressed by the 2009 amendments to the Renewable Energy Support law, it is not yet clear if it will be effective.

Overall, however, there is no doubt that given the need for fuelling the country's growing economy, more power grids will be built in China. One indication is the priority that the Chinese government has given to infrastructure projects in its 2008 economic recovery plan.

The current power sector plans require the capacity of each of the west–east transmission connections to increase from about 7 GW (2005) to 40 GW by 2020[2]; and as many of China's prime wind sites are far to the west and north of main centres of population, exploiting them fully will require the construction of much new dedicated transmission.

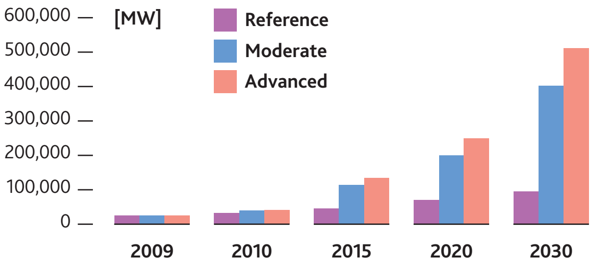
OFFSHORE WIND IN CHINA

Summer 2010 saw reports that China's first offshore wind farm – the 102 MW Donghai Daqiao installation near Shanghai's East Sea Bridge – has started feeding power into the transmission grid following completion of construction in February. 34 Sinovel 3 MW turbines make up the first phase of the wind farm. Construction also began this year on what will eventually be 1,000 MW of offshore wind off Shandong Province.

In April 2009, the National Energy Administration (NEA) asked each of China's coastal provinces to compile a provincial offshore wind development plan, and divided the potential offshore wind sites into three categories, depending on the depth of water: an 'inter-tidal' zone for water depth of less than 5 m; an 'offshore' zone for water depth of 5-50 m; and a 'deep sea' zone deeper than 50 m. The provincial governments are required to draft offshore development plans for 'inter-tidal' and 'offshore' wind development up to 2020.

2 *PennWell: Global Power Review, 2010.*

CHINA: CUMULATIVE WIND POWER CAPACITY 2009-2030



Year	Reference	Moderate	Advanced
2009	25,805	25,805	25,805
2010	32,805	39,608	41,030
2015	45,305	115,088	134,712
2020	70,305	200,026	250,397
2030	95,305	403,741	513,246

THE GWEO SCENARIOS FOR CHINA

In our previous Outlook, published in 2008, the 2020 projections for total installed capacity in China were 27 GW under the Reference scenario, 101 GW under the Moderate growth scenario, and 201 GW under the Advanced growth scenario. Projections for capacity additions in 2010 were 9 GW (Reference), 17.5 GW (Moderate) and 19.6 GW (Advanced). However – by the end of 2009 China's total installed capacity had already reached 25.8 GW. If 2010 sees the same level of new build as 2009, with no annual market growth at all, China will have close to 40 GW of wind power installed by the end of this year.

With these developments in mind, the scenarios presented in this report have been updated radically, while the IEA's Reference scenario remains rather pessimistic.

According to the IEA, the Chinese wind energy market will experience a considerable decrease in annual installations from 13.8 GW of new capacity added in 2009 to a mere 2.5 GW in 2015 and 2030. This would translate into a total installed capacity of 70 GW by 2020, which is significantly lower than the unofficial Chinese target of 150 GW by this time.

This slump in the annual market would have a dramatic effect on investment and jobs in China, with investment figures dropping from the current €18.6 billion per year to a

Helan Shan wind farm, China
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mere 3.2 billion by 2015, and employment plummeting from an estimated 150,000-200,000 jobs to only 50,000 in this timeframe.

Such development, as foreseen by the IEA, would not help China's effort to curb its carbon emissions, as wind power would then save only 103 million tons of CO_2 annually by 2020, and 140 million tons by 2030.

Given the Chinese government's commitment to developing the countries wind resources, the GWEO Moderate scenario foresees a more realistic continuation of wind power growth in China, with annual installations increasing from the current 13.8 GW to 17.7 GW by 2020 and 22.1 GW by 2030. By 2015, the total installed capacity would increase to reach 115 GW, and this would grow to 200 GW by 2020 and 400 GW by 2030.

As a result, €21.3 billion would be invested in Chinese wind development every year by 2020, and 24.6 billion in 2030. Employment in the sector would grow from the currently estimated 200,000 jobs to reach close to 300,000 by 2020 and 400,000 by 2030.

But the GWEO shows that the wind development in China could go even further. The most ambitious Advanced scenario is looking at 135 GW of total installed capacity by 2015 and 250 GW by 2020. This would grow to reach 513 GW by 2030, with annual markets growing to 25.5 GW over that period.

This kind of very large scale deployment of wind energy would have significant economic and environmental benefits for the world's most populated country.

By generating 330 TWh of clean electricity in 2015, wind power would start to make up a considerable share of China's overall power demand, and this would grow to 614 TWh by 2020 and as much as 1,258 TWh by 2030. This would represent around 11% of China's total electricity consumption in 2020, and 18% by 2030, based on the IEA's assumptions for the country's power consumption growth, and it would help fuel the country's growing economy and provide a hedge against volatile fossil fuel prices.

Such development would also result in more than €25 billion of investment flowing into the Chinese wind sector every year by 2030, which would go along with a doubling of the wind sector work force from the current 200,000 to reach close to 400,000 in this timeframe.

And, last but not least, exploiting the country's wind resources to this level would significantly improve China's carbon emissions balance. By 2015, wind power would help save 190 million tons of CO_2 every year, and this figure would grow to 750 million tons by 2030.

However, in order for China to fully exploit the economic and environmental benefits that wind power can offer, certain remaining obstacles need to be addressed. This concerns the issue of grid infrastructure to accommodate ever larger amounts of wind power in the national electricity grid and transport them from the windy but remote areas to population and industry centres.

A different, yet related issue concerns the government target for wind power development. Although the current official target of 30 GW by 2020 has already been met, the target has not been increased yet. Ambitious targets, however, are key to demonstrating political commitment to wind power development, and to encouraging investment, both in manufacturing and in grids.

Eastern Europe/Eurasia

This group of countries ranges from new EU members such as the Baltic states (Estonia, Latvia, Lithuania), Bosnia and Herzegovina, Croatia, Serbia, Slovenia, through Romania and Bulgaria and then eastwards into Russia and Ukraine, and finally south-eastwards into Central Asia, across the countries that used to make up the Soviet Union. The IEA has also included Cyprus and Malta in this grouping.

The group covers radically different economies and power systems. Some countries, such as Turkmenistan or Azerbaijan, have massive reserves of oil and gas; others, such as Tajikistan and Albania meet their power needs almost entirely from hydro, while some countries have to import either electricity, fuel or both. Centre stage is resource-rich Russia, which is the world's fourth-largest power generator. Many of these countries have power stations or pipelines that are now nearing the end of their life, and which will need replacement regardless of any increase in demand.

All these areas have been assessed to some extent for their renewable energy potential, and much of this vast Eurasian landmass has excellent wind resources.[1] But how, when, and indeed whether this will be tapped is more tricky to answer.

To date, the main wind developments have been in those eastern European and Baltic states which became members of the European Union in 2004[2], such as Romania, Bulgaria and the Baltic states. These new member states had to apply the 2001 EU Renewables Directive, and their accession treaty set national indicative targets for renewable power production for each state. They are of course now also bound by the EU's new legislation for 20% of the bloc's energy consumption to come from renewable sources, which includes a binding target for each country.

Another driver for the introduction of wind development across the Eastern Europe and Eurasia region has been the Joint Implementation mechanism that forms part of the Kyoto Protocol. Under this arrangement, any Annex 1 (industrialized) country can invest in emissions reduction projects in any other Annex 1 country as an alternative to reducing its own emissions. This mechanism was targeted at the so-called 'transition economies', but as many of these have now

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become EU members, the main focus for JI is now on Russia and Ukraine. As of August 2010, there were 30 wind energy projects in the JI pipeline, totalling an installed capacity of 1,280 MW. The largest one of these, at 300 MW, is located in Ukraine.

Wind power development has already started in some of the countries covered in this section. While **Romania,** which according to the EU Directive must meet 24% of its energy demand by renewables in 2020, had only 14 MW of wind power installed at the end of 2009, the country's project pipeline is impressive. EWEA's scenarios indicate that in 2020 the country could have up to 3.5 GW installed, and the Romanian wind energy association believes that 3 GW could be reached as early as 2013. In April 2010, Iberdrola Renovables was granted permission to build 1,500 MW of new wind capacity between 2011 and 2017, and German RWE is planning to develop 350 MW.

The situation in **Bulgaria** is also promising. With a renewable energy target of 16% under the EU Directive, the country introduced favourable policies to promote renewable energy development, and wind power installations have been growing considerably in recent years, with a total of 177 MW operating at the end of 2009. According to the EBRD, around 1,000 MW worth of wind projects are currently at various planning stages, and the overall potential is estimated at around 2.2-3.4 GW.

1 Much of the information in this chapter, including the resource assessment, is derived from the EBRD's Renewable Development Initiative (www.ebrdrenewables.com)
2 Note that some of these countries, such as Poland, are covered in the OECD Europe section

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The **Baltic States** have also started to develop wind power, with 142 MW of installed capacity in Estonia, 91 MW in Lithuania and 28 MW in Latvia at the end of 2009. Under the new EU Directive, these countries have binding targets of meeting 25%, 23% and 40% respectively of their energy needs with renewable sources, and they all have significant wind resources, especially along the coastlines, which can go a long way towards achieving their goals.

Russia is, due to its sheer size, key when it comes to determining potential renewable energy growth in this region. The world's fourth-largest electricity generator of electric power produces 68% of its power from thermal power generation, 21% from large hydro plants and 10% from nuclear power. 'New' renewable energy currently only accounts for around 1% of Russia's electricity supply.

Russia's massive reserves of gas, coal and oil lead to a low cost of energy, which creates a challenge for the development of renewable sources. However, the country has a significant potential for renewable energy development, not least due to its size and geography.

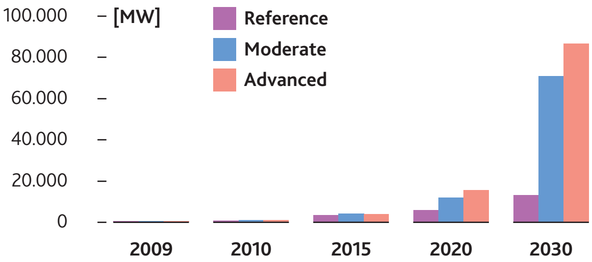
With many current power plants reaching the end of their lifetime, the Russian government estimates that 186 GW of new or replacement generation capacity is needed by 2020. Part of Russia's strategy is to reduce the proportion of its power generation from gas, partly by addition of more nuclear power and large hydro. However, in January 2009 the government set a target for renewable power generation to supply 4.5% of demand by 2020, up from less than 1% at present. In a system as large as Russia's, this signifies an additional 22 GW of new renewables generation – the Russian Wind Energy Association calculates that this could include 7 GW of new wind power by 2020.

Russia has huge potential for wind power development, according to the EBRD, with the windiest regions concentrated along the coastline, in the steppes and in the mountains, mainly in the North and West of the country. To date, the development of the wind sector has been slow, with only a little over 20 MW of wind installed, and no new construction of commercial wind farms since 2002. More recently, however, the wind power industry in Russia has started gaining a little bit of traction, with a demonstration project becoming operational in Murmansk in 2008. Planning has also begun to build a large-scale wind farm in the same region. At present more than 1,700 MW of wind projects are reported to be under development.

Ukraine, also a country covering a vast land mass, has good wind resources and a developing economy. According to EBRD estimates, over 40% of the country's territory would be suitable for wind generation. About 5,000 MW of wind power could be developed in the mid-term, and as much as 20-30% of the country's total electricity demand could be met by wind. In 1996, the Ukrainian government announced a target of installing 200 MW by 2010, but by the end of 2009, only 94 MW had been reached.

Further east, several countries including **Kazakhstan, Turkmenistan, Azerbaijan** and **Uzbekistan** have areas with

EASTERN EUROPE/EURASIA: CUMULATIVE WIND POWER CAPACITY 2009-2030



Year	Reference	Moderate	Advanced
2009	484	484	484
2010	869	910	938
2015	3,369	4,214	4,073
2020	5,869	12,083	15,784
2030	13,369	71,011	86,815

excellent wind resources, but large oil and gas reserves have to date been a disincentive to any renewable energy development. Countries with fewer fossil fuel resources, such as **Kyrgyzstan, Georgia** and **Tajikistan** might be more promising for wind power development in the short and medium term, but no development has taken place to date.

THE GWEO SCENARIOS FOR EASTERN EUROPE/ EURASIA

Apart from the new EU member states in this region, which are undertaking considerable efforts to catch up in terms of renewable energy deployment, no significant development has taken place in Eastern Europe. Prognostication of the installed wind power capacity in the near and mid-term future is particularly difficult in this region, as this will largely depend on political decisions in some key countries, especially Russia and Ukraine. If these governments decide to exploit the tremendous resource at their doorstep and provide the necessary incentives for attracting investors, wind power generation could play a key role in fuelling these growing economies. Without this political will, however, the wind markets are set to stagnate.

According to the IEA's Reference scenario, this is exactly what will happen. This scenario sees annual markets across the whole region (including the new EU member states) increase from 275 MW in 2009 to reach 500 MW by 2015, and then 750 MW by 2030. This would result in a total installed capacity of close to 6 GW by 2020 and 13 GW by 2030, up from under 500 MW in 2009.

