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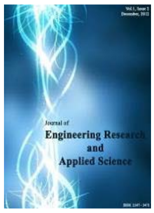

Global energy issues, climate change and wind power for clean and sustainable energy development

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Abstract
Renewable energy sources, derived principally from the enormous power of the sun's radiation, are at once the most ancient and the most modern forms of energy used by humanity. Wind energy is an indirect form of solar energy; the solar heating of the atmosphere along with the earth's rotation creates planetary and local wind patterns. In this chapter the wind resource is described and a method for reducing wind data to a useful mathematical form is presented. A simplified theory of wind turbines is then presented. This simplified theory leads to a basic understanding of the characteristics of actual wind turbines. Combining the analytical description of the wind resource with the characteristic of an actual wind turbine leads to a prediction of electrical energy production. Turkey added 804 MW of new wind power in 2014 for a total installed capacity of 3,763 MW. Turkey's installed capacity has grown at over 500 MW per year since 2010 and it will be annual installations to reach 1 600 MW per year from 2020 onwards.

Keywords: Energy issues; wind power; sustainable energy; climate change; Turkey

1. Introduction

Renewable energy sources, derived principally from the enormous power of the Sun's radiation, are at once the most ancient and the most modern forms of energy used by humanity. Solar power, both in the form of direct solar radiation and in indirect forms such as bioenergy, water or wind power, was the energy source upon which early human societies were based [1]. When our ancestors first used fire, they were harnessing the power of photosynthesis, the solar-driven process by which plants are created from water and atmospheric carbon dioxide. Societies went on to develop ways of harnessing the movements of water and wind, both caused by solar heating of the oceans and atmosphere, to grind corn, irrigate crops and propel ships. As civilizations became more sophisticated, architects began to design buildings to take advantage of the Sun's energy by enhancing their natural use of its heat and light, so reducing the need for artificial sources of warmth and illumination [2, 3].

Technologies for harnessing the power of Sun, firewood, water and wind continued to improve right up to the early years of the industrial revolution [4]. However, by then the advantages of coal, the first of the fossil fuels to be exploited on a large scale, had bec ome apparent. These highly-concentrated energy sources soon displaced wood, wind and water in the homes, industries and transport systems of the industrial nations. Today the fossil fuel trio of coal, oil and natural gas provide over 80% of the world's energy [1].

Harnessing the sun's energy is within our grasp, and for developing countries, this is a golden opportunity. Solar power is an increasing market for more developed countries, which can benefit from less electric expense over time. It is also good for the environment because it replaces the traditional, and in effect harmful, methods of energy production. There are other renewable energy sources besides solar, but it is especially practical for sunny areas which have less wind and water resources [1].

Because of the extensive research being conducted in this field, solar panels are developing into more efficient models than ever [5]. The higher competition level between manufacturers allows for cheaper prices as well. Reasons for choosing solar energy are also clearly indicated by the growing number of projects conducted by various organizations and governments [1]. Applications for

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this energy source can be from single houses and large electrical grids to cars, exhibiting a versatility perfect for the needs of a developing country.

2. Global primary energy consumption and climate change

2.1. Global primary energy consumption

Global primary energy consumption increased by just 0.9% in 2014, a marked deceleration over 2013 and well below the 10-year average of 2.1%. Growth in 2014 slowed for every fuel other than nuclear power, which was also the only fuel to grow at an above-average rate. Growth was significantly below the ten-year average for Asia Pacific, Europe & Eurasia, and South & Central America. Oil remained the world's leading fuel, with 32.6% of global energy consumption, but lost market share for the fifteenth consecutive year [6, 7].

Although emerging economies continued to dominate the growth in global energy consumption, growth in these countries was well below its ten-year average of 4.2%. China and India recorded the largest national increments to global energy consumption. OECD consumption fell by 0.9%, which was a larger fall than the recent historical average. A second consecutive year of robust US growth was more than offset by declines in energy consumption in the EU and Japan. The fall in EU energy consumption was the second-largest percentage decline on record [7].

Global oil consumption grew by 0.8 million barrels per day (b/d). Countries outside the OECD once again accounted for all of the net growth in global consumption. OECD consumption declined by 1.2%, the eighth decrease in the past nine years. Chinese consumption growth was below average but still recorded the largest increment to global oil consumption. On the other hand, Japan recorded the largest decline, with Japanese oil consumption falling to its lowest level since 1971. Light distillates were the fastest-growing refined product category for a second consecutive year [7].

Global oil production growth was more than double that of global consumption, rising by 2.1 million b/d. Production outside OPEC grew by 2.1 million b/d. The US (+1.6 million b/d) recorded the largest growth in the world, becoming the first country ever to increase production by at least one million b/d for three consecutive years. Along with the US, production in Canada (+310,000 b/d) and Brazil (+230,000 b/d) also reached record levels in 2014. OPEC output was flat, and the group's share of global production fell to 41%. Declines in Libya (-490,000 b/d) and Angola (-90,000 b/d) were offset by gains in Iraq (+140,000 b/d), Saudi Arabia (+110,000 b/d) and Iran (+90,000 b/d) [7].

World natural gas consumption grew by just 0.4%, well below the ten year average of 2.4%. Growth was below average in both the OECD and emerging economies, with consumption in the EU experiencing its largest volumetric and percentage declines on record. The Europe region had the four largest volumetric declines in the world in Germany, Italy, France and the UK. The US, China and Iran recorded the largest growth increments. Globally, natural gas accounted for 23.7% of primary energy consumption [7]. On the other hand, the global natural gas production grew by 1.6%, below its ten-year average of 2.5%. Growth was below average in all regions except North America. EU production fell sharply. The US recorded the world's largest increase, accounting for 77% of net global growth. The largest volumetric declines were seen in Russia and the Netherlands [7].

