

Wind Power Assessment for Turkey and Evaluation by APLUS Code

Ibrahim H. Kilic, A.B. Tugrul

Abstract—Energy is a fundamental component in economic development and energy consumption is an index of prosperity and the standard of living. The consumption of energy per capita has increased significantly over the last decades, as the standard of living has improved. Turkey's geographical location has several advantages for extensive use of wind power. Among the renewable sources, Turkey has very high wind energy potential. Information such as installation capacity of wind power plants in installation, under construction and license stages in the country are reported in detail. Some suggestions are presented in order to increase the wind power installation capacity of Turkey. Turkey's economic and social development has led to a massive increase in demand for electricity over the last decades. Since the Turkey has no major oil or gas reserves, it is highly dependent on energy imports and is exposed to energy insecurity in the future. But Turkey does have huge potential for renewable energy utilization. There has been a huge growth in the construction of wind power plants and small hydropower plants in recent years. To meet the growing energy demand, the Turkish Government has adopted incentives for investments in renewable energy production. Wind energy investments evaluated the impact of feed-in tariffs (FIT) based on three scenarios that are optimistic, realistic and pessimistic with APLUS software that is developed for rational evaluation for energy market. Results of the three scenarios are evaluated in the view of electricity market for Turkey.

Keywords—APLUS, energy policy, renewable energy, wind power, Turkey.

I. INTRODUCTION

ENERGY is fundamental to the quality of our lives. All humanity is totally dependent uninterrupted supply of energy for living and working. Energy is a component to meet the needs for mechanical power, thermal requirements, raw material needs, and lighting requirements. All of these requirements are met by different energy sources.

Any problem experienced in the issue of energy shows the effect of societies both directly in the capacity and variety of production and on quality of life. For this reason, the issue of energy supply plays a lead role in the forming of international relations while at the same time occupying the agendas of state administrators, and even confronts us sometimes as a cause for war and at others a cause of mandatory cooperation. The chaos that came out of the oil crisis of the 1970s and the

new world order that showed it afterwards is the best example of this situation. Today, the sustainability problem of fossil fuels with regards to climate and large developments in renewable energy changing international balances in the equilibrium between states is expected [1].

Primary energy sources comprise of fossil, renewable, and nuclear sources. The share of fossil fuels in the total primary energy consumption in 2014 was 86.3%, for renewable energy this share was 9.3%, while nuclear energy had a 4.4% share of global primary energy consumption [2]. Fig. 1 shows the global primary energy consumption by source in 2014 [2].

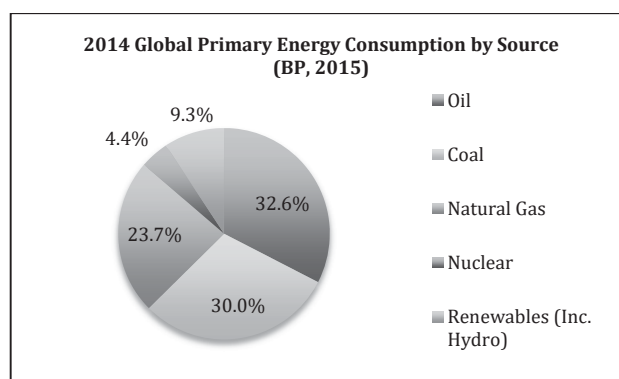


Fig. 1 2014 Global primary energy consumption

Global population, which has shown continuous growth beginning from the very earliest known ages, rates of industrialization, and modern societies adopting an energy intensive lifestyle have caused a constant growth trend in global energy consumption. It has been predicted by various organizations that this trend will continue. According to these predictions, the rate of increase of annual energy demand will be 0.6% for OECD countries, 2.3% for non-OECD countries, and 1.6% for the world in general [3].

There are several important reasons that make renewable energy extremely important for the future of our society. Positive environmental impact is certainly one of the top reasons. Also, renewable energy reduces import dependency through energy diversification. Furthermore, renewable energy being a popular subject is attracting large number of investors to the energy sector to make renewable energy investments.