Such a development would not have any substantial impact on power generation, economic growth or emissions savings in these countries. In 2020, wind power would only produce 14.3 TWh across the entire region – compared to an estimated electricity consumption of 880 TWh in Russia alone at that time and 1,500 TWh in the whole region of Eastern Europe/Eurasia, according to the IEA.

Investment in wind equipment would also be negligible, amounting to only around €600 million in 2020, and employment in the wind sector would stand at around 8,500 jobs by then.

The Moderate scenario is slightly more optimistic, assuming that both the EU member states and some other countries with existing renewable energy targets will meet these as planned. This would result in annual markets increasing nearly tenfold between 2009 and 2020, and reaching more than 8GW by 2030. The installed capacity would then stand at 12 GW in 2020 and 71 GW by 2030.

The resulting benefits for power generation and climate protection would be more sizeable under this scenario. In 2020, wind power would produce close to 30 TWh of clean electricity, and this would grow to 174 TWh by 2030, saving 17.7 mil tCO_2 and 104.5 mil tCO_2 respectively. If we consider that the region's electricity demand is forecast to reach 1,800 TWh by 2030, though, the overall share of wind power in the electricity system would still be rather small compared to other regions in this scenario.

In terms of investment and jobs, the Moderate scenario figures would translate into investments worth €2.7 billion in 2020, creating 33,000 jobs, and €9.1 billion in 2030 with a workforce of 121,500 million people employed in the wind sector.

The figures in the Advanced scenario are slightly higher. Here, 15.8 GW of wind power would be installed by 2020, producing 38.7 TWh and saving 23 million tons of CO2. Annual markets running at around 4 GW in 2020 would attract €4.8 billion in investment every year, and this would increase to close to 10 GW by 2030, which would translate into €10.6 billion invested in the sector. More than 145,000 people would by then be working in the field of wind energy.

India

India's rapidly growing economy and expanding population make it hungry for electric power. In spite of major capacity additions over recent decades, power supply struggles to keep up with demand. Electricity shortages are common, and a significant part of the population has no access to electricity at all. India's electricity demand is projected to more than triple between 2005 and 2030. The IEA predicts that by 2020, 327 GW of power generation capacity will be needed, which would imply the addition of 16 GW per year.

This urgent need is reflected in the target the Indian government has set in its 11th Five Year Plan (2007-2012), which envisages an addition of 78.7 GW in this period, 50.5 GW of which is coal, and 10.5 GW new wind generation capacity, plus 3.5 GW other renewables.

The Indian Ministry of New and Renewable Energy (MNRE) estimates that there is a potential of around 90 GW for power generation from different renewable energy sources in the country, including 48.5 GW of wind power, 14.3 GW of small hydro power and 26.4 GW of biomass.

The current figures are based on measurements from only nine states, and which were taken at low hub heights, in line with old technology. A more recent wind atlas published by the Center for Wind Technology (CWET) in April 2010 estimated the resource potential at 49,130 MW. This was based on an assumed land availability of 2% and 9 MW of installable wind power capacity per square kilometre.

It seems likely that the wind power potential is considerably underestimated. The Indian Wind Turbine Manufacturers Association (IWTMA) estimates that at hub heights of 55–65 metres, potential for wind development in India is around 65–70 GW. The World Institute for Sustainable Energy, India (WISE) considers that with larger turbines, greater land availability and expanded resource exploration, the potential could be as great as 100 GW.[1]

At the end of 2009, India had 10,926 MW of installed wind capacity, and 11,807 MW were reached by the end of the country's financial year on 31 March 2010. However, wind power in India is concentrated in a few regions, especially

Gujarat wind farm, Kutch, India
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the southern state of Tamil Nadu, which maintains its position as the state with the largest wind power installation. It had 4.6 GW installed on 31 March 2010, representing close to 40% of India's total wind capacity. This is beginning to change as other states, including Maharashtra, Gujarat, Rajasthan, Karnataka, West Bengal, Madhya Pradesh and Andhra Pradesh start to catch up, partly driven by new policy measures.

India ratified the Kyoto Protocol in August 2002, and the possibility to register projects under the Clean Development Mechanism (CDM) provided a further incentive to wind energy development. By 1 September 2010, 416 Indian wind projects were in the CDM pipeline, accounting for 6,839 MW, second only to China.

India's wind energy potential has only been partially realised due to the lack of a coherent national renewable energy policy. Currently, the promotion of renewable energy in India is mainly driven by state governments. While some states have set high renewable portfolio standards, other states only have low or no targets, and enforcement is insufficient. Furthermore, while in theory, RPS and feed-in-tariffs can coexist, this needs to be well managed to avoid inefficiencies. The lack of a national policy is hampering genuine progress.

Until very recently, the promotion of renewable power generation at a national level relied on one clause of the 2003 Electricity Act. This act restructured the Indian electricity industry by unbundling the vertically integrated electricity supply utilities in the Indian States and establishing

1 *WISE (G.M. Pillai): Wind Power Development in India, 2006.*

State Regulatory Commissions (SERCs) in charge of setting electricity tariffs. It also required the SERCs to set Renewable Portfolio Standards for electricity production in their state, and the Ministry for New and Renewable Energy (MNRE) issued guidelines to all state governments to create an attractive environment for the export, purchase, wheeling and banking of electricity generated by wind power projects.

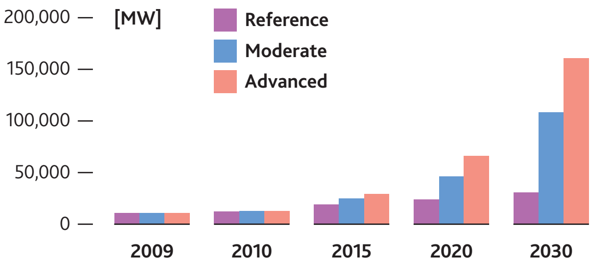
Some of the government's broad national policy guidelines include fiscal and financial incentives, wheeling, banking and third party sales, buy-back facility by states, land policies favouring wind farm development, financial assistance, and wind resource assessment.

In December 2009, India's Ministry of New and Renewable Energy (MNRE) announced a national generation-based incentive (GBI) scheme for grid connected wind power projects, for the cumulative capacity of 4,000 MW to be commissioned by March 2012. The GBI scheme provides an incentive of 0.5 Rupees per KWh (0.8 Euro cents) in addition to the existing state feed-in tariff. Investors who because of their small size or lack of tax liability cannot benefit from accelerated depreciation under the Income Tax Act can opt for this alternative incentive instead, up to 31 March 2012 or before the introduction of a new Direct Tax Code, whichever is earlier. After this date, the Accelerated Depreciation may be phased out. This should facilitate the entry of large Independent Power Producers (IPPs) into the wind market, attract foreign direct investment and level the playing field between different types of investors. In addition, since this incentive is based on actual electricity production, rather than installation, it stimulates higher efficiencies.

India has a solid domestic manufacturing base, with current production capacity of 4,500-5,000 MW/year. Wind turbine manufacturers operating in India include Indian company Suzlon, which is now a global leader. 17 companies now manufacture wind turbines in India and another eight are in the process of entering the Indian wind power market, through either joint venture under licensed production, as subsidiaries of foreign companies or as Indian companies with their own technology. Thanks to new market entrants, it is expected that the annual production capacity will rise to 10,000+ MW by 2012-2013, according to WISE.

Some of these foreign companies now source more than 80% of the components for their Indian-manufactured turbines

INDIA: CUMULATIVE WIND POWER CAPACITY 2009-2030



Year	Reference	Moderate	Advanced
2009	10,926	10,926	10,926
2010	12,276	12,629	12,833
2015	19,026	24,747	29,151
2020	24,026	46,104	65,181
2030	30,526	108,079	160,741

from India. Wind turbines and turbine blades have been exported from India to the USA, Europe, Australia, China and Brazil.

However, for India to reach its potential and to boost the necessary investment in renewable energy, it will be essential to introduce clear, stable and long-term support policies, carefully designed to ensure that they operate in harmony with existing state level mechanisms and do not reduce their effectiveness.

THE GWEO SCENARIOS FOR INDIA

Under the IEA's Reference scenario, India's wind power market would shrink considerably from the current annual additions of around 1,300 MW to only 600 MW per year by 2030. The result would be a total installed capacity of 24 GW by 2020 and 30.5 GW by 2030. Wind power would then produce close to 60 TWh every year by 2020 and 75 TWh by 2030, and save 35 million tons of CO_2 in 2020 and 45 million tons in 2030. Investments in wind power in India would also drop from the current levels of €1.7 billion per year to only €730 million by 2030.

Under the GWEO scenarios, we expect that by the end of 2010, between 12,600 MW and 12,800 MW will be installed in India. Under the Moderate scenario, the total installed capacity would reach almost 25 GW by 2015, and this would go on to grow to 46 GW by 2020 and 108 GW by 2030.

Gujarat wind farm, Kutch, India
© Wind Power Works

In this scenario, €3.7 billion would be invested in Indian wind development every year by 2020, representing a quadrupling of 2009 investment figures. Employment in the sector would grow from the currently estimated 21,400 jobs to over 84,000 by 2020 and 113,000 ten years later.

Yet the GWEO Advanced scenario shows that the wind development in India could go much further: By 2020 India could have almost 75 GW of wind power in operation, supplying 183 TWh of electricity each year, while employing almost 150,000 people in the sector and saving almost 173.5 million tonnes of CO_2 emissions each year. Investment would by then have reached a level of €7 billion per year.

As mentioned above, the IEA Reference scenario predicts that by 2020, a total of 327 GW of power generation capacity will be needed in India, which would imply an addition of 16 GW per year. As the Advanced scenario shows, wind power could be providing a significant proportion of this by 2020.

With that level of momentum established in India's wind sector, the ten years between 2020 and 2030 would then see spectacular growth, more than doubling the installed capacity for wind power and taking it to over 160 GW under the Advanced scenario. This would go even further towards meeting India's growing need for electric power. By 2030 wind power would be generating almost 400,000 GWh per year and be avoiding the emission of 373 million tonnes of CO_2 each year.

Latin America

Latin America, a region of great cultural and economic diversity, has some of the world's best wind resources. Home to many growing economies with increasing electricity demand, plus a broad commitment to environmental protection, this part of the world is considered prime territory for the deployment of wind power.[1]

Beginnings have been modest to date. At the end of 2009, only 1,072 MW of wind power capacity had been installed across the entire region. 505 MW of this was installed during 2009, with new wind installations in six countries. There are signs, however, that wind power is now finally reaching critical mass in a number of Latin American markets, and that the region is on the verge of developing a substantial wind power industry to complement the region's rich hydro and biomass (and potentially solar) resources.

However, we have to bear in mind that Latin America is far from being a homogeneous region. In fact, the continent's 40+ countries and overseas territories are at vastly different stages of economic development. There are a number of emerging economies in the region whose per capita income is similar to – or greater than – that of some new EU member states; yet at the same time the region is still plagued with extreme poverty and underdevelopment in some countries and sub-national regions.

BRAZIL

Wind power is making the most progress in Brazil, the region's largest economy. This country has areas with tremendous potential for wind energy, combined with a growing electricity demand and solid industrial infrastructure.

Brazil has historically relied heavily on hydro power generation, which until recently produced 80% of the country's electricity needs. As wind and hydro power work well together within a power system, this combination forms an ideal basis for large-scale wind power development.

After a few early developments in the first half of this decade, the Brazilian wind market now seems to be taking off. In 2008, 94 MW were added, and another 264 MW in 2009,

1 Please note that Mexico is part of OECD North America, according to the IEA's classification which is used in this report for comparison purposes

Rio do Fogo wind farm, Brazil
© Wind Power Works

meaning that 606 MW were in operation by the end of 2009. During the first half of 2010, another 180 MW had been added, with nearly 300 MW more under construction. Cumulative installed capacity should reach more than 900 MW by the end of the year.

Wind projects awarded through the PROINFA programme account for over 95% of wind power installations to date in Brazil. This programme was initially passed by the Brazilian Congress in 2002 in order to stimulate the addition of over 1,100 MW of wind energy capacity, which was later expanded to 1,400 MW. It looks increasingly likely that the 1,100 MW target will be met, if not necessarily the full 1,400 MW.

In December 2009, the Brazilian energy regulator, Agencia Nacional de Energia Eletrica (ANEEL), hosted the country's first wind-only auction. Through that, 71 wind energy projects were contracted for a total capacity of 1,800 MW. Two more auctions took place at the end of August 2010 with a total contract volume of about 2,000 MW.

ARGENTINA

Argentina also has massive wind resources. Some analysts claim that the winds in Argentina are sufficient to supply Latin America's entire electrical demand seven times over.[2] A tentative start at developing this resource was made during the 1990s; in fact, that is when almost all of Argentina's currently operating wind farms were built. Since then, the country's market has languished. New hope has now arisen with the tender of 500 MW of wind power under the GENREN programme with a target of 8% renewable electricity, and several new projects are under development.

OTHER MARKETS

Another promising market is **Chile**, which had nearly 170 MW in operation at the end of 2009. A number of large wind power projects are under development, and they are desperately needed to help alleviate chronic gas shortages.

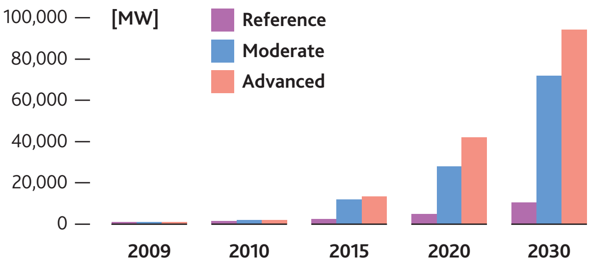
Other wind power markets in the region include **Costa Rica**, which had about 120 MW of wind power at the end of 2009, and a new 50 MW project is expected to come on line in 2010; **Peru,** which had nearly 150 MW under construction at the end of 2009; **Uruguay,** which has a target of 500 MW by 2015; **Venezuela** with 100 MW currently under construction, scheduled to come on line in 2011; **Jamaica,** with 23 MW installed capacity, and **Nicaragua,** which added 40 MW of new wind 2009, thereby joining the list of countries with commercial-scale wind power development.