Global coal consumption grew by 0.4% in 2014, well below the ten-year average annual growth of 2.9%. Coal's share of global primary energy consumption fell to 30.0%. Consumption outside the OECD grew by 1.1% and driven by a flattening of Chinese consumption. Ukraine and the UK posted significant declines. India experienced its largest volumetric increase on record, and the world's largest volumetric increase. OECD consumption fell by 1.5%, led by a 6.5% decline in the EU. Global coal production fell by 0.7%, with large declines in China and Ukraine more than offsetting large increases in India and Australia [6, 7].

Global nuclear output grew by an above-average 1.8%, the second consecutive annual increase, and the first time nuclear power has gained global market share since 2009. Increases in South Korea, China and France outpaced declines in Japan, Belgium and the UK. Japanese nuclear power output ceased in 2014 as the country's last operating reactor was taken off line [6, 7].

Global hydroelectric output grew by a below average 2.0%. Growth in the Asia Pacific region offset drought-driven declines in the Western Hemisphere and Europe [6]. Chinese hydroelectric output grew by 15.7% and accounted for all of the net increase in global output. Drought conditions reduced output in Brazil by 5.5% and in Turkey by 32%. Hydroelectric output accounted for a record 6.8% of global primary energy consumption [7].

Renewable energy sources continued to increase in 2014, reaching a record 3.0% of global energy consumption [7]. Renewable energy used in power generation grew by 12.0%. Although this increase was below its ten-year average, it meant that renewables accounted for a record 6.0% of global power generation. China recorded the largest increment in renewables in power generation for a fifth consecutive year; growth last year was one-third the ten-year average. Globally, wind energy (14.8 Mtoe) grew by less than half of its ten-year average, with below average growth in all regions except Africa and South & Central America. Solar power generation grew by 38.2% (11.6 Mtoe). Global biofuels production grew by a below-average 7.4% (4.9 Mtoe), driven by increases in the US (5.6%), Brazil (5.5%), Indonesia (40.4%) and Argentina (30.9%). Figure 1 shows share of global renewable energy [6, 7].

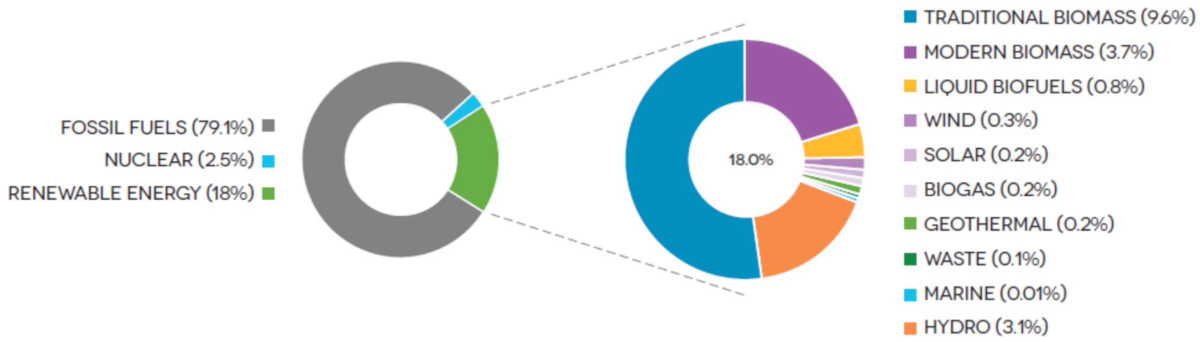


Figure 1.Share of global renewable energy [6].

2.2. Fossil fuels and climate change

Society's current use of fossil and nuclear fuels has many adverse consequences. These include air pollution, acid rain, the depletion of natural resources and the dangers of nuclear radiation. This brief introduction concentrates on one of these problems: global climate change caused by emissions of greenhouse gases from fossil fuel combustion [8]. On the other hand, the surface temperature of the Earth establishes itself at an equilibrium level where the incoming energy from the Sun balances the outgoing infrared energy re-radiated from the surface back into space [9]. If the Earth had no atmosphere its surface temperature would be –18 °C; but its atmosphere includes 'greenhouse gases' such as H_2O, CO_2 and CH_4 acts like the panes of a greenhouse, allowing solar radiation to enter but inhibiting the outflow of long-wave infrared radiation [10]. The natural greenhouse effect these gases cause is essential in maintaining the Earth's surface temperature at a level suitable for life at around 15 °C [11]. Since the industrial revolution, however, human activities have been adding extra greenhouse gases to the atmosphere. The principal contributor to these increased emissions is carbon dioxide from the combustion of fossil fuels. Humanity's rate of emission of CO_2 from these fuels has increased enormously since 1950. There have also been significant additional contributions from emissions of methane [8-11]. Scientists estimate that these 'anthropogenic' emissions caused a rise in the Earth's global mean surface temperature of approximately 0.8 °C between 1950 and 2005 [10, 11]. If emissions are not curbed, the IPCC estimates that the Earth's surface temperature couldrise by between 1.4 and 5.8 °C by the end of the twenty-first century [11]. Such rises would probably be associated with an increased frequency of climatic extremes, such as floods or droughts, and serious disruptions to agriculture and natural ecosystems. The thermal expansion of the world's oceans could mean that sea levels would rise by around 0.5 m by the end of the century, which could inundate some low-lying areas. Beyond 2100, or perhaps before, much greater sea level rises could occur if major Antarctic ice sheets were to melt [10]. Figure 2 shows the global CO_2 emission. The threat of global climate change, mainly caused by carbon dioxide emissions from fossil fuel combustion, is one of the main reasons why there is a growing consensus on the need to reduce such emissions [8]. In order to ensure that global mean temperature rises do not exceed 2 °C above pre-industrial levels by 2050, studies show that global carbon emissions will need to be reduced by approximately 80% by that date. This implies that global CO_2 emissions need to peak almost immediately and then fall sharply over the course of the rest of this century. Emission reductions on this scale will inevitably involve a switch to low- or zero-carbon energy sources such as renewables [8-11].

