World Wind Resource Assessment Report—— Executive Summary

world Wind Energy Association (WWEA)

Introduction

Winds blow in every nook and corner on the surface of this planet. Fundamentally,winds carry a part of the energy in solar radiations received on earth. Uneven heating of earth's surface and varying pressure differences cause movement of air in the atmosphere or the wind as we experience it.

As an energy source, it seems winds were harnessed even in the ancient times.Perhaps, the earliest use of wind energy was in the form of sails to steer ships.Egyptian civilization, even as far back as 3000 BC, was using boats and ships with sails. There is a mention of ambitious plans of Mesopotamian ruler Hammurabi to use windmills for irrigation around 1790 BC.

Today, modern wind turbines convert the kinetic energy in the wind to electrical energy and clusters of wind turbines in the form of wind farms generate electricity on a utility scale.

Over the last 50-60 years, electricity generation has grown in most parts of the world. The steepest growth has been in developing countries and, therefore,balancing energy access, economic development and environmental sustainability is going to be a major challenge not only for the nations concerned but also for the global community. The potential for utilization of wind generated electricity, which we have assessed in this report, can play the most significant role in mitigating global warming.

Three important challenges concerning sustainable development, i.e. energy security, climate change and energy access make a compelling case for large-scale utilization of wind energy across the world. As of June 2014, about 337 GW wind power generation capacity has been set up in the world. This capacity is more than the total installed electricity generation capacity from all sources in some of the largest countries in the world. With such a large wind power capacity having been installed and widespread geographical deployment in more than 100 countries, we can say that wind energy has arrived at the center-stage of the mainstream electricity sector.

Energy Security Perspective

Across the world, greater dependence on imported fossil fuels adds to national energy insecurity and uncertainty. Most countries do not have adequate indigenous fossil fuel reserves and hence have to import oil, coal and gas. Fluctuations in price and supply uncertainty results in serious

long-term concerns for national economies.Those regions of the world that face energy resources constraints to meet their electricity demand are also the regions where wind energy has been utilized to the largest extent. Europe, where between 2000 and 2013 more than 100 GW of capacity was added, is one example. Europe's import dependency on fossil fuels is expected to rise and imported gas is likely to make up 80% of consumption by 2030. Similarly,in the United States, more than 80% of energy consumed comes from oil, natural gas or coal. By the end of 2013 more than 61.1 GW of wind power capacity had been installed in the US. In India heavy and growing dependence on imported fossil fuels, apart from adding to energy insecurity, creates serious monetary problems for the country. India has achieved nearly 21 GW of cumulative installed capacity of wind power by the end of March 2014. China is the largest global energy consumer and has overtaken US as the largest net importer petroleum and other liquid fuels in 2014. Energy security is of immense importance to this country because of massive industrialization. In just about eight years, China has emerged as the leading country with more than 91 GW of wind farmed capacity. Europe, India, China & US together account for 93% of the total wind power installed capacity.

Climate Change Perspective

The Intergovernmental Panel on Climate Change (IPCC) has established that the climate is changing across our planet, largely as a result of human activities that have led to the accumulation of atmospheric greenhouse gases (GHG). Between 1971 and 2010, global CO2 emissions almost doubled and about 44% of these emissions in 2010 were from the electricity sector. According to the IPCC, Wind energy offers significant potential for near-term (2020) and long-term (2050) greenhouse gas (GHG) emissions reductions. The need to reduce GHG emissions is yet another major driver and a compelling reason for countries to set up wind power plants. The countries and regions that face energy security issues also face the challenge of environmental sustainability in planning their future energy mix.

Energy Access Perspective

Per capita energy consumption as well as total electricity consumption in vast areas of the developing world is a fraction of electricity consumption in some of the rich and developed countries. Most of Africa and large parts of Asia fall in this category.

One can see that electricity access, too, is going to be one of the main drivers of wind power development in those countries that have an adequacy of wind resources. In countries with less than 50% electricity access, wind power generation in combination with solar energy, biomass and hydro can be a low carbon solution.

Wind Resource Assessment

The question of wind energy potential is important from different perspectives. At any given location or in a region, the question is how much electricity can be generated from wind, for how long and what may the total quantum of such energy in a given period of time be?

Anyone investing in wind energy would like to know how much electricity can be generated from a project so that the economic rationale of such an investment can be examined. This information could be of interest to various stakeholders -investors, financiers, utility managers or policy makers. It is the process of

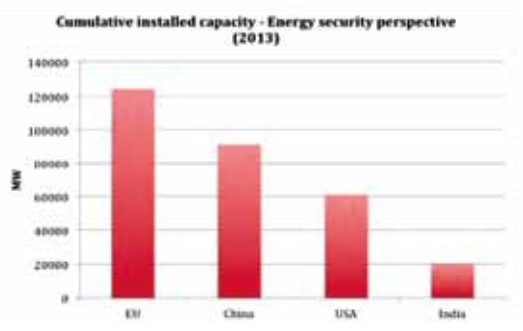

Fig (a): The energy security perspective

answering this question of 'how much capacity and how much energy from wind?' that we term as 'Wind Resource Assessment' or 'Wind Potential Assessment' and it is this question that we have tried to address in this report at a world-wide level.

The Wind Resource Assessment (WRA) is the most important aspect of wind power development. At project level, it enables developers and investors to take a "go"/ "no go" decision and at a national or regional level, it enables the concerned agencies or the governments to figure out if there is enough potential to utilize wind energy and whether certain policy and regulatory frameworks are required in order to harness such potential on a large scale.

The techniques of undertaking WRA at project level differ from the techniques and approaches to assess the resource on a regional or a meso-scale. Project level WRA involves design of an optimized layout of wind turbines of a certain make or type in a given patch of land and assessment of the annual energy output.

The regional or meso-study differs significantly as here the area in question can be thousands of square kilometers. Some studies have covered the entire globe.

Generally, Meso studies require global data sets such as NCEP/ NCAR and digitized terrain and satellite data.

A large number of such studies have been carried out across the world and we were able to compile these studies to arrive at an idea of the total global potential for wind farms in the world.

Table (a) below summarizes the worldwide potential for wind farms according to currently available official estimates, in most cases excluding offshore wind potential. It is easy to see that some of these figures, in particular "Rest of the World", are far too low, when considering the land masses in comparison with Europe, USA, Russia or India (where so far, the most comprehensive analysis has been done). In reality the wind potential in "rest of the world" must be significantly higher than that of Europe.

According to the IEA, the world's total energy consumption for all sectors, including industries, heating and cooling as well as transport, in 2011 was 103'711TWh1, which included 19'299 TWh 2 for power consumption. It is easy to see that the world's wind potential of at least 94.5 TW is sufficient to cover the whole world's energy demand - assuming on average 2000 full load hours, the identified wind potential could almost cover it twice. Of course, the actual deployment of a very large wind capacity will depend on smart integration into energy supply structures, combination with other renewable technologies, storage options, demand-side management etc. Wind integration will be dealt with in another report of the WWEA Technical Committee to be published soon.

Table (a): Total worldwide potential for wind (in TW)

US	11
EU	37.5
Russia	36
Rest of the World	10.3953
Total	94.8953