Finally, although there is some development of wind power in the island economies in the **Caribbean,** which currently mostly rely on imported fossil fuels, wind power could play a much more substantial role in helping grow their economies on a more sustainable basis.

Unfortunately, however, all of these early markets suffer from the lack of a clear, long-term policy framework for the devel-

2 *Alan D. Poole: The Potential of Renewable Energy Resources for Electricity Generation in Latin America, 2009.*

LATIN AMERICA: CUMULATIVE WIND POWER CAPACITY 2009-2030



Year	Reference	Moderate	Advanced
2009	1,072	1,072	1,072
2010	1,522	1,956	2,082
2015	2,522	11,932	13,329
2020	4,772	28,004	42,224
2030	10,522	72,044	93,347

opment of a wind power industry, which continues to hamper market development. Signals are needed from governments indicating to the private sector and the finance community that there is clear political commitment to develop renewable energy in general and wind power in particular. This would at the same time foster economic development, attract investment and create the 'green' jobs that have been the object of government policy in many other parts of the world – as the scenario figures underline.

THE GWEO SCENARIOS FOR LATIN AMERICA

GWEC expects wind energy installations in Latin America to be considerably stronger than previously thought, with encouraging developments in markets such as Brazil, Argentina and Chile.

Under the Reference scenario, wind power could provide Latin America with 26 TWh of electricity every year while saving 15.6 million tonnes of CO_2 emissions by 2030; or it could, under the Advanced scenario, generate nearly ten times as much (231.4 TWh) and save 139 million tonnes of CO_2 emissions per year by then. This stark difference underlines the enormous impact that a positive political framework can make across this wind-rich continent.

Under the Reference scenario there would be 10.5 GW of wind installed across the entire continent by 2030. This would, in fact, mean that the annual market would shrink from the 505 MW installed in 2009 to as little as 200 MW by 2015. Only by 2030 would it again reach its current size, according to the IEA's Reference Scenario.

The Moderate scenario, which takes into account current policies and targets, foresees a much more rapid development, with annual additions reaching 3,000 MW as early as 2015, and more than 5,000 MW by 2030. This would bring the total installed wind capacity to 28 GW by 2020 and 72 GW by 2030. The impact on electricity production would be considerable, with 68.7 TWh of wind power generated in 2020 and 176.7 TWh in 2030.

The Advanced scenario outlines that even more could be achieved, given the extraordinary wind conditions in many Latin American countries. If fully exploited, wind power could boom here, with more than 13.3 GW of wind power installed across the continent in 2015. This could then go on to increase to 42.2 GW by 2020 and as much as 93.3 GW by 2030.

With such a development, wind power would start to account for a significant part of electricity demand, producing more than 100 TWh by 2020 and 231 TWh by 2030.

Wind power developed at such a scale would not only strengthen Latin America's energy independence, but it would also have a direct impact on regional economic development and jobs.

In terms of employment, there were about 7,400 jobs in the Latin American wind sector in 2009. Under the Reference scenario, this number would fall to just over 3,600 by 2015 and only reach current levels again in 2020. The Advanced scenario shows that from 2015 to 2030, the sector could, each year, have employment figures more than ten times as high as in the Reference scenario, reaching 100,000 by 2030.

Equally, wind power would attract substantial investment; the Advanced scenario estimates that Latin America's wind sector could be worth as much as €4.3 billion each year as early as 2015, growing to €6.5 billion by 2030, compared to just €680 million in 2009.

Middle East

As a region, the Middle East – classified by the IEA as Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates and Yemen – is rich in oil and gas. Yet the economies of the various countries reflect the fact that these reserves are unevenly distributed – members of the Gulf Cooperation Council (Abu Dhabi, Bahrain, Kuwait, Saudi Arabia, Oman and Qatar) are generally most affluent. While those countries are major exporters of oil, others are importers, often at a very high cost compared to their overall GDP. Increased prosperity in much of the region means that the demand for power has been growing rapidly for industrial and consumer needs, with extra loads for cooling and desalination. Some of the wealthiest countries in the Middle East region are among the world's most carbon intense economies.

Given the overall aridity of the region, it may be surprising that hydro power is well developed in countries such as Iran, with some 7,500 MW of installed capacity generating just over 18 TWh per year and Syria with 1,500 MW, producing 4 TWh per year. Iraq has 2,225 MW of installed hydro capacity but current production is only about 500 GWh/year[1]. Most other power production in the region is based on natural gas.

A number of governments in the Middle East have developed national plans for renewable energy. The latest Energy [R]evolution Scenario[2] anticipates that, given political support and well-designed policy instruments, by 2050, 95% of the electricity produced in the Middle East could come from renewable energy sources – mainly wind, solar thermal energy and photovoltaics. The installed capacity of these renewable energy technologies will grow from the current 10 GW to 556 GW in 2050, meeting 83% of the region's demand for heating and cooling, says the report.

As regards wind power, the region had 101 MW installed at end of 2009. While less evenly distributed than solar, the region's wind resource is excellent in some areas, as several of the governments are now recognizing. Iran and Oman have good wind regimes, as do Syria and Jordan.

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Iran is the only country in the region with any large scale wind power installations. The country currently has two wind farms: the Manjil wind farm in Giland province, and the Binalook wind farm in Khorasan Razavi province, which have an installed capacity of 91 MW. There are plans for expanding wind capacity to reach 400 MW in the coming years. Studies have shown that overall, Iran has a potential for wind power development of around 15 GW[3]. Iran offers tax and investment credits to support renewables development. In addition, Iran is home to the region's only wind turbine manufacturer, Saba Niroo.

Jordan currently generates 1.5% of its electric power from renewable sources. Its policy is to achieve 7% of its primary energy demand from renewables by 2015, and 10% by 2020. In January 2010 the government passed a new Renewable Energy Law, which requires the National Electric Power Company (NEPCO) to purchase all electricity produced by independent and small-scale renewable plants at full retail price (net metering). The government is reportedly considering introducing an incentive system to promote investment in wind power, which could include a feed-in tariff.

Jordan's best wind resources are in Aqaba and the Jordan Valley, and the government intends to build 600 MW of wind by 2015 and a further 600-1,000 MW by 2020. In summer 2010 negotiations for Jordan's first wind farm were under way again (having stalled earlier) – this is to be a 30-40 MW wind power plant in Kamshah.

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1 *World Energy Council: Survey of Energy Resources, 2009: see www.worldenergy.org/documents/hydro_7_1_1.pdf*
2 *www.energyblueprint.info*
3 *University of Tehran: Recent Advances in the Implementation of Wind Energy in Iran, 2006. www.jgsee.kmutt.ac.th/see1/cd/file/B-002.pdf*

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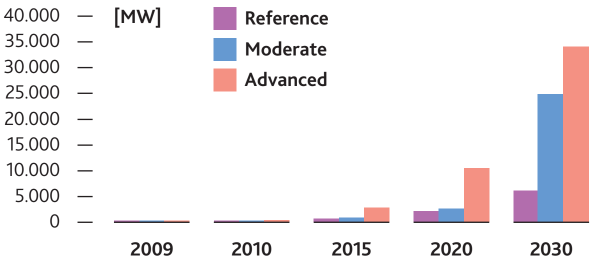
MIDDLE EAST: CUMULATIVE WIND POWER CAPACITY 2009-2030



Year	Reference	Moderate	Advanced
2009	101	102	102
2010	112	119	123
2015	465	737	2,706
2020	2,027	2,487	10,523
2030	5,987	24,791	34,159

Syria's target is for renewable energy to make up 4.3% of primary energy demand by 2011, and it has two wind farms (100 MW and 30 MW) in planning, with two locations being opened up for investment by Syrian and foreign companies.

A new plan for Syrian energy, entitled 'Masterplan for Energy Efficiency and Renewable Energies' (MEERE), is being drawn up together with the Germany's GTZ (Gesellschaft für Technische Zusammenarbeit – German Technical Cooperation) and expected to be released later this year.

Meanwhile an interim MEERE report from January 2010 confirmed that Syria has good potential for wind energy development, and indicated that a possible 2030 target could be 1,000-1,500 MW.

Oman is a small country with only 2.6 million inhabitants, and considerable reserves of natural gas and crude oil, and a total installed power generation capacity of around 3.5 GW. To meet increasing demand, this is forecast to grow by 2.8 GW by 2014.

Natural gas and oil exports account for around half of Oman's GDP, and preserving its reserves is the key incentive for the government to look at developing the country's renewable energy resources. A recent study commissioned by the government found an excellent potential for solar energy deployment and considerable wind power potential. Wind energy could be developed mainly in the southern part of Oman and in the mountains north of Salalah. Interestingly, the measured wind speeds were highest in summer months, when electricity demand in Oman is at its peak.[4]

THE GWEO SCENARIOS FOR MIDDLE EAST

Considering the significant potential for wind power in some Middle Eastern countries, the GWEO scenarios for the region are by far more optimistic than the IEA's Reference scenario. This forecasts that the region's total installed wind capacity, which stood at 101 MW by the end of 2009, will grow to around 2.5 GW by 2020 and 6 GW by 2030.

Under the Moderate scenario, which takes into account current and anticipated government targets and a growing interest in reaping the benefits wind power can bring to the region, the Middle East's installed wind capacity would grow to 2.5 GW by 2020 and 24.8 GW by 2030. In the Advanced scenario, this would grow even further, to reach 10.5 GW by 2020 and 34.2 GW by 2030.

The electricity generated through wind power in these scenarios would enable some of the Middle Eastern countries to improve their energy independence and help those rich in fossil fuel resources to realise considerable fuel savings.

By 2020, between 6 (Moderate scenario) and 26 TWh (Advanced scenario) could be produced every year, and this would increase to 61-84 TWh by 2030. Accordingly, CO_2 emission savings would be between 3.6 and 15.5 million tons per year by 2020, and as much as 36.5 and 50 million tons by 2030.

4 *Authority for Electricity Regulation, Oman: Study on Renewable Energy Resources, Oman. May 2008. http://www.aer-oman.org/pdf/studyreport.pdf*

Non-OECD Asia

This region groups together all Asian countries apart from China, India, Japan and South Korea, which are covered in other sections. The 'region' ranges thus from Afghanistan through Mongolia, to Southeast Asia and the islands of the Pacific (see p. 18 for a full list of countries).

At present, there is little development of wind power in many of these countries. However, that is not to say that there is no potential, or no plans. While one might expect a country such as Mongolia to have an outstanding wind resource, the potential for development in countries such as Vietnam or Laos may come as a surprise; for it is often believed that there is not a viable wind resource in the tropics – where many of these countries are located.

Factors other than pure wind resource potential are involved in projecting when (or indeed if) wind power is likely to be developed and how much: demographic factors, dependence on fuel imports, economic growth and consequent increase in electrical demand, state of the transmission and distribution system, etc. One potential enabler open to many of these countries is the Clean Development Mechanism of the Kyoto Protocol (CDM), which can potentially stimulate investment in renewable energy projects by industrialized countries. While the take-up of this has already been very good in some sectors (such as in Thailand's biomass power sector), there are so far few wind power projects in the CDM pipeline in the in this region – two in the Philippines, and one each in Mongolia, Vietnam and Sri Lanka.

Across the region covered here there are at least a dozen vibrant and rapidly growing markets in which wind energy could play a significant role. There is also a noticeable shift in the attitude of policymakers and utility executives to wind power. While wind would have been dismissed as 'too expensive' by most developing country energy planners just a few years ago, the continuing success of the technology in an ever widening group of countries has changed that attitude to one of dramatically increased knowledge about wind generation and the role that it can play in a country's power mix.

The markets covered below give some idea of the technical potential, and also the wide range of background conditions in this diverse grouping. In some cases, an acute need for

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additional power capacity comes together with an excellent resource – and such is the case for countries such as Vietnam or Pakistan.

Developing a substantial share of renewable power generation always requires government targets and incentives. Quite a few of the countries in this region do have targets in place – though that does not necessarily mean that incentives are also in place to support the achievement of those targets.

For instance, Bangladesh wants 5% of its electricity to come from renewables by 2015; Pakistan has set a target of 10% by 2012. Mongolia plans to increase its share of renewable electricity from the current 3% to 20–25% by 2020. The Philippines is targeting 4.7% by 2013; Sri Lanka wants to go from the current 5% to reach 10% by 2017 and 14.1% by 2022, Tonga is targeting 50% by 2012, and Indonesia wants to build 255 MW of wind capacity by 2025 (alongside other renewable technologies such as 6 GW of geothermal).[1]

Some wind power development has already taken place in this region, including:

The **Philippines'** existing power generating capacity is about 15 GW. Electricity generated from renewable sources such as hydro, biomass and geothermal power comprise 33% of the Philippines' current power mix, and the government has said it hopes to increase that to 40% in a decade, adding wind,

1 All these figures are taken from REN21 Global Status Report 2010

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solar and ocean energy to the renewable mix. A 41.7 million USD fund has been set up to help with this process. As far as wind resource goes, according to SWERA figures[2], 11,000 km2 – or 3.7% of the land area – have good wind resources, which could potentially support the development of 55 GW of wind power – over three times the current total installed power capacity.