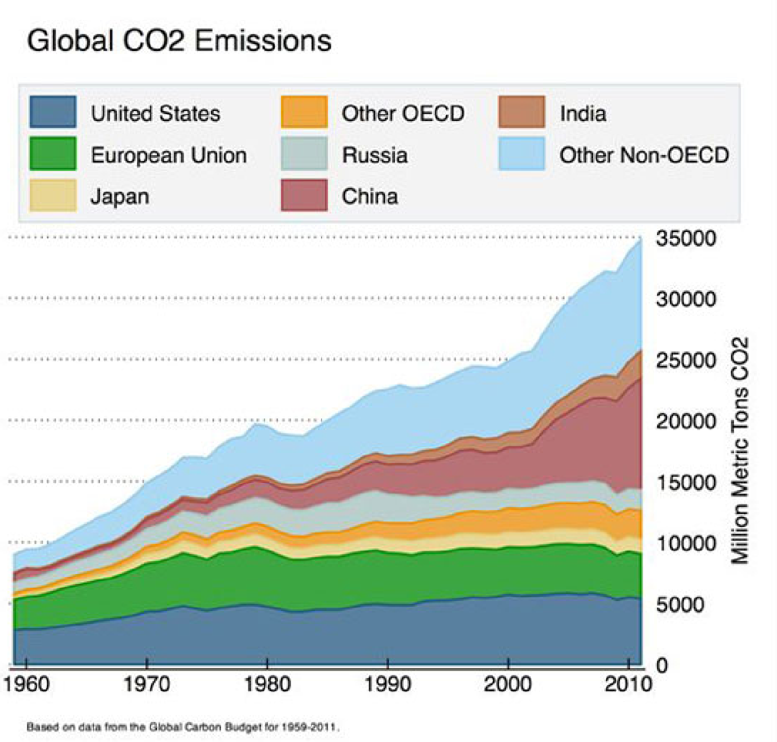


Figure 2. Global CO_2 emissions [8].

3. Wind energy for clean and sustainable development

3.1. Sustainable energy systems

Sustainable energy is to provide the energy that meets the needs of the present without compromising the ability of future generations to meet their needs. Sustainable energy has two components: renewable energy and energy efficiency. Renewable energy uses renewable sources such biomass, wind, sun, waves, tides and geothermal heat. Renewable energy systems include wind power, solar power, wave power, geothermal power, tidal power and biomass based power. Renewable energy sources, such as wind, ocean waves, solar flux and biomass, offer emissions-free production of electricity and heat. For example, geothermal energy is heat from within the earth. The heat can be recovered as steam or hot water and use it to heat buildings or generate electricity. The solar energy can be converted into other forms of energy such as heat and electricity and wind energy is mainly used to generate electricity. Biomass is organic material made from plants and animals. Burning biomass is not the only way to release its energy. Biomass can be converted to other useable forms of energy, such as methane gas or transportation fuels, such as ethanol and biodiesel [1-3; 12-14].

In addition to renewable energy, sustainable energy systems also include technologies that improve energy efficiency of systems using traditional non renewable sources. Improving the efficiency of energy systems or developing cleaner and efficient energy systems will slow down the energy demand growth, make deep cut in fossil fuel use and reduce the pollutant emissions [12]. For examples, advanced fossil-fuel technologies could significantly reduce the amount of CO2 emitted by increasing the efficiency with which fuels are converted to electricity [13]. Options for coal include integrated gasification combined cycle (IGCC) technology, ultra-supercritical steam cycles and pressurized fluidized bed combustion. For the transportation sector, dramatic reductions in CO2 emissions from transport can be achieved by using available and emerging energy-saving vehicle technologies and switching to alternative fuels such as biofuels (biodiesel, ethanol)

[12-14].

For industrial applications, making greater use of waste heat, generating electricity on-site, and putting in place more efficient processes and equipment could minimize external energy demands from industry. Advanced process control and greater reliance on biomass and biotechnologies for producing fuels, chemicals and plastics could further reduce energy use and CO_2 emissions. Energy use in residential and commercial buildings can be substantially reduced with integrated building design. Insulation, new lighting technology and efficient equipment are some of the measures that can be used to cut both energy losses and heating and cooling needs. Solar technology, on-site generation of heat and power, and computerized energy management systems within and among buildings could offer further reductions in energy use and CO_2 emissions for residential and commercial buildings [6].

The development of cleaner and efficient energy technologies and the use of new and renewable energy sources will play an important role in the sustainable development of a future energy strategy. The promotion of renewable sources of energy such as wind energy and the development of cleaner and more efficient energy systems are a high priority, for security and diversification of energy supply, environmental protection, and social and economic cohesion [11-14].