Vietnam's (purely technical) wind potential could support 642 GW of wind power according to SWERA figures. In addition, Vietnam has a fast-growing economy and a growing demand for electric power. The country has been expanding its generating capacity, including through new large hydro dams, but still needs to import electricity from China. The Vietnamese government is aiming for renewable power to provide about 5% of the nation's electricity by 2020.

Vietnam's first wind developments took place in 2009. One of the country's first plants at Binh Thuan will soon be connected to the grid, and two more projects are reported to be in the pipeline in Lam Dong Province (150 MW and 80 MW).

Investor interest in the Vietnamese wind market is considerable, and overall, some 20 wind power projects with a combined capacity of 20 GW are reportedly in the pipeline.

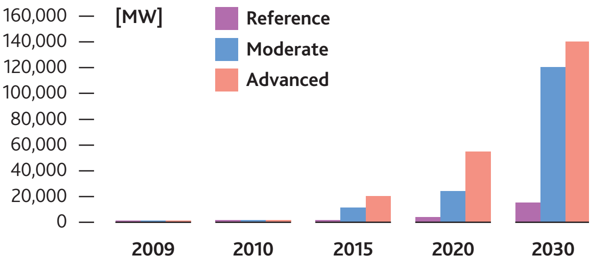
Thailand's growing affluence has led to a startling rise in per capita electricity consumption, which has grown by almost 25% in the past five years. An estimated 30.2 GW of new generation capacity will be needed by 2021. At present, Thailand's electricity generation is dominated by fossil fuels, but the government recently announced a 15-year Alternative Energy Development Plan (AEDP) with a target of increasing the share of renewable energy from 6.4% in 2008 to 20% in 2022, with an 800 MW target of wind capacity. According to SWERA figures, Thailand's technical wind resource could support the development of 190 GW of wind power.

Prosperous **Taiwan** generated and consumed 230 TWh in 2008, yet it has to import 98% of its fuel requirements. Taiwan has set a target for renewables to meet 10% of its electricity needs by 2010, up from 5.8% currently. Wind power is expected to meet 80% of that, and a feed-in tariff was introduced in 2009. During 2009, Taiwan installed 78 MW of new wind power, bringing the total to 436 MW. Taiwan does have a good wind resource on its western coast as well as offshore, but it remains to be seen if the guaranteed purchase price is high enough to encourage investment.

In **Pakistan**, the far-reaching implications of the flood disaster of 2010 on infrastructure in general, and the power infrastructure specifically, cannot yet be assessed at the time of writing. There was an acute power shortage even before this disaster, and a strong increase in power demand. Most of the country's power needs to date are met by fossil fuels. To support the addition of renewable capacity, the Asian Development Bank set up a 510 million USD financing facility in 2006, and during that same year, a feed-in tariff was introduced.[3]

2 *UNEP's Sun and Wind Energy Resource Assessment (SWERA) programme, see www.swera.net*

NON-OECD ASIA: CUMULATIVE WIND POWER CAPACITY 2009-2030



Year	Reference	Moderate	Advanced
2009	475	475	475
2010	575	709	709
2015	1,825	11,393	20,228
2020	4,325	24,204	54,813
2030	15,575	120,313	140,462

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According to Pakistan's Alternative Energy Development Board, wind power offers a technical potential of 360 GW, and this is supported by figures from SWERA, which estimate a 349.3 GW potential.

THE GWEO SCENARIOS FOR NON-OECD ASIA

Across the whole region, 78 MW of new capacity was installed in 2009, and the total stood at 475 MW at the end of the year.

Under the Reference scenario, the speed of wind power development will not increase substantially in non-OECD Asia, and the annual market across this vast region will grow to just 250 MW by 2015 and 500 MW by 2020, bringing the total installed capacity to 4.3 GW by 2020. Thereafter, the annual market will increase gradually to 1,150 GW, which would result in a total capacity of 15.6 GW by 2030.

Given the excellent wind resources in some of the Asian countries, and recent government initiatives to help exploiting them, the Moderate scenario describes a more positive development. More than 2,500 of new wind capacity would be installed in the region every year by 2015, and this would gradually increase to a pace of 19.5 GW every year by 2030. The result would be a total installed capacity of 24.2 GW by 2020, and 120.3 GW by 2030 – nearly 8 times the size of the Reference scenario.

The difference in terms of power produced and consequently CO_2 savings would be considerable. While under the Reference scenario, wind energy would produce only 10 TWh by 2020 and save 6.3 million tons of CO_2, the Moderate scenario would achieve a production of 59 TWh in this timeframe, thereby saving the emissions of 35.6 tons of CO_2 every year. This would grow to close to 300 TWh by 2030 and savings of 177 million tons of CO_2.

Economically, also, such a development would have a considerable impact. By 2015, wind energy could attract around €3 billion worth of investment to the region every year, and create around 40,000 jobs.

The Advanced scenario assumes that current efforts to promote renewable energy are intensified, reflecting governments' aim of making the most of the natural wind resources and reaping the related benefits. This would attract annual investments in the region of €8-10 million over the course of the scenario period, and create 150,000 jobs.

It is in this scenario that wind power would start to make a small but noticeable contribution to the region's electricity supply. A total installed capacity of 20 GW would produce around 50 TWh of clean power by 2015, and this would rise to 55 GW generating 134 TWh only five years later. By 2030, the installed capacity would increase to 140 GW, with an annual power production of 345 TWh.

3 *http://www.adb.org/Media/Articles/2006/11118-Pakistan-renewable-energy-development*

OECD Europe

While individual markets within this group of countries may move at different rates from year to year, the overall trend has been one of steady upward growth. 10.5 GW of new wind power were added during 2009, bringing the total installed capacity to 75.5 GW, which, in a normal year, can be expected to generate about 162.5 TWh of electricity. This would account for between 4% and 5% of this region's demand for electric power. In both 2008 and 2009, more new wind generating capacity was added than any other type of power generating plant, including natural gas.

Spain and Germany remain the two largest annual markets for wind power, competing each year for the top spot (2,459 MW and 1,917 MW of new installations respectively in 2009), followed by Italy (1,114 MW), France (1,088 MW), and the UK (1,077 MW). A further three countries (Portugal, Sweden, Turkey) each installed about 500 MW in 2009. Both Turkey and Poland are now starting to develop rapidly.

Eleven of these countries now have more than 1 GW each of total installed wind energy capacity, while one more is just below the 1 GW mark.

OFFSHORE WIND

Europe is pioneering the development of offshore wind, which is set to become a mainstream energy source in its own right. In 2009, 582 MW of offshore wind was installed in the EU, up 56% on the previous year. Cumulative capacity increased to 2 GW. The main markets in 2009 were the United Kingdom and Denmark, but several others now also have offshore wind power installations. By July 2010, Europe was home to 948 offshore wind turbines in 43 fully operational offshore wind farms, with a total capacity of 2,396 MW. In the first half of 2010 alone, 118 new offshore wind turbines had been fully connected to the grid, according to the European Wind Energy Association (EWEA). These new turbines have a combined capacity of 333 MW, which is testament to continuing strong growth in offshore wind power despite the financial crisis. In addition, EWEA reported that a further 151 turbines (440 MW) had been installed though not yet connected to the grid. At the start of 2010, it was estimated that 1,000 MW of new offshore wind would be installed in Europe during the year, representing between 9% and 10% of the region's anticipated 2010 wind market.

Driving the growth of wind power in Europe (at least for EU member states) up to 2010 were a Kyoto-led target for 22% of electricity supply to come from renewables by 2010 and country by country support measures encouraged by the 2001 EU Renewable Energy Directive. This has now been extended into a new target for 20% of final energy consumption across all EU countries to be generated by renewable sources by 2020. The new target is binding on all 27 member states, each of which has a different percentage target depending on its renewable energy resource and on the level of its existing renewables development. Many countries in Europe have introduced feed-in tariffs to stimulate the growth of wind power and other renewable energy technologies.

GERMANY

Wind power is the leading renewable energy source in Germany, and provides around 7% of the country's electricity consumption. Installed capacity reached 25,777 MW at the end of 2009, on a par with China as the second largest wind power market after the US. One of Germany's federal states (Lower Saxony) has almost 6.5 GW of wind installations, and several states now receive over 40% of their electricity from wind.

Germany's current national target is for 25%–30% of electricity to come from all renewables, mainly wind, by 2020; but Germany's wind market has already had strong government encouragement for two decades. A law first introduced in 1991 (with a major revision in 2000) includes a guaranteed feed-in tariff for all renewable power generators. Consequently the sector has developed steadily, and German turbine manufacturers are among the market leaders, with a global market share of 30%. The sector currently employs more than 100,000 people, according to the German Wind Energy Association (BWE).

Although Germany's installation rate has slowed down, it still holds fourth place globally in terms annual wind power additions. The market is poised to pick up again as the as the offshore sector is developed. Germany got off to a slow start in the field of offshore wind due to strict planning requirements which stipulate that offshore wind farms need to be built a long distance from shore. 2009 saw the installation of Germany's first offshore wind farm, the 60 MW Alpha Ventus test field, which consists of twelve 5 MW turbines.

A further impetus came in the form of revised feed-in tariffs in January 2009, which increased the rates for onshore wind and added a special bonus for 'repowering' – the replacement of turbines aged 10 years or more with ones at least double the output, either at the same site or a neighbouring one. Offshore projects were also given improved feed-in tariffs, with several bonuses available.

SPAIN

The Spanish wind energy market has seen tremendous growth, and the country led Europe in 2009 with 2.46 GW of new installations, taking total wind capacity up to 19.1 GW. This made wind power Spain's third-largest power generation technology (behind combined cycle gas and nuclear power): 36.2 TWh were generated by wind in 2009, which met 14.5% of the country's electricity demand.

Spain is home to some leading international wind power companies, including Iberdrola Renovables (the world's largest wind farm owner), Acciona and Gamesa. Wind energy has proven to be a key driver for economic development, creating over 41,000 jobs and €3.8 billion in GDP in 2008.

However, due to new legislation adding considerable complexity and delays to wind farm approval, and a lowering of the premium granted to wind power, future market developments are less than certain.

Prior to that development, the Spanish Wind Energy Association (AEE) had estimated that 40,000 MW of onshore and 5,000 MW of offshore capacity could be operating by 2020, providing close to 30% of Spain's electricity. It is unclear now if these projections, or even the government target of 21,000 MW in installed wind power capacity by the end of 2010, will be met.

ITALY

The last few years have seen real growth in Italy's wind sector – the 1.1 GW of new capacity installed during 2009 took the total to 4.85 GW, and the Italian Wind Energy Association (ANEV) estimates that 6 TWh of electricity were generated from wind power during 2009. The country is well on its way to achieving its 2020 national target of 12 GW of wind power, and ANEV estimates that as much 16.2 GW of wind capacity could be installed by then.

Holding back development are issues of regional planning, especially over landscape issues, and grid connection difficulties remain unsolved – the sector is waiting for a structural solution that will make Italy's grid more suitable for the connection of wind power. In some areas during 2009, wind farms have had their output curtailed by 30%, some even 70%, as the inadequate grid could not cope with the output. Some operators are calling for compensation for their lost income.

Wind power is offering increased employment opportunities. In 2008, 15,152 people were employed in Italy's wind sector, 4,430 of them employed directly, the remainder in associated jobs such as transport or accounting. If Italy reaches the industry goal of 16.2 GW by 2020, the sector would be employing 66,000 people, with 19,000 of them in direct employment.

FRANCE

France has good wind resources, and Europe's second-largest wind potential. Although the country had a late start, wind power development has been rapid over the past decade. While only 30 MW of wind power capacity was installed in 2000, by the end of 2009 the total capacity was up to nearly 4.5 GW, with almost 1.1 GW added in 2009, which accounted for 41% of all the new power generation plant installed that year. The 7.8 TWh generated by wind power during 2009 accounted for only 1.6% of the country's power consumption, but this is still twenty times more than six years ago. It remains to be seen if the deployment of wind power will be rapid enough for France to meet its 2020 objective of renewable energy supplying 23% of its final energy demand, a quarter of which is poised to come from wind power.

The French government has set a target of achieving 25 GW of wind capacity by 2020, 19 GW of which onshore and 6 GW offshore. The interim target for 2012 is of 11.5 GW (10.5 GW onshore and 1 GW offshore). As yet, France has seen no offshore wind developments, but the government is planning a process of three calls for tender in 2010, 2012 and 2014, the first of which will be for a total capacity of 3 GW. A consultation process on zoning for offshore wind developments should be completed by the end of September 2010.

Lake Ostrowo wind farm, Poland
© Wind Power Works

UNITED KINGDOM

Very slow to embrace wind developments on a large scale, the United Kingdom market has finally taken off both on and offshore. The UK was the world leader in new offshore capacity in both 2008 and 2009 (with 198 MW and 306 MW, respectively), and in 2009, for the first time, the UK installed over a gigawatt of new wind capacity, taking its total to 4.05 GW. With a healthy project pipeline, the wind and marine power association Renewable UK (formerly the British Wind Energy Association) expects about 10 GW of new projects to be built by the end of 2012.

The UK has a target to source 15% of its final energy consumption from renewables by 2020. This will require about 35% of the UK's electricity to come from renewables, and wind power is expected to play a major part in achieving this. Government targets are for 13–14 GW of new onshore wind by 2020, while suitable sites for up to 50 GW offshore have been identified.

Although a feed-in tariff for renewable energy installations up to 5 MW was introduced in April 2010, the existing 'Renewable Obligation' scheme for large wind was maintained. This came into effect in April 2002 and requires all power suppliers to ensure that a certain percentage of the electricity they supply comes from renewable sources.

POLAND

With excellent wind speeds in much of the country, Poland is one of Eastern Europe's most promising wind markets. Total installations were 724.6 MW at the end of last year, including 181 MW of new capacity added in 2009.

Heavily dependent on coal power for its electricity, Poland needs – in order to meet EU targets – 15% of its final energy consumption to come from renewable energy by 2020, up from 7.2% in 2005. In 2005, the Polish government introduced a stronger obligation for all energy suppliers to source a percentage of their supply from renewable energy sources. In practice however, It has not beren rigorously enforced. Now there are fears that new legislation, which came into force in March 2010, might inadvertently put wind farm developers at a disadvantage and discourage wind investment. The Polish government is currently working on a new amendment to the Energy Law that will implement the provisions of the new EU Renewables Directive, with the objective of adopting it by the end of 2010.

The Polish Wind Energy Association is expecting dynamic growth. It has calculated that 13 GW could be installed in Poland by 2020, with 11 GW onshore, 1.5 GW offshore and 600 MW of small wind. However, it is not expected that offshore will take off until late in that period, around 2018.

TURKEY

Turkey's power consumption is increasing by 8% to 9% each year. As it has very limited oil and gas reserves, the country is looking to renewable energy as a means of improving its energy security and independence from imports. And as the country prepares to join the European Union and meet carbon reduction targets, it is becoming much more aware of its wind power potential.

2009 saw the installation of 343 MW of new wind power, bringing total capacity up to 801 MW. Addition of a further 500 MW is expected in 2010.

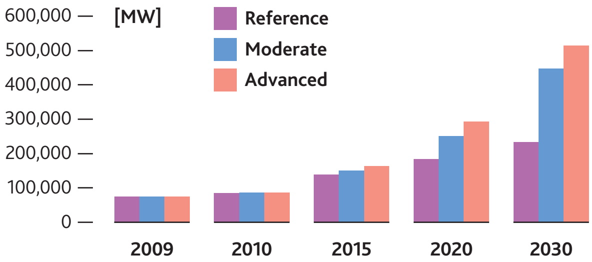
There has been a huge response to government calls for tender, making evaluation slow. By early 2010 almost 3 GW of projects had been licensed by the authorities, and it is expected that the remainder of the tenders received before November 2007 will be processed soon. Licences for a further 10 GW are scheduled to be granted within the next five years, 15 GW within ten years, and 20 GW in the long term. However, experts caution that Turkey's transmission grid will need substantial upgrading if wind power on this scale is to be accommodated.

THE GWEO SCENARIOS FOR OECD EUROPE

Given the level of maturity of some European markets, the policies already in place, and the potential of others in the region, it is surprising that the Reference scenario as put forward by the International Energy Agency anticipates that annual markets already peaked in 2009 at 10.3 GW, and will from now on see a decline, falling to 9 GW by 2020 and under 5 GW by 2030. This would result in levels of investment decreasing from €14.2 billion in 2010 to €11.3 billion in 2020 and a mere €5.9 billion in 2030. At that level, wind power would by 2030 produce 573.5 TWh and save the emission of 344 million tonnes of CO_2 each year.

Within the Moderate scenario, the annual market over the next decade up to 2020 is expected to grow at a more healthy rate, from 10.3 GW in 2009 to 24.2 GW, with annual investments in the wind sector increasing from €14 billion to €29.2 billion. That steady trend would ensure that wind power would deliver about 615 TWh of electricity to the region each year by 2020. By 2030, close to 450 GW would produce more than 1,000 TWh of electric power in this region every year, saving the emission of over 650 million tonnes of CO_2 annually.

OECD EUROPE: CUMULATIVE WIND POWER CAPACITY 2009-2030



Year	Reference	Moderate	Advanced
2009	75,565	75,565	75,565
2010	85,696	86,175	87,140
2015	138,596	150,049	163,109
2020	183,996	250,824	293,963
2030	233,796	447,432	514,806

Interesting here is the contrast between these first two scenarios when it comes to employment. The Reference scenario sees employment peak early, in 2015, by when the sector would be employing just under 200,000 people across Europe, then dropping off to 136,000 by 2030. In the Moderate scenario, however, a longer, sustained growth curve shows an expansion of jobs between 2010 and 2020, by when the wind sector would employ close to 400,000 people in Europe alone.

If you focus on the 2020 and 2030 figures, the gap between the Moderate scenario and the Advanced scenario seems less pronounced than in the models for some of the other regions. However, a comparison shows that, in an ideal world, Europe could go even a step further in exploiting its wind resources.

By 2020, the Advanced scenario forecasts a total capacity of close to 300 GW, with annual markets running steadily at around 24 GW between 2020 and 2030. This would trigger annual investments of around €26 billion by 2030 and a workforce of 460,000 people would be employed by the wind sector at that time. In terms of electricity generation and resulting CO_2 savings, the Advanced scenario also shows what could be achieved: wind power would generate close to 1,300 TWh of electricity every year, while avoiding the emission of 760 million tons of CO_2 every year in 2030.

OECD North America

North America as defined by the IEA includes Canada, the USA and Mexico, and thus includes a variety of geographic areas. Some of these, especially the plains and coastlines, have excellent wind resources.

THE UNITED STATES

The past decade has seen enormous growth in the US wind power. Back in 2000, slightly more than 2.5 GW had been installed. By the end of 2009, that had risen to a world-leading installed capacity of more than 35 GW.

However, that growth has never been steady. For reasons that often seem to have more to do with Washington politics than political will, national policy has been short-term and inconsistent, with the industry (especially in the first five years of the decade) either speeding to catch the green light, or braking hard. Although the last few years have seen more stability, as this report is being written (late July 2010) the American Wind Energy Association (AWEA) has announced that wind power installations in the first half of 2010 (1239 MW) have dropped by 71% compared with the same period in 2009 (in total, 2009 saw the addition of a massive 10 GW of new wind) and by 57% compared with the first half of 2008. However, despite a strong pipeline and a slight increase in turbine orders in the second quarter, 2010 will continue to be affected by the low level of orders in the immediate aftermath of the economic crisis as well as a drop in electricity demand.

Wind power now generates close to 2% of US electricity needs, but experts estimate that with the right policies in place, the potential is much greater. And with the US Energy Information Administration calculating that the country needs the addition of 89 GW of new power generating capacity by 2030, largely to replace ageing power plants, wind can make a powerful contribution.[1]

In 2008, the US Department of Energy released a groundbreaking report, finding that wind power could provide 20% of US electricity by 2030.[2] A more recent analysis of wind integration in the Eastern region of the country drew similar conclusions, while a new assessment from the National Renewable Energy Laboratory published in February 2010 showed that onshore US wind resources could generate nearly 37 million GWh annually, more than nine times current total US electricity consumption.

Thirty-six US states now have utility-scale wind farms, and 14 of these have over 1 GW in operation. Texas leads, with over 9 GW of wind power, of which 2.3 GW were new installations in 2009 (including the world's largest wind farm, the 627-turbine, 781.5 MW Roscoe wind farm). Iowa, California, Washington state and Minnesota follow in terms of installed capacity, with Iowa receiving 14% of its 2009 electricity consumption from wind.

The US wind market has had two policy stimuli for some years. At the national level there has been a Production Tax Credit (with erratic terms/extensions); while a growing number of states followed the Texan example by introducing a state Renewable Energy Standard (RES), requiring a certain percentage of power in the state to come from renewable sources (with wind generally providing the majority of this). Twenty-eight states currently operate an RES (sometimes known as an RPS).

In February 2009 a package of measures were introduced as part of the American Recovery and Reinvestment Act: extension of the PTC to 2012; an option to receive an investment credit tax instead of the PTC; tax credits for new wind manufacturing facilities; a 6 billion USD renewable energy loan guarantee programme. Together these were very beneficial in maintaining momentum in the sector during the 2008–2009 economic downturn.

However, to sustain the growth over a longer period, increase wind energy manufacturing jobs, and solidify wind's place in the US energy market, the US wind industry is seeking a national renewable energy standard (RES). This would stimulate utilities to buy wind power and conclude power purchase agreements, which are currently difficult to obtain, due to the drop in overall electricity demand, lower natural gas prices, and the absence of a clear national renewable energy policy. There is still some chance that such a measure could be adopted before the end of 2010.

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1 US Energy Information Administration, Annual Energy Outlook 2010. May 2010. http://www.eia.doe.gov/oiaf/aeo/aeoref_tab.html, Table 9.
2 US Department of Energy: 20% Wind Energy by 2030: Increasing Wind Energy's Contribution to U.S. Electricity Supply. May 2008.

Horse Hollow wind farm, United States
© Wind Power Works

Another policy issue that needs to be addressed is the regulatory structure for transmission. New transmission is needed to connect the good wind sites with towns and cities – at present planning, financing and permitting are slow and difficult processes and according to AWEA, many new wind power projects are on hold in the United States due to transmission limitations.

At the end of 2009 the US wind industry employed 85,000 people, and the eight leading suppliers of turbines to the US market have either established manufacturing facilities or announced plans to do so. GE Wind supplied over 46% of new turbines installed during 2009, with seven others supplying between 4% and 12% each.[3]

Although the United States has yet to enter the offshore wind sector, the 420 MW Cape Wind project off the Massachusetts coast won final approval in April 2010, and there are a number of projects at different stages of development, including in the Great Lakes.

CANADA

Canada has an immense wind resource, and its wind power capacity has grown tenfold in between 2004 and end of 2009, a year during which 950 MW was installed. Canada was a relatively slow starter so the total installed capacity at the end of 2009 was 3.3 GW – yet this is sufficient to provide 1.1% of the country's electricity.

Each of the provinces now has some wind installed, and new government power purchase agreements for at least six provinces in 2010 should ensure a record-breaking year. The Canadian Wind Energy Association (CanWEA) in its 'WindVision 2025' document sets a goal of producing 20% or more of the country's electricity from wind power by 2025.

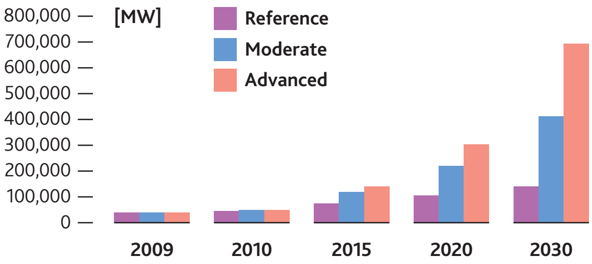
Canada's leading province in terms of wind power is Ontario, with 1,168 MW of wind installed and a further 647 MW under contract at the end of 2009. Ontario's Green Energy Act, announced in 2009, introduced a feed-in tariff for wind power, with enhanced tariffs for community projects and 'First Nations' (i.e. Native American) projects, and a higher rate for offshore wind.

The Ontario Power Authority has a plan that calls for 4.6 GW of wind energy by 2020, and many other provinces have signed contracts to expand their wind energy capacity during 2010 and beyond.

At federal level there is disappointment about the government's decision not to extend Canada's ecoENERGY federal

3 *BTM Consult: World Market Update 2030. March 2010.*

OECD NORTH AMERICA: CUMULATIVE WIND POWER CAPACITY 2009-2030



Year	Reference	Moderate	Advanced
2009	38,585	38,585	38,585
2010	45,085	49,329	49,648
2015	75,585	119,190	140,440
2020	106,085	220,041	303,328
2030	141,085	410,971	693,958

incentives. It was announced in March 2010 that the ecoENERGY programme – set up in 2007 to support the construction of over 4 GW of renewable energy projects – had already allocated all of its funding and would be supporting no wind energy projects built after March 2011. The concern is that this would make Canada less attractive to investors than its southern neighbour.

MEXICO

Mexico, too, has an outstanding wind resource, especially in the Oaxaca region. In 2009, Mexico's installed wind capacity more than doubled, adding 117 MW of new capacity to the 85 MW that were operating at the end of 2008, bringing the total installed wind power capacity to 202 MW. This increase was the result of two private self-supply projects brought online in 2009, 'Parques Ecológicos de México' (79.9 MW) and the first phase of the 'Eurus' project (37.5 MW). The first half of 2010 saw the addition of a further 300 MW. At present, however, hardly any of Mexico's wind power makes its way into the national grid. Rather, it is used on-site by self generators, such as heavy industry. The government is struggling to come up with a regulatory framework that could really open up the very substantial resources in the country.

Though it is the Oaxaca region that has seen most development so far, the Baja region also has good potential and is attracting the eye of potential developers from the US.

THE GWEO SCENARIOS FOR OECD NORTH AMERICA

Within this region we are looking at the three distinct markets of the United States, Canada and Mexico. And with the various states and provinces having policies of their own, there is potentially more variability here than in the single market of China, for instance.

Our three possible projections start with 2010, and the Reference scenario predicts relatively modest growth of 6.5 GW (as compared with the actual figure of 11 GW added during 2009), while the Moderate and Advanced scenarios anticipate addition of about 11 GW for 2010.

In fact the Reference scenario anticipates a flat market of some 6 GW per year, across North America, for the next couple of decades, slowing to 3.5 GW by 2030. This is considerably less than the US Department for Energy projections of annual markets reaching 16 GW by 2018 and stabilising at this rate, in the US alone, not even counting growth in Canada and Mexico.

The Reference scenario numbers would result in a total wind power capacity of 141 GW by 2030, which would produce 346 TWh of electricity and save the emission of 207.6 million tonnes of CO_2 every year. Jobs in the sector would peak ten years from now, when the industry would employ under 90,000 people.