3.2. Wind turbine power

Wind energy is an indirect form of solar energy; the solar heating of the atmosphere along with the earth's rotation creates planetary and local wind patterns. In this paper the wind resource is described and a method for reducing wind data to a useful mathematical form is presented. A simplified theory of wind turbines is then presented. This simplified theory leads to a basic understanding of the characteristics of actual wind turbines [4,5]. Combining the analytical description of the wind resource with the characteristic of an actual wind turbine leads to a prediction of electrical energy production. Much about wind energy is not discussed in this paper, such as the complex meteorology that produces favorable wind sites, the aerodynamics of turbine blades, the needed controls for producing acceptable electrical waveforms, the mechanical aspects of gears trains and tower structures, the visual and avian siting issues, and noise problems [12-18].

The Wind turbines work by converting the kinetic energy in the wind first into rotational kinetic energy in the turbine and then electrical energy. The wind power available for conversion mainly depends on the wind speed and the swept area of the turbine [12]:

$$PW = ½ \rho AV^3 \qquad (1)$$

Where ρ is the air density (Kg/m^3), A is the swept area (m^2) and V the wind speed (m/s). Albert Betz (German physicist) concluded in 1919 that no wind turbine can convert more than 16/27 (59.3%) of the kinetic energy of the wind into mechanical energy turning a rotor. The theoretical maximum power efficiency of any design of wind turbine is 0.59. No more than 59% of the energy carried by the wind can be extracted by a wind turbine. The wind turbines cannot operate at this maximum limit. The power coefficient Cp needs to be factored in equation (1) and the extractable power from the wind is given by [4, 5, 12]:

$$P = ½ C_P \rho AV^3 \qquad (2)$$

Example: Given the following data: Blade length l = 52 m, wind speed, V = 12 m/s, air density ρ = 1.23 Kg/m^3 and power coefficient $C_P = 0.4$. Calculate the power converted from the wind into rotational energy in the turbine?

Answer: The swept area $A = \pi r^2 = \pi l^2 = 3.14 * 522 = 8495\ m^2$

The available power $P = ½ C_P \rho A V^3 = ½ x 1.23 x 8495 x 123 x 0.4 = 3.6$ MW

3.3. Characteristics of wind energy

Wind resource evaluation is a critical element in projecting turbine performance at a given site. The energy available in a wind stream is proportional to the cube of its speed, which means that doubling the wind speed increases the available energy by a factor of eight. With a wind speed of 8 meters per second we get a power of 314 Watts/m^2 exposed to the wind. At 16 m/s we get eight times as much power such as 2509 W/m^2. Further more the wind speed also varies with the time of day, season, height above ground, and type of terrain. Proper sitting in windy locations, away from large obstructions, enhances a wind turbine's performance. In general, annual average wind speeds of 5 meters per second are required for grid-connected applications [4]. Annual average wind speeds of 3 to 4 m/s may be adequate for nonconnected electrical and mechanical applications such as battery charging and water pumping. Wind resources exceeding this speed are available in many parts of the world [5]. The wind power density is a useful way to evaluate the wind resource available at a potential site. The wind power density, measured in watts per square meter, indicates how much energy is available at the site for conversion by a wind turbine. Classes of wind power density for two standard wind measurement heights are listed in the Table 1 below. Wind speed generally increases with height above ground. In general, sites with a wind power class rating of 4 or higher are now preferred for large scale wind turbines [12].

Table 1. Classes of wind power density at two different wind measurements heights [12]

	10 meters		**50 meters**	
Wind power class number	Wind power density (W/m^2)	Speed (m/s)	Wind power density (W/m^2)	Speed (m/s)
1	< 100	< 4.4	< 200	< 5.6
2	100-150	4.4-5.1	200-300	5.6-6.4
3	150-200	5.1-5.6	300-400	6.4-7.0
4	200-250	5.6-6.0	400-500	7.0-7.5
5	250-300	6.0-6.4	500-600	7.5-8.0
6	300-400	6.4-7.0	600-800	8.0-8.8
7	> 400	> 7.0	> 800	> 8.8

The wind shear is the sudden, drastic change in wind direction or speed over a comparatively short distance [4]. Most winds travel horizontally, as does most wind shear, but under certain conditions, including thunderstorms and strong frontal systems, wind shear will travel in a vertical direction [5]. With its sharp shifts in wind direction and relative wind speed, it can cause a reduction of wind turbine performance and may also cause damage to the wind turbine blades [12]. The wind turbine must never be located such that it is subject to excessively wind shear and turbulent air flow. Light turbulence will decrease performance since a turbine cannot react to rapid changes in wind direction, while heavy turbulence may reduce expected equipment life or result in wind turbine failure. Turbulence may be avoided by following a few basic rules: (1) the wind turbine should be mounted on a cleared site free from minor obstructions such as trees and buildings and (2) If it is not possible to avoid obstructions, tower height should be increased to a value of approximately 9 meters greater than the height of obstructions, and (3) A good "rule of thumb" is to locate the turbine at a minimum height of three times that of the tallest upwind barrier [4, 5, 12, 13].