However, the alternative scenarios show wind taking a much more significant role across this continent. Even the Moderate scenario shows that by 2020, the annual market for new wind installations could be more than twice the size of the record-breaking 2009 market, and by 2030 wind power would be producing over a thousand terawatt hours of electricity per year while saving the emission of over 600 million tonnes of CO_2 each year – three times that in the Reference scenario. Under this scenario, investments in wind power would peak around 2020, reaching some US$37 billion per year, but then tailing off.

If the Advanced scenario could be realised, all these figures would be dwarfed: massive CO_2 savings of over 1,000 million tonnes would be made each year by 2030, the sector would be employing 700,000 people, and wind power alone would be providing 1,700 TWh of electricity per year across North America.

OECD Pacific

The geographies and populations of the four countries covered here – Australia, New Zealand, Japan and Korea – are very different. Sited in different hemispheres, and separated by miles of Pacific Ocean (South Korea and New Zealand are ten thousand kilometres apart) what they have in common is high per capita energy consumption, and all except Korea have emission reduction obligations under the Kyoto Protocol.

AUSTRALIA

Historically, Australia has relied heavily on coal and hydro for its electric power. Yet it has some of the world's best wind (and solar) resources. The total operating wind capacity at the end of 2009 was 1,712 MW, 406 MW of which was installed that year. According to the Clean Energy Council, in mid-2010, the country was host to more than 1,000 wind turbines spread over 52 wind farms generating around 5 TWh of electricity per year.

At the end of 2009, nearly half of the country's wind capacity (around 740 MW) was located in South Australia, and a further 428 MW in Victoria. However, there are currently over 7 GW of large-scale wind farm energy projects proposed around the country, many of them having already received planning permission.

Driving this growth is Australia's expanded Renewable Energy Target (RET) Scheme. This was passed by the federal parliament in August 2009 and mandates 20%, of Australia's electricity supply (or 45 TWh) to be sourced from renewable energy by 2020. A further revision in March 2010 introduced a new target for large-scale renewables of 10.4 TWh by 2011, increasing gradually each year to 18 TWh by 2015 and 41 GWh by 2020. Achieving this target will mean the addition of around 10 GW of new renewable energy capacity in the coming decade, with wind power likely to play a leading role.

NEW ZEALAND

New Zealand has abundant renewable energy resources, and renewables supply 73% of the country's electricity (55% large hydro, 15% geothermal and 3% wind). Overall, with a population of only about 4.5 million, the country's total installed power generation capacity stands at just less than

Woolnorth wind farm, Tasmania, Australia
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10 GW, but electricity demand is growing and there are plans to phase out 500 MW of coal-fired generation.

New Zealand's wind resource is so rich that, according to a study completed for the Electricity Commission (New Zealand's electricity market regulator), wind power could potentially meet annual demand several times over.

The New Zealand government has a target for renewable energy to supply 90% of the country's electricity by 2025, which is creating good opportunities for wind, especially as wind power and hydro combine so effectively. Within 20 years, wind power's share of New Zealand's electricity supply could potentially grow from 3% to 20%. During 2009 New Zealand's installed wind capacity expanded from 325 MW to 497 MW.

SOUTH KOREA

South Korea is the world's tenth-largest consumer of energy, and its greenhouse gas emissions have doubled since 1990, partly through the heavy use of coal. Korea's electricity generating capacity has increased by 50% over the past decade, and now stands at 73 GW, most of which is coal, natural gas and nuclear power, and an additional 32.4 GW are planned to become operational by 2022, including 12 nuclear, 11 LNG and seven coal plants.

'New' renewables only provide around 0.25% of all electricity generated, according to Korea's Electric Power Corporation (KEPCO). 2009 saw the installation of 112 MW of new wind

Woolnorth wind farm, Tasmania, Australia
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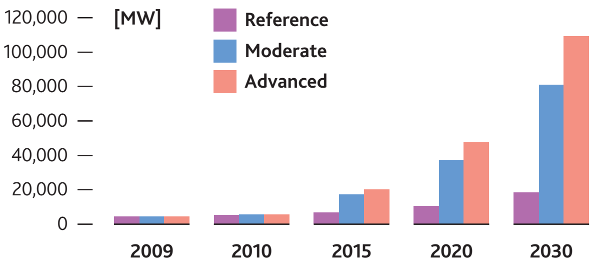
OECD PACIFIC: CUMULATIVE WIND POWER CAPACITY 2009-2030



Year	Reference	Moderate	Advanced
2009	4,613	4,613	4,613
2010	5,318	5,740	5,870
2015	6,818	17,303	20,255
2020	10,568	37,259	47,876
2030	18,568	81,159	109,367

power, bringing the total capacity to 348 MW. However, South Korea has a target for renewables to provide 11% of the country's primary energy (not just electricity) by 2030. A new bill was passed in March 2010 that requires utilities to increase the current share of renewable energy in their total power generation (excluding large hydro) from the current 1% to 4% by 2015, growing to 10% by 2022.

Wind power development in Korea will also be facilitated by the fact that several major international companies including Samsung, Daewoo and Hyundai have recently entered the wind business.

JAPAN

Japan's power sector is divided between nuclear, coal and (mostly imported) natural gas. While demand is expected to remain fairly steady in the short to medium term, the share of different forms of power generation is likely to shift, as some coal-fired generation is likely to be phased out in the coming decades as Japan is aiming to cut its CO_2 emissions by 25% in 2020 compared with 1990 levels. However, Japan is focusing more heavily on expanding its nuclear power generation than renewables to achieve this, and its target for electricity from non hydro renewables is 1.63% by 2014.

Japan's official government target for wind power by 2010 was 3,000 MW, and by the end of 2009, 2,056 MW of these had been installed. With the pace of new installations slowing down considerably in recent years due to technical, regulatory and grid connection problems, it seems unlikely that this target will be achieved.

Despite a struggling domestic market, Japan's wind turbine manufacturer Mitsubishi Heavy Industry has become a significant exporter and in 2009 had about 1.5% of the global market.

THE GWEO SCENARIOS FOR OECD PACIFIC

Given the diversity of the four countries covered, it is worth drawing a quick side-by-side comparison:

Japan has a massive power sector market – over three times the size of Korea's, five times the size of Australia's, and 25 times the size of New Zealand's. So far, Japan has this group's highest installed wind capacity, at 2.1 GW, but its development is slowing down, while Australia is moving forward rapidly. Both Australia and New Zealand have excellent wind resources, but given that New Zealand has such good hydro and limited power demand, the total market likely to be developed here is likely to remain modest. Korea has the smallest and youngest wind market of the four, but has several home-grown turbine manufacturers and a plan to expand renewable energy.

The Reference scenario for OECD Pacific expects wind market growth to decline until 2015, with installations dropping from 867 MW in 2009 to just 300 MW per year by 2015. In the second half of the decade, the Reference scenario sees the market creeping back up so that, by 2030, 2009 levels

Woolnorth wind farm, Tasmania, Australia
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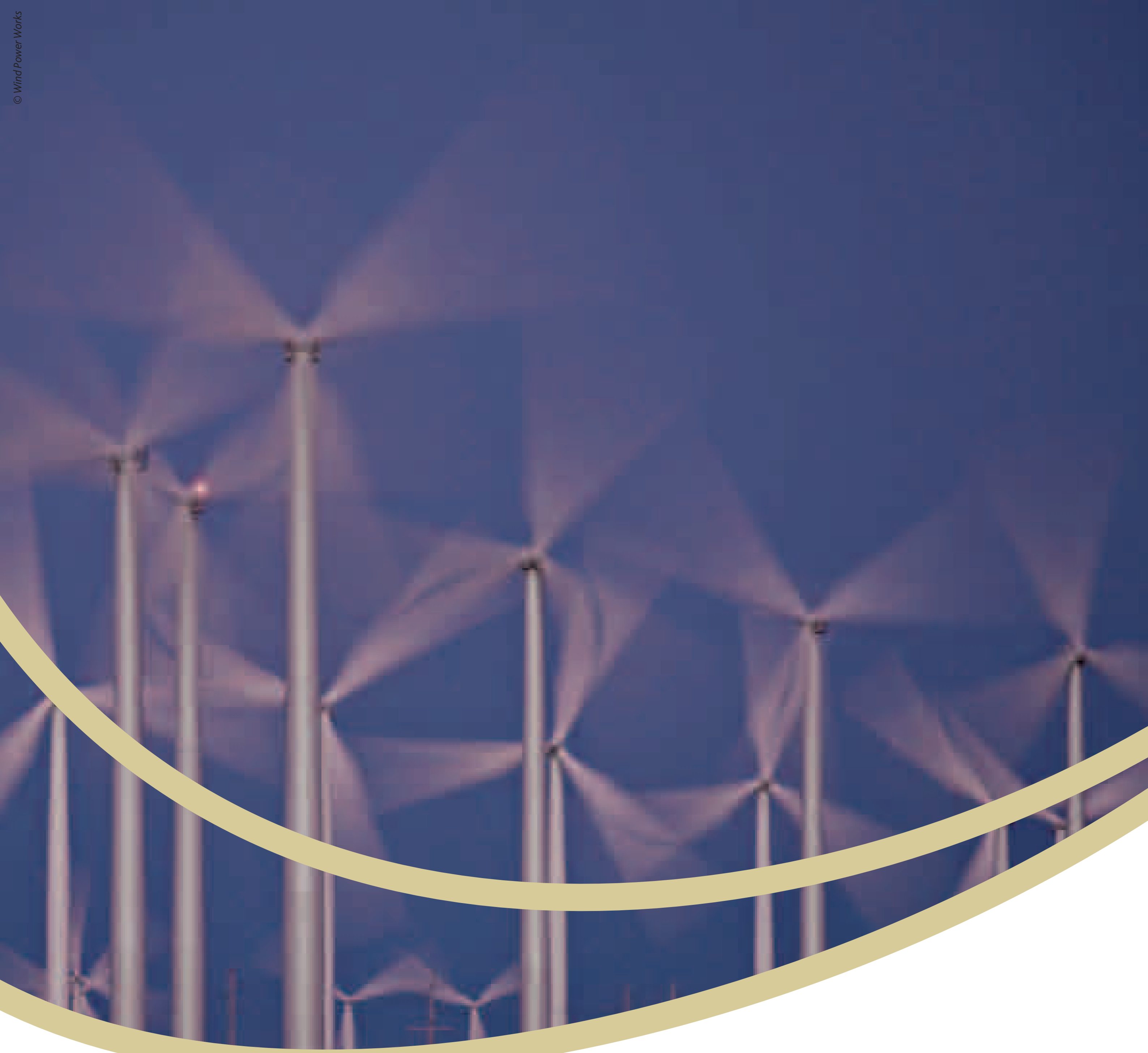
have been regained. By 2030 the cumulative capacity of wind power would be 18.6 GW, up from 4.6 GW in 2009.

The effects on both economy and climate would be marginal, compared to these countries total economic power. Annual investments would drop by two-thirds from the current €1.2 billion to just €400 million in 2015, and will not regain the 2009 levels until the end of the scenario period.

In terms of climate change, wind power would, in this scenario, not help these countries achieve their targets – only 15.5 million tons of CO_2 would be saved every year across the whole region by 2020, compared to 500 million tons currently emitted by the Japanese electricity sector alone.

The Moderate scenario shows that, with a more positive operating framework, there could be 81 GW of wind power in operation by 2030 – more than four times the Reference scenario's capacity – while the Advanced scenario anticipates 109 GW. This is close to the present total power capacity (123 GW) of Australia and Korea combined, or close to half of Japan's.

With 109 GW of wind power in place, these countries would produce close to 270 TWh and save the emissions of 161 million tonnes of CO_2 per year. Economically, €6.7 billion worth of investment would flow into these countries wind markets every year by 2030, and the sector would employ over 110,000 people, compared with the 13,700 employed in 2009.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THE WORLD'S WIND RESOURCES

Wind farm in Canada
© Nordex

Horse Hollow wind farm, United States
© Wind Power Works

When evaluating different methods of power generation some of the main questions inevitably concern the fuel proposed. Is there enough of it? Is it in the right places? It is available when you want it? What does it cost? What emissions does it have? What residue does it leave? For wind power generation, wind is of course the 'fuel' and these questions are as relevant as they are for any other source.

The last of these questions has the simplest answer: unlike fuels that are burnt, wind is free and clean. Questions about how much wind there is, where it is to be found, and when it is available, however, are very pertinent.

On a global scale numerous studies confirm the enormity of the resource, and how it could theoretically meet global electricity demand many times over. A recent addition to this sequence is a collaboration by researchers at Harvard University in the United States and VTT in Finland that concluded that 'a network of land-based, 2.5 MW turbines, restricted to non-forested, ice-free and nonurban areas, operating at as little as 20% of their rated capacity could supply more than 40 times current worldwide consumption of electricity'.[1]

A slightly earlier comprehensive study by researchers from Stanford University's Global Climate and Energy Project based its conclusions on five years of data from the US National Climatic Data Center. Using an extensive set of surface and balloon measurements, they concluded that 13% of the sites tested had a good wind resource (Class 3) at 80 metres off the ground, and using one in five of these sites for power generation would allow wind energy to meet the world's electricity demand (using the figure from the year 2000) seven times over.[2]

Similarly, an earlier study in 2003 by the German Advisory Council on Global Change calculated that the global technical potential for energy production from both onshore and offshore wind was 270,000 TWh per year. Assuming 10%–15% of this was realisable in a sustainable fashion, the resulting 39,000 TWh would meet more than double the current global electricity demand. A literature search shows up numerous similar studies with broadly similar conclusions.[3]

Each of the studies varies in its outcome, depending on the assumptions used. One variable concerns the size, capacity factor and rated power of the turbines used for estimations of wind power potential. In addition, the higher the turbine is mounted, the better the wind resource. Further, higher turbines are less prone to be affected by turbulence caused by obstructions, topography, surface roughness or thermal effects. In addition, advances in technology can not only increase the capacity factor of wind turbines, but also the range of wind speeds in which they can operate, thus broadening the range of sites at which they can be used.

Another variable concerns assumptions about the land areas on which turbines can be deployed. While most studies will rule out conservation areas, forests and urban sites, some

1 *Xi Lu, M.B. McElroy and J. Kiviluoma: Global potential for wind-generated electricity. Proceedings of the National Academy of Sciences, 2008. ww.pnas.org/cgi/doi/10.1073/pnas.090410110*
2 *Archer, C.L. and M.Z. Jacobson: Evaluation of global wind power, 2005. JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 110, D12110, doi:10.1029/2004JD005462, 2005*
3 *German Advisory Council on Global Change: World in Transition – Towards Sustainable Energy Systems, 2004. http://www.wbgu.de/wbgu_jg2003_engl.pdf*

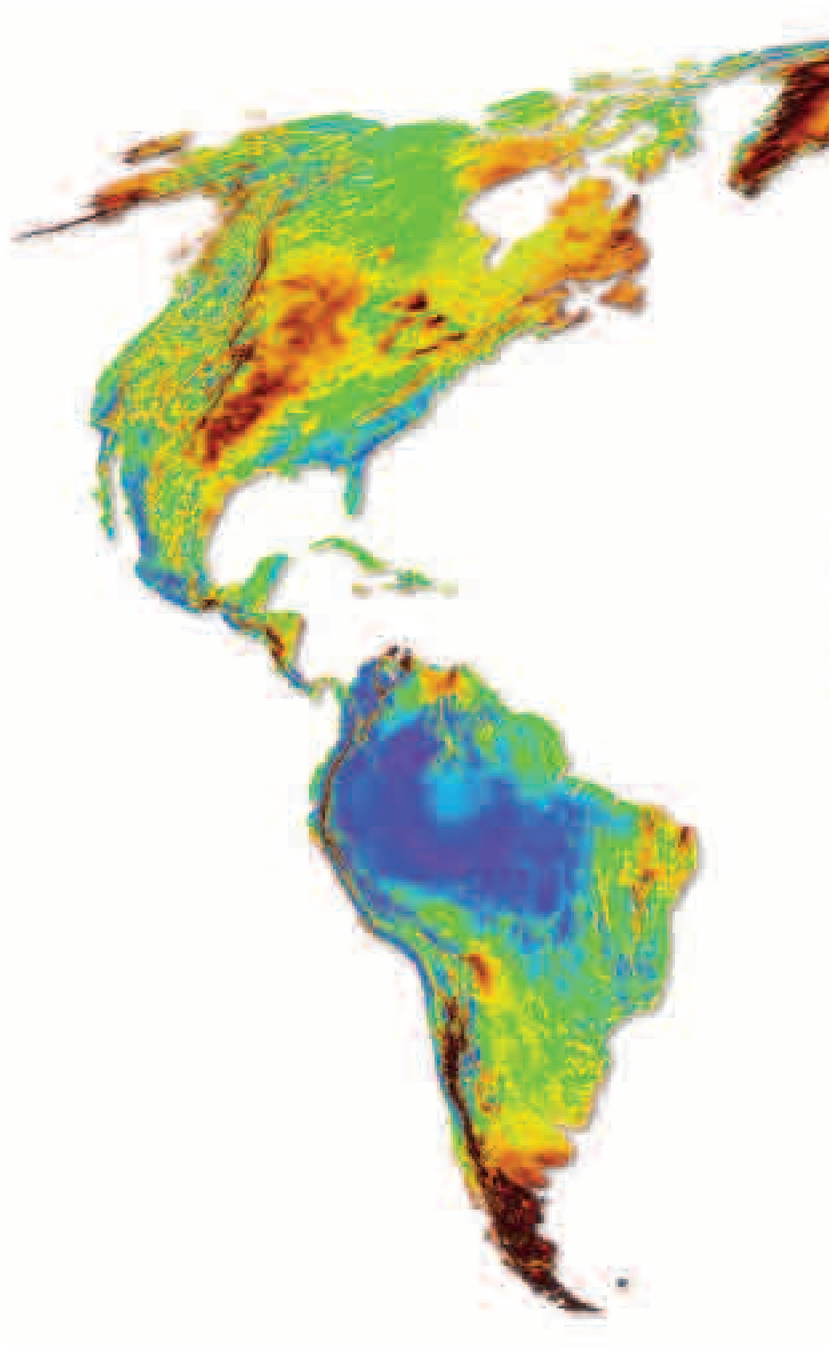
types of agricultural land such as pastures are easily compatible with wind farms without constraining the overall wind potential of a region.

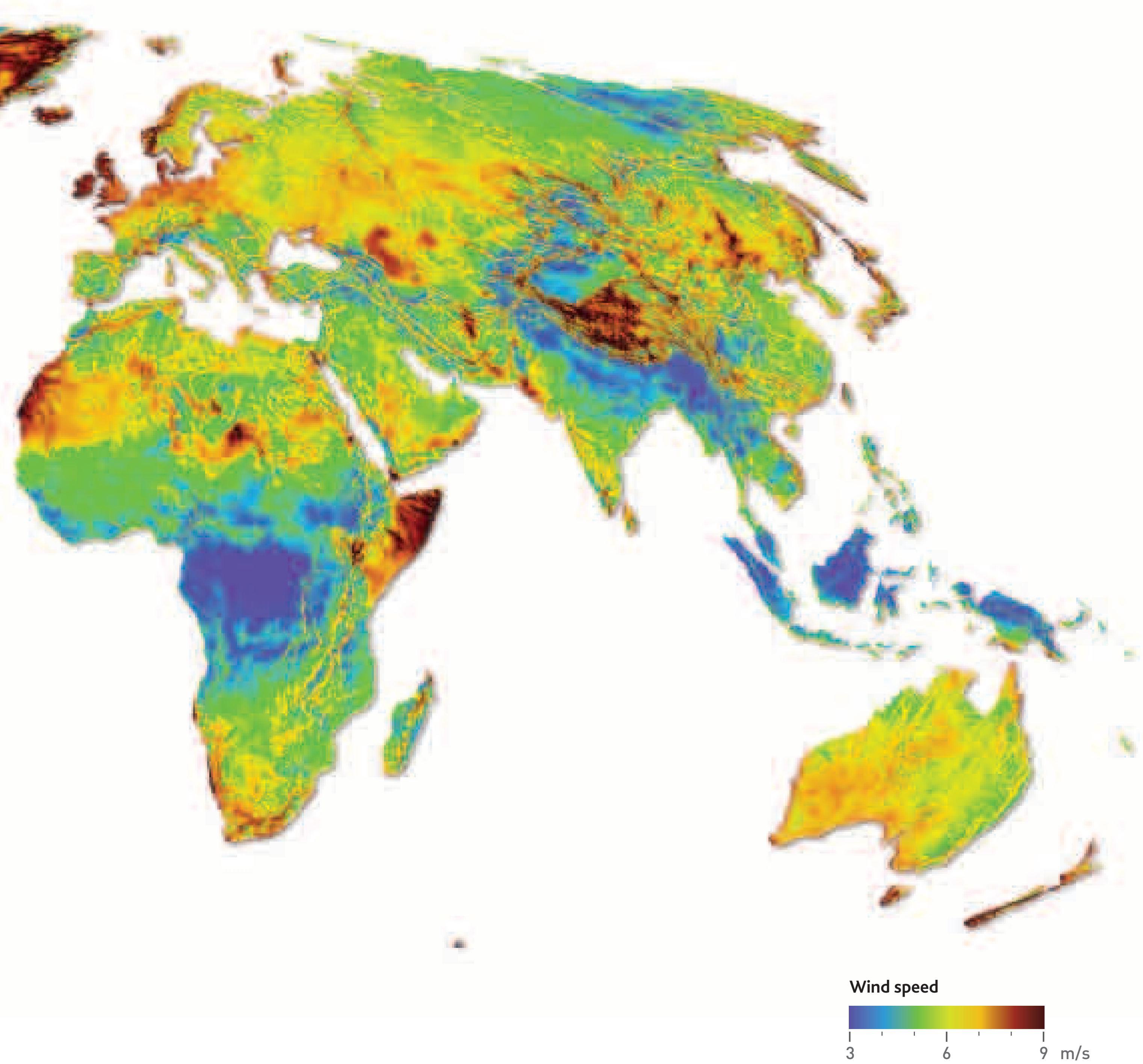
Methodologies for assessing offshore wind resources also differ in terms of the underlying assumptions used. An assumption needs to made concerning the areas in which wind farms can be built, both for practical reasons (maximum distance to shore, water depth etc), as well as taking into account environmental and regulatory limitations (nature reserve areas, shipping lanes, minimum distance to shore, etc). Some new configurations that deploy turbines on floating structures and are thus suitable for use in deep water are at a preliminary stage of test deployment. These could dramatically increase the technically usable fraction of the offshore wind potential.

Evidence from a large number of studies into the world's wind resources suggests that there is no shortage of suitable sites for wind power development. However, it is worth noting that the rate of deployment of wind power in each county has largely been dependent on political will rather than resource criteria. Germany has a lower wind potential than many other European countries, yet its favourable political climate has led to rapid and large-scale deployment of wind power. On the other hand, there are numerous parts of the world with a good wind resource – places such as Argentina, Russia and South Africa – where development of wind power has barely started.

Overall, it is clear that the wind's energy offers a practically unlimited, clean and emissions free power source of which only a tiny faction is currently being exploited. There may be concerns about 'Peak Oil' but 'Peak Wind' is not a concept that need worry us!

5 km Wind Map at 80m




Wind speed
3
6
9 m/s

INTEGRATING WIND POWER INTO ELECTRICITY SYSTEMS

Inside the power system

The availability of electric power has become a vast enabler for human beings, yet has also fostered a massive dependency. While food and clean water have been a fundamental requirement for millennia, electric power has become a recent essential in homes, factories, offices, hospitals. When the power blacks out, countless human activities now halt in an instant.

It is quite remarkable how far the process of generating electricity has come in the past 130 years, since the invention of the electric generator and the incandescent light bulb enabled Thomas Edison set up the first-ever electric company. Supplying electric lighting to the offices of New York's Wall Street, his business provided local generation for local customers – a model that was replicated in many other towns and cities in many parts of the world. There were no transmission lines in those days, just small, coal-fired steam generators providing power on a local system.

Since then the system has grown in complexity and scale. An extra level of complexity was added when, in the 1980s, the process of liberalizing the electric power industry began in many industrialised countries. Gradually this has separated the generators, the transmission system operators (TSOs) who run the high-voltage grids, the distribution service operators (DSOs) who manage the delivery of consumer-voltage power to customers, and the power sellers. Many power companies are both generators and retailers of electricity.

Electricity is more of a will o' the wisp than a commodity. It can't be 'held' somewhere in a storage tank or reservoir. It is generated, and used, in a second. Transmission system operators (TSOs) – who have little control over demand – have the remarkable task of matching supply to meet whatever demand might be at any moment of the day, or night, during winter and summer alike.

TSOs are like conductors of the 'orchestra' of power supply, bringing in one section of the orchestra and quietening another; or are like controllers of traffic at a busy and complex intersection. What they are doing is matching supply to demand – without ever being absolutely certain what demand will be. Of course, consumption patterns have been recorded and analysed, so the TSOs know broadly what to expect, and when. Forecasting of demand has become a sophisticated business, especially as it also underlies the prices at which electricity is bought and sold.

Large scale coal and nuclear plants are usually 500-1,000 MW or more, and have little flexibility in their output – regardless of the demand. Hydro is supremely controllable, constantly 'willing' to release the vast energy of water that wants to obey the law of gravity, but with the supply of water to its turbines fully adjustable. Gas-fired generation can also offer a quick response to match demand.

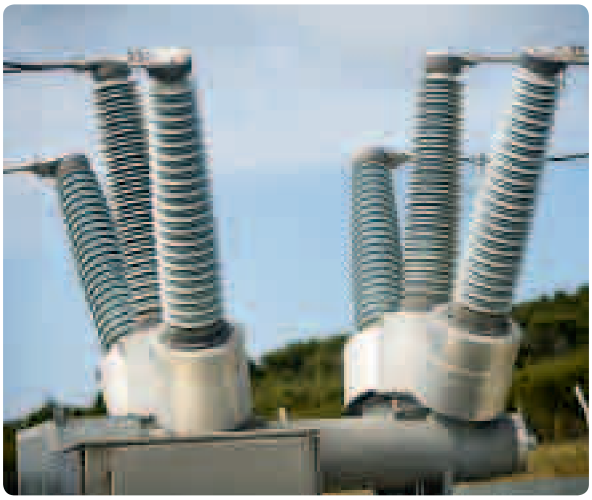
It is the peaks of power demand that are trickiest for TSOs to handle. In order to maintain voltage within the system they may have to call on every available resource, especially if neighbouring operators have no spare power that can be brought in via the 'interconnectors' between different grid systems. This can mean bringing some plant out of semi-retirement, or calling on diesel generator sets. This 'peaking' or 'peaker' power can often be most among the most polluting, and expensive to run. In open markets it can also command a high price.

Dealing with wind farms' variable power output

Power output from an individual wind turbine or wind farm varies over time, depending on the weather conditions. The fact that wind output varies is not itself a problem, provided that good information is available in advance to predict how much power wind farms will be producing at any given time. Predictability, by means of accurate forecasting, is an essential tool to the successful integration of wind power into the electric power system.