3.2. Global wind energy status

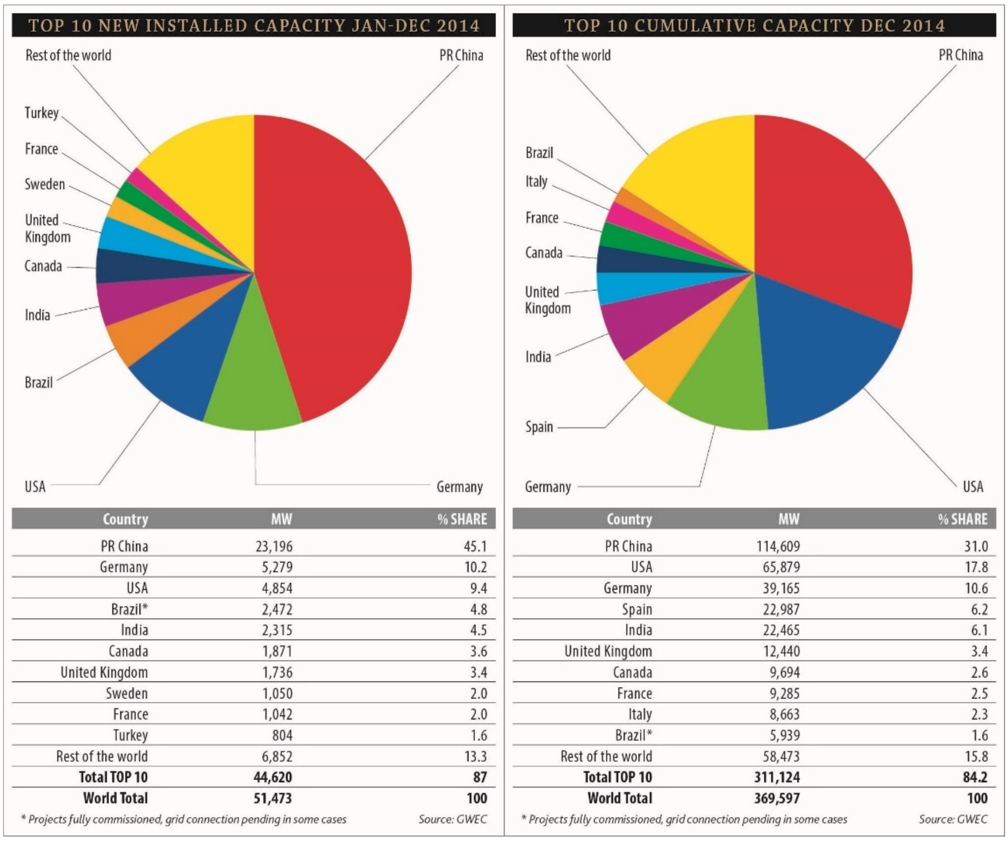
In 2014, the wind power was a record year for the wind industry as annual installations crossed the 50 GW mark for the first time. More than 51 GW of new wind power capacity was brought on line, a sharp rise in comparison to 2013, when global installations were just over 35.6 GW. The previous record was set in 2012 when over 45 GW of new capacity was installed globally [16].

In 2014 total investments in the clean energy sector reached a high of USD 310 billion. The global wind sector saw investments rise 11% to a record USD 100 billion during the year. This was signifi cant growth over 2013 investment of USD 80 billion, and USD 81 billion in 2012. The new global total at the end of 2014 was 370 GW, representing cumulative market growth of more than 16%, which is lower than the average growth rate over the last ten years of almost 23%. At the end of 2013, the expectations for wind power market growth were uncertain, as continued economic slowdown in Europe and political uncertainty in the US made it diffi cult to make projections for 2014, which we called at just over 47 GW, not anticipating the dramatic growth in the Chinese market [15-17].

China, the largest overall market for wind since 2009, had another remarkable year, and retained the top spot in 2014 (see Figure 3). Installations in Asia again led global markets, with Europe reliably in the second spot, and North America a distant third. A result of this was that in 2014, as in 2013, the majority of wind installations globally were outside the OECD once again. This was also the case in 2010 and 2011, and is likely to continue to be so for the foreseeable future. Figure 4 shows the annual global installed wind energy. Figure 5 and 6 also shows global annual and cumulative installed capacity [16]. By the end of last year six countries had more than 10,000 MW of installed capacity including China (114,609 MW), the US (65,879 MW), Germany (39,165 MW), Spain (22,987 MW), India (22,465 MW) and the UK (12,440 MW). Table 2 shows the global installed wind power capacity in 2014 [16].

Table 2. Global installed wind power capacity in 2014 (MW) [16]

Africa & Middle East	**Total: 2 535**
Morocco	**787**
Egypt	**610**
South Africa	**570**
Asia	**Total: 141 964**
PR China	114 609
India	22 465
Japan	2 789
Europe	**Total: 134 000**
Germany	39 165
Spain	22 987
UK	12 440
France	9 285
Italy	8 663
Sweden	5 425
Portugal	4 914
Denmark	4 883
Poland	3 834
Turkey	3 763
Latin America	**Total: 8 526**
Brazil	5 939
Chile	836
North America	
Pasific Region	**Total: 4 441**
Australia	3 806
WORLD TOTAL	**369 597**



Country	MW	% SHARE
PR China	23,196	45.1
Germany	5,279	10.2
USA	4,854	9.4
Brazil*	2,472	4.8
India	2,315	4.5
Canada	1,871	3.6
United Kingdom	1,736	3.4
Sweden	1,050	2.0
France	1,042	2.0
Turkey	804	1.6
Rest of the world	6,852	13.3
Total TOP 10	**44,620**	**87**
World Total	**51,473**	**100**

** Projects fully commissioned, grid connection pending in some cases* *Source: GWEC*

Country	MW	% SHARE
PR China	114,609	31.0
USA	65,879	17.8
Germany	39,165	10.6
Spain	22,987	6.2
India	22,465	6.1
United Kingdom	12,440	3.4
Canada	9,694	2.6
France	9,285	2.5
Italy	8,663	2.3
Brazil*	5,939	1.6
Rest of the world	58,473	15.8
Total TOP 10	**311,124**	**84.2**
World Total	**369,597**	**100**

** Projects fully commissioned, grid connection pending in some cases* *Source: GWEC*

Figure 3. Top ten contries by installed capacity and by cumulative capacity in 2014 (MW) [16].

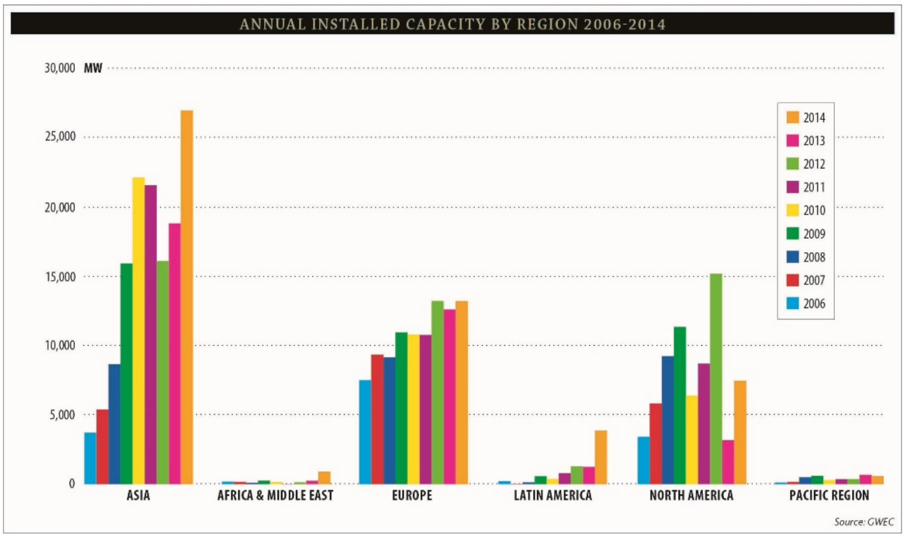


Figure 4. Annual global installed wind energy capacity by region [16].

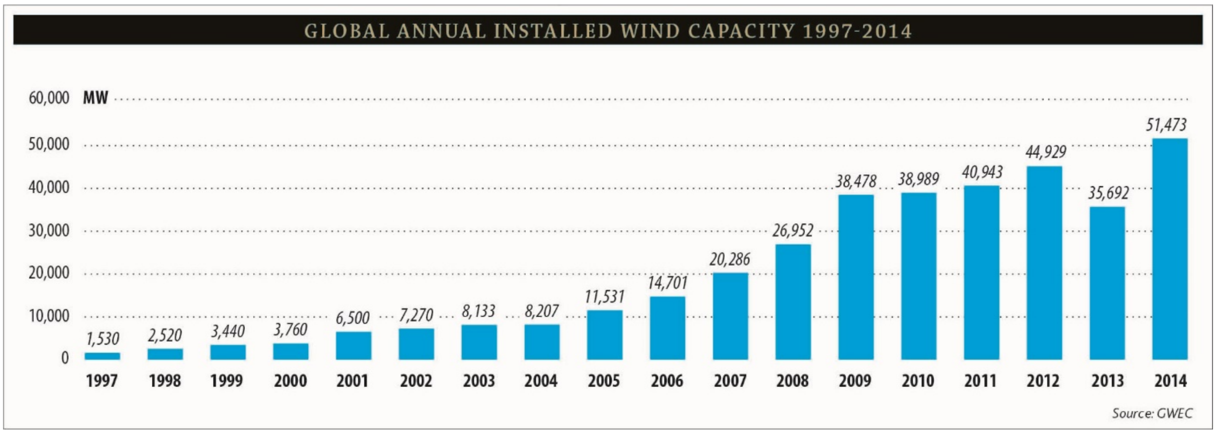


Figure 5 . Global annual installed wind capacity [16].

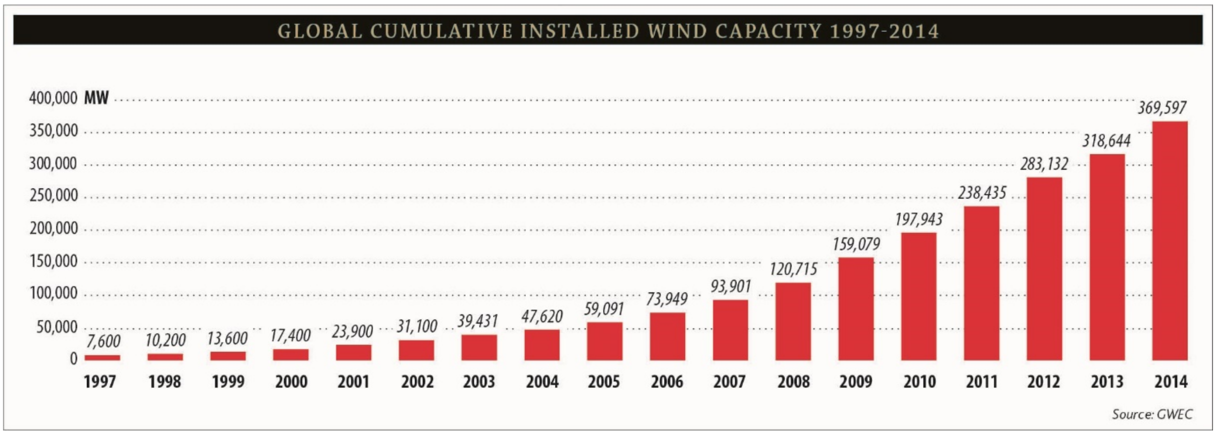


Figure 6. Global cumulative installed wind capacity [16].