Extensive evaluation and modelling is carried out before a wind farm is built. That provides a great deal of information about what these wind plants will deliver on a seasonal or monthly basis. This is reinforced once wind farms are in operation.

In countries with 'priority access' for renewable energy producers, such as Germany and Spain, TSOs manage the grid as a whole to ensure that the system can always accept the maximum output from the wind plants in windy periods, yet maintain the power supply to power consumers during less windy periods. TSOs can now be supplied not only with seasonal/monthly expectations, but a combination of



Woolnorth wind farm, Tasmania, Australia
© Wind Power Works

good meteorological forecasting and sophisticated software enables them also to have reliable hour-by-hour forecasts of available wind power. These are of particular value for their complex task.

While there can be variations between forecast and actual, this is of course also the case on the demand side. Any power system is influenced by a large number of planned and unplanned factors, but they have been designed to cope effectively with these variations through their configuration, control systems and interconnection.

On the demand side, changes in weather makes people switch on or off their heating, cooling and lighting, and millions of consumers expect instant power for hair dryers, washing machines and TVs – sometimes all at the same time such as during a popular TV programme.

On the supply side, also, there are variations, and not only from renewable energy sources. When a large power station suddenly shuts down, whether by accident or for maintenance, this causes the immediate loss of many hundreds of megawatts of capacity. With wind power, which is produced by hundreds or thousands of individual wind turbines rather than a few large power stations, such sudden drops should never occur, and significant variations should be forecast and planned for. This makes it easier for system operators to predict and manage the changes in supply.

Grid operators in a number of European countries, including Spain, Denmark and Portugal, have now introduced central control centres that can monitor and manage efficiently the entire national fleet of wind turbines. Thanks to a combination of technology, forecasting and TSO expertise, in some parts of Europe wind power is routinely providing 30% of the electricity supply, and at times this goes far higher. In western Denmark, and in parts of Germany, wind has at times provided more than 100% of demand, meaning that 'spare' electricity generated from wind has been available to export to neighbouring grid systems.

In addition, large, interconnected grids lessen the overall impact if the wind stops blowing in one particular place. The idea of new electric 'superhighways', such as the 'supergrid' proposed to tap into the vast offshore wind resource in northern Europe and link these countries' electricity grids with the entire continent, would dramatically help to smooth out the variable output of the individual wind turbines.

A frequent misunderstanding concerning wind power relates to the amount of 'back up' generation capacity required to balance the variability of wind power in a system. The additional balancing costs associated with large-scale wind integration tend to amount to less than 10% of wind power generation costs, depending on the power system flexibility, the accuracy of short-term forecasting and functioning of the individual power market. The effect of this on the consumer power price is close to zero.[1]

New transmission lines?

Unless electricity is generated on-site, from solar, wind, biogas or small hydro, and is then used on-site, some kind of transport is needed – either of fuel (coal, gas, LNG, diesel, biomass, nuclear fuel), or of waste products (fly-ash, spent nuclear fuel), or of the electricity itself.

Some forms of power generation (large hydro, geothermal) have little flexibility in their siting because of the nature of the resource. Coal power is more flexible – industry and power generation have to some extent grown up around coal resources, but more often the coal itself is transported by ship, rail or truck. Natural gas has to be piped – sometimes vast distances across continents. Increasingly it is pressurized and then shipped in containers in liquid form as LNG. Nuclear fuel and waste need especially secure transport. All these

1 European Wind Energy Association: Wind Energy – The Facts, 2009 forms of transport and processing add to the cost of those fuels, and to the amount of carbon emitted in getting their energy from the ground and to the electric plug.

Wind power can be developed in a very wide range of locations, and at many scales – from one or two turbines to hundreds. Optimizing the siting can make a big difference to the power output from a wind turbine, and this is greatly magnified over a turbine's operating lifetime of 20+ years. However, as pointed out earlier in this book, up to now the rate of deployment of wind power by country has largely been dependent on political issues rather than resource criteria. In Germany, for instance, a favourable political climate has led to the large-scale deployment of wind power, while its wind resource (especially in the centre and south of the country) is lower than in some other European countries with much less installed capacity.

So while wind power can work effectively in many locations, it is true that some regions have an excellent resource that is located away from the towns and cities needing power (in fact, truly windy locations have historically been avoided as places to live). This might be true on a small scale (western Texas has excellent wind, but its cities are further east and south) or a larger one (Xinjiang's excellent wind is many miles from China's eastern seaboard cities). And then there is the case of connecting large-scale offshore wind with electricity users. Connecting those resources to the locations where power is needed does require new lines – just as new lines would be needed for large hydro, or pipelines for gas.

A further factor to bear in mind is that the power lines built decades ago in some parts of the world badly need upgrading to cope with the demands and size of today's power sector, so investment in grid upgrades is needed in any case. The IEA estimates that by 2030, over 1.8 trillion USD will have to be invested in transmission and distribution networks in the OECD alone[2]. In some parts of the world – such as Europe – grid upgrades are also a prerequisite for the operation of the market without conflicting with legislation allowing competition.

Yet with all this talk of power grids and centralized generation, it is worth noting that a high-voltage grid is not always the answer. In many parts of both the developed and developing world, the cost of building transmission lines to reach every part of the countries is simply prohibitive. There are thousands of communities that the grid may never reach. Occasionally high-voltage lines even pass overhead, busily on their way from a large hydro plant to a big city – but there are no substations and distribution networks to deliver usable power to the people who live beneath. Here wind power, sometimes in combination with other renewables, can work on a smaller scale, off-grid, or on so-called mini-grids that serve a pocket of need.

The right quality of power

Another aspect to bear in mind is that the performance of, and output from, wind turbines harmonizes with the grid's requirements and does not create any disturbances to the system. This is ensured by means of so-called 'grid codes' that lay down the parameters within which wind turbines must operate.

Grid codes cover the technical aspects relating to the operation and use of a country's electricity transmission system. They also lay down rules that define the ways in which generating stations connecting to the system must operate in order to maintain grid stability.

Technical requirements within grid codes vary from system to system, but the typical requirements for generators normally concern tolerance (i.e. minimum and maximum voltage and frequency limits), control of active and reactive power, protective devices and power quality. Specific requirements for wind power generation are changing as penetration increases and as wind power is starting to function more like other large power plants.

Earlier generations of wind turbines were unable to respond if there was a fault on the network, and could even aggravate the situation. Today, however, modern wind turbines contribute substantially to the stability of the grid. The majority of turbines being installed today are capable of meeting the most severe grid code requirements, with advanced features including fault-ride-through capability. This enables them to assist in keeping the power system stable when disruptions occur. Modern wind farms are wind energy power plants that can be actively controlled and provide grid support services.

2 *International Energy Agency, World Energy Outlook 2008.*

REFERENCE

Year	Cumulative [GW]	Global Annual Growth Rate [%] – excluding repowering	Annual [MW] incl. repowering	Capacity factor [%]	Production [TWh]	Wind power penetration of world's electricity in % Reference
2007	94	28	19,865	25	206	
2008	120	36	28,700	25	263	
2009	159	41	38,343	25	347	
2010	185	17	26,753	25	406	2,3
2015	296	3	20,887	28	725	
2020	415	4	25,712	28	1,019	4,5
2025	494	3	25,841	28	1,212	
2030	573	3	41,219	28	1,405	4,9
2035	653	2	41,426	28	1,601	
2040	732	2	46,262	30	1,925	5,6
2045	807	2	46,494	30	2,120	
2050	880	2	55,538	30	2,312	5,9

MODERATE

Year	Cumulative [GW]	Global Annual Growth Rate [%] – excluding repowering	Annual [MW] incl. repowering	Capacity factor [%]	Production [TWh]	Wind power penetration of world's electricity in % Reference
2007	94	28	19,865	25	206	
2008	120	36	28,700	25	263	
2009	159	41	38,343	25	347	
2010	199	26	40,212	25	435	2,4
2015	460	17	62,887	28	1,129	
2020	832	9	88,133	28	2,041	8,9
2025	1,274	7	104,391	28	3,125	
2030	1,778	5	148,416	28	4,360	15,1
2035	2,275	4	158,122	28	5,580	
2040	2,741	3	181,185	30	7,203	20,9
2045	3,213	3	208,433	30	8,444	
2050	3,702	3	214,126	30	9,729	24,7

ADVANCED

Year	Cumulative [GW]	Global Annual Growth Rate [%] – excluding repowering	Annual [MW] incl. repowering	Capacity factor [%]	Production [TWh]	Wind power penetration of world's electricity in % Reference
2007	94	28	19,865	25	206	
2008	120	36	28,700	25	263	
2009	159	41	38,343	25	347	
2010	202	27	43,263	25	442	2,5
2015	533	20	87,641	28	1,308	
2020	1,071	9	120,135	28	2,628	11,5
2025	1,687	6	135,747	28	3,805	
2030	2,342	4	185,350	28	5,429	18,8
2035	2,877	3	185,350	28	6,823	
2040	3,305	2	185,350	30	8,473	24,6
2045	3,678	2	185,350	30	9,477	
2050	4,028	2	185,350	30	10,403	26,4

REFERENCE

Year	Wind power penetration of world's electricity in % – ER 2010	CO_2 reduction (with 600 g CO_2/kWh) [annual Mio tCO_2]	Avoided CO_2 since 2003 [cumulative Mio tCO_2]	Capital costs [€/kW]	Investment [€1000]	Jobs Total (including O&E)
2007		123	406	1,300	25,824,500	329,232
2008		158	564	1,350	38,745,000	470,559
2009		208	772	1,350	51,763,050	627,927
2010	2,3	243	1,016	1,327	35,506,629	462,982
2015		435	2,834	1,276	26,649,758	411,801
2020	4,8	611	5,539	1,240	31,894,089	524,027
2025		727	8,944	1,227	31,714,995	552,233
2030	5,6	843	12,928	1,216	50,136,247	809,006
2035		960	17,495	1,210	50,121,623	838,677
2040	6,9	1,155	23,017	1,204	55,712,355	937,796
2045		1,272	29,143	1,202	55,881,975	966,089
2050	7,3	1,387	35,854	1,200	56,064,231	1,125,967

MODERATE

Year	Wind power penetration of world's electricity in % – ER 2010	CO_2 reduction (with 600 g CO_2/kWh) [annual Mio tCO_2]	Avoided CO_2 since 2003 [cumulative Mio tCO_2]	Capital costs [€/kW]	Investment [€1000]	Jobs Total (including O&E)
2007		123	362	1,300	25,824,500	329,232
2008		158	521	1,350	38,745,000	470,559
2009		208	729	1,350	51,763,050	627,927
2010	2,5	261	990	1,329	53,459,495	629,137
2015		678	3,507	1,258	79,109,203	1,033,721
2020	9,5	1,225	8,466	1,208	106,504,829	1,422,874
2025		1,875	16,512	1,156	120,639,772	1,676,965
2030	17,5	2,616	28,061	1,116	165,691,953	2,372,911
2035		3,348	43,372	1,088	172,107,655	2,496,911
2040	25,7	4,322	63,516	1,068	193,493,633	2,905,770
2045		5,066	87,350	1,051	219,021,620	3,362,692
2050	30,6	5,838	114,982	1,036	221,788,479	3,573,838

ADVANCED

Year	Wind power penetration of world's electricity in % – ER 2010	CO_2 reduction (with 600 g CO_2/kWh) [annual Mio tCO_2]	Avoided CO_2 since 2003 [cumulative Mio tCO_2]	Capital costs [€/kW]	Investment [€ 1000]	Jobs Total (including O&E)
2007		123	406	1,300	25,824,500	329,232
2008		158	564	1,350	38,745,000	470,559
2009		208	772	1,350	51,763,050	627,927
2010	2,5	265	1,037	1,328	57,450,452	672,827
2015		785	3,812	1,245	109,072,886	1,404,546
2020	12,3	1,577	9,953	1,172	140,762,811	1,918,530
2025		2,283	19,667	1,128	153,100,985	2,190,680
2030	21,8	3,257	34,027	1,093	202,600,198	3,004,081
2035		4,094	52,926	1,059	196,291,917	2,996,955
2040	30,3	5,084	77,001	1,037	192,191,671	3,139,263
2045		5,686	104,256	1,020	189,092,016	3,263,611
2050	32,7	6,242	134,363	1,006	186,507,424	3,380,018

ABOUT GWEC
GLOBAL REPRESENTATION FOR THE WIND ENERGY SECTOR

GWEC is the voice of the global wind energy sector. GWEC brings together the major national, regional and continental associations representing the wind power sector, and the leading international wind energy companies and institutions. With a combined membership of over 1,500 organisations involved in hardware manufacture, project development, power generation, finance and consultancy, as well as researchers, academics and associations, GWEC's member associations represent the entire wind energy community.

THE MEMBERS OF GWEC REPRESENT:

- Over 1,500 companies, organisations and institutions in more than 70 countries
- All the world's major wind turbine manufacturers
- 99% of the world's installed wind power capacity

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Greenpeace is a global organisation that uses non-violent direct action to tackle the most crucial threats to our planet's biodiversity and environment. Greenpeace is a non-profit organisation, present in 40 countries across Europe, the Americas, Asia and the Pacific. It speaks for 2.8 million supporters worldwide, and inspires many millions more to take action every day. To maintain its independence, Greenpeace does not accept donations from governments or corporations but relies on contributions from individual supporters and foundation grants.

Greenpeace has been campaigning against environmental degradation since 1971 when a small boat of volunteers and journalists sailed into Amchitka, an area north of Alaska, where the US Government was conducting underground nuclear tests. This tradition of 'bearing witness' in a non-violent manner continues today, and ships are an important part of all its campaign work.

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