China in 2014 crossed the 100,000 MW mark, adding another milestone to its already exceptional history of renewable energy development since 2005. Largely driven by China, Asia overtook Europe as the region with the most deployed wind capacity by the end of 2014. Looking ahead, the picture is complex across various regions. 2015 is likely to be another good year: Europe's framework legislation and its 2020 targets ensure a degree of stability; the US and Canada are both anticipating strong years;

China is expected to continue strong; and emerging markets in Africa and Latin America are expected to continue to grow. It is after 2016 that policy uncertainty is likely to cause a downturn in North America, and perhaps elsewhere [16-18].

The political and regulatory support for wind across the two large Asian markets is on the rise. The slowdown in Asia in 2012-2013 was a result of a combination of factors, but these conditions were expected to be shortlived. In the next five years Asian dominance of global wind markets is expected to continue. On the other hand, Brazil, Canada, Mexico and the US are expected to have a strong 2015. More than 934 MW came online in Africa this year. Global installations will be further aided by new projects coming on line in Japan, Australia, Pakistan, Kenya, and South Africa [16].

3.3. Wind energy market in Turkey

Turkey added 804 MW of new wind power in 2014 for a total installed capacity of 3,763 MW [19-22]. Turkey's installed capacity has grown at over 500 MW per year since 2010 and Turkey's National Transmission Company expects annual installations to reach 1,000 MW per year from 2015 onwards [22]. On the other hand, the Turkish market at present has a large pipeline of projects. The Turkish Wind Energy Association estimates that under the current regulatory framework a total installed capacity of about 10.5 GW will be reached within the next ten years, but it could be as high as 20 GW with the right amendments to the regulatory framework. Regardless, Turkey's vast wind resources are likely to attract signifi cant investment in the coming years [16, 21, 22].

Turkey's best wind resources are located in the provinces of Çanakkale, Izmir, Balıkesir, Hatay and Istanbul. As of the end of 2014, the Aegean region had the highest installed wind capacity with a total of 1,486 MW, followed by Marmara region with 1,359 MW and the Mediterranean region with 543 MW [19]. The Turkish wind market is mostly dominated by local developers: the 1,210 MW currently under construction is divided between the Borusan-EnBw Partnership, Güriş and Bereket Enerji. The leading players in the Turkish wind market are Polat Energy (457 MW), Demirer Holding (331 MW) and Bilgin Energy (295 MW), followed by Aksa Energy (237 MW) and Eksim (235 MW) [16, 19].

Turkey has one of the fastest growing power markets in the world which until now has not seen any adverse impact from the global financial crisis. With very limited oil and gas reserves, Turkey is increasingly turning to renewable energy sources to improve its energy security, and seeks to provide 30% of its electricity from renewable energy by 2023. However, to match the rapidly growing energy demand, more investments are needed [22].

After the amendment of Turkey's Renewable Energy Law (No. 5346 dated 18th May 2005) the feed-in tariff was set at USD 7.3 cent/kWh for wind power, for a period of ten years and will apply to power plants that come into operation before 1st January 2016. The law allows for an additional bonus of up to USD 3.7 cent for up to fi ve years for using locally manufactured components. Wind power producers are also free to sell to the national power pool or engage in bilateral power purchase agreements [19].

Additionally, another incentive is the 85% discount for the right of easement on State owned land for transportation and transmission. This incentive applies to facilities that begin operations before 31 December 2020. The discount will apply during the first ten years after the establishment of the wind farm. The amended law also allows for the construction of renewable energy projects in national and natural parks, protected regions, conserved forests, wildlife development zones, special environmental protection zones and natural protected areas, provided that the necessary permissions are obtained from the Ministry of Environment and/or regional protection boards.

A new Energy and Electricity Market Law was published in April 2013 and included a new Electricity Market License regulation which entered into force in November 2013. According to this regulation, there are now two stages for the licensing procedure: pre-license and license. In the pre-license period, applicants are given 24 months to seek the necessary permits for urban planning, construction, land acquisition etc. If the necessary permits cannot be obtained over a period of 24 months, or the requirements specifi ed by Turkey's Energy Market Regulatory Authority (EPDK) cannot be fulfilled, the applicant will not be granted an electricity generation license [19].

Another change under the Electricity Market License regulation is related to wind power project transformer capacity, which is established on a regional basis. The Turkish Electricity Transmission Company (TEİAŞ) will announce this capacity, which determines how much wind power can be connected to the regional grid system, every year on a fixed date. There is an ongoing process to add 3,000 MW of new grid capacity across Turkey. Developers have started conducting measurements and will be able to apply for pre-licenses in April 2015. A new grid capacity announcement is expected to take place in April 2015 in parallel with pre-license applications from the previous licensing round [16, 19].

Although many improvements have been achieved in the regulatory framework and new steps towards a more liberalised power market have been taken, some barriers to wind development in Turkey still remain, including [16, 19]:

- immature electricity and gas market, which impedes the predictability of market prices
- technical diffi culties in transmission and lack of continuous and predictable grid connection capacity allocation; and
- long administrative procedures with the involvement of numerous central and local authorities

The Turkish Wind Energy Association expects Turkey to reach an installed capacity of 5,000 MW by the end of 2015 and 6,200 MW by 2016. To ensure that these targets are met, the transmission system operator has announced investments in grid reinforcements for the period from 2015 to 2020. Presently, Turkey is one of the biggest on-shore wind markets in Europe with an 11 GW pipeline of wind power projects [16, 19, 22].

4. Conclusion

Current trends in energy supply and use are unsustainable – economically, environmentally and socially. Without decisive action, energy-related greenhouse-gas (GHG) emissions could more than double by 2050, and increased oil demand will heighten concerns over the security of supplies. We can and must change the path we are now on; sustainable and low-carbon energy technologies will play a crucial role in the energy revolution required to make this change happen. On the other hand, there is a growing awareness of the urgent need to turn political statements and analytical work into concrete action. To address these challenges, the International Energy Agency (IEA), at the request of the Group of Eight (G8), has identified the most important technologies needed to achieve a global energy-related CO2 target in 2050 of 50% below current levels. It has thus been developing a series of technology roadmaps, based on the Energy Technology Perspectives modelling, which allows assessing the deployment path of each technology, taking into account the whole energy supply and demand context.

Wind is the most advanced of the “new” renewable energy technologies and then, the development and deployment of wind power has been a rare good news story in the deployment of low-carbon technology deployment. A much greater number of countries in all regions of the world now have significant wind generating capacity. In a few countries, wind power already provides 15% to 30% of total electricity. The technology keeps rapidly improving, and costs of generation from land-based wind installations have continued to fall. Wind power is now being deployed in countries with good resources without special financial incentives.

Turkey is facing serious challenges in satisfying its growing energy demand. To fuel a rapidly growing economy, the country’s electricity consumption is increasing by an average of 8-9% every year, and significant investments are needed in generation, transmission and distribution facilities to balance the power system’s supply and demand. Finally, Turkey is an energy-importing country. In order to be less dependent on other countries, Turkey needs to use its sustainable sources. From this point of view, wind power is a very attractive choice, since it is economical, sustainable, environmental friendly and a domestic energy source.

In general, potential wind energy areas in Turkey lie in northern and the north-western parts, at locations along the Aegean Sea and Marmara Sea coast. Aegean, Marmara, East-Mediterranean and South East Anatolia regions of Turkey are generally seen as promising of higher wind power potential compared to other part of Turkey. In Turkey the available wind power was 3763 MW by the end of the year 2014. This capacity became 20 415 MW at the end of 2023. The installed wind capacity of Turkey is approximately 24% of Turkey’s total economical wind potential. However this rate will be increased after installing the licensed projects.

References

[1] Boyle, G (Ed.). Renewable energy: power for a sustainable future. 3th ed. Oxford, 2012.

[2] Kaygusuz, K. Clean energy policies for sustainable development in Turkey.

[3] Journal of Engineeri,ng Research and Applied Science 2012; 1(2): 1-10.

[4] Toklu, E., Kaygusuz, K. Present situation and future prospect of energy utilization in Turkey. Journal of Engineeri,ng Research and Applied Science 2012; 1(2): 11-24.

[5] Walker JF, Jenkins N. Wind energy technology. New York: John Wiley; 1997.

[6] Gash R, Twelve J. Wind power plants: fundamentals, design, construction and operation. Germany: Solarpraxis AG; 2002.

[7] IEA. International Energy Agency. World energy outlook 2014. Paris: IEA; 2014.

[8] BP, British Petroleum. Statistical review of world energy 2014. BP, UK, 2014.

[9] Boden, T.A., Marland, G. and R.J. Andres (2010), Global, Regional, and National Fossil-Fuel CO2 Emissions, Carbon Dioxide Information Analysis Center, Oak Ridge national Laboratory, U.S. DOE, Oak Ridge, TN., http://cdiac.ornl.gov/ (accessed 3 October 2014).

[10] IEA, International Energy Agency. CO2 emissions from fuel combustion (2013 edition):IEA, Paris, 2013; http://www.iea.org/co2highlights/ (accessed 5 May 2014).

[11] IPCC, Intergovernmental Panel on Climate Change. Climate Change 2007: The Physical Scientific Basis, Cambridge University Press. http://www.ipcc.ch/ (accessed 01.5.2012).

[12] IPCC, Intergovernmental Panel on Climate Change. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Geneva, IPCC, 2007.

[13] Ghenai, C., Sargyan, N. Wind Energy in “Paths to Sustainable Energy”, Artie, NG (Ed.), InTech, 2010, Available from: http://www.intechopen.com/(accessed 12.06.2014).

[14] Kaygusuz, K. Wind energy status in renewable electrical energy production in Turkey.Renewable and Sustainable Energy Reviews 2010; 14: 2104–2112.

[15] IEA. International Energy Agency. Technology roadmap: wind energy. Paris: IEA; 2013.

[16] EWEA, European Wind Energy Association, Pure power, wind energy scenarios up to 2030; 2009. Available from: www.ewea.org.

[17] GWEC, Global Wind Energy Council, Global wind 2014 report. Available from: www.gwec.net/ [accessed 05.11.2015].

[18] AWEA, American Wind Energy Association, Global wind energy market report, Wind energy industry grows at steady pace; 2014. http://www.awea.org [accessed 10.10.2015].

[19] Kaygusuz K. Wind power for a clean and sustainable energy future. Energy Sources Part B 2009;4:122–33.

[20] EPDK, Energy Market Regulatory Authority. Electricity market; 2009. Available from: www.epdk.gov.tr [accessed date 02.04.09].

[21] Turkish Statistical Institute (TURKSTAT). http://www.tuik.gov.tr.

[22] General Directorate of Electrical Power Resources (EIE), Turkey’s wind map. http://www.eie.gov.tr [accessed date 10.07.09].

[23] WECTNC. World Energy Council Turkish National Committee. In: Turkey’s energy report in 2014; 2015. Ankara, Turkey.