By 2014, a substantial recovery has been experienced in investments made in the renewable energy sector. For the first time in the last 3 years, global new investments entered an increase trend and reached \$270 billion in 2014 with an increase of 17% compared to 2013. Renewable energy has surpassed fossil fuels at the end of the fifth year in terms of net

I. H. Kılıç is MSc student in Energy Institute of Istanbul Technical University in Energy Science and Technology Program and also engineer in a private company (phone: +90-542 416 54 00; e-mail: ibrahimhaliklc@gmail.com).

A. B. Tugrul is Professor in Energy Institute of Istanbul Technical University and also Head of Division and Coordinator of Graduate Program in Energy Institute of Istanbul Technical University, Ayazaga Campus-34469, Istanbul, Turkey (phone: +90-532 311 88 10; e-mail: beril@itu.edu.tr).

investments made in new power capacities. With an increase of 36%, investments made in developing economies have reached the total investments in developed economies, which have only recorded an increase of 3% on this issue [4].

II. RENEWABLE ENERGY

Renewable energy sources that are used prevalently today are hydro, wind, solar, geothermal, and biomass energy [5]. Using of these energy sources increases day by day by means of keeping the reduction of environmental problems to minimum levels during the production of energy and their conversion [6]. One of the most important sources of renewable energy is wind energy. Solar energy that reaches the world from the sun does not heat the whole world equally, and there are heat differences between air masses. The moving of air masses in different heats horizontally or close to horizontally is known as wind, and in short wind is convection movements originating from air pressure that are a result of solar radiation. The ability of moving air masses to be able to work is a type of kinetic energy that has been given the name wind energy potential [7].

III. WIND ENERGY

Wind energy, which plays an important role in the fight against climate change and at the same time for countries in the security of their power supply, has possessed a significant position amongst the other renewable energies by gaining importance since 2000. The total capacity, which in the year 2000 was 17 GW, has in just 15 years increased roughly 25 times and has been able to reach 432 GW in 2015. This increase means an annual increase of around 25% [8].

The spread of the installed global wind energy capacity between regions, the Asia-Pacific continent is seen in the position of leader. While the continent of Europe dominated the sector between the years 2009 and 2013, Asia-Pacific overtook Europe in 2014. Wind energy is newly becoming prevalent in Africa and other continents, and the rate of distribution of the total installed capacity is increasing, despite being small [8].

When looking at Turkey's energy figures, the end of 2015 259.194 GWh of electricity was produced. The share of natural gas in the energy generation portfolio fell from 50% to below 40% with the beginning of 2015. Electricity generation obtained from renewable sources, which was at the level of 17% in 2008, reached above 30% in 2015 [9].

The installed capacity of wind energy plants (WEP) in Turkey is increasing every year, and the installed capacity that was 8,7 MW in 1998 reached 4.718 MW at the end of 2015 [10]. With these values, Turkey has the 15th largest installed wind energy capacity in the world [8]. According to Turkey's targets for the year 2023, it is aimed that 30% of the total electricity energy production is obtained from renewable energy sources by 2023. For wind energy, reaching a 20,000 MW installed capacity is being targeted [11].

When looking at policies made to encourage renewable energy investments in the world, it can be seen that financial

incentives through tariffs (feed-in-tariffs) that support electricity production in particular and regulations (renewable-portfolio-standards) that ensure that companies give a mandatory share to renewable energy sources in their electricity generation portfolios are coming into prominence [12].

The Turkish Government has adopted incentives for investments in renewable energy production. Most crucial are the so-called FIT, which are available for 10 years from commissioning of the renewable energy plant. A FIT is the USD price paid to a (small or large scale) producer of renewable energy. In Turkey, FIT has two components: one is the 'basic' tariff for the electricity produced, the other one is a kind of 'bonus' in case that electricity is generated using equipment produced in Turkey [13].

In the scope of the rising demand for energy today, one of the most important sources that is a core source for every country and is preferred with regards to it being a renewable energy source is wind energy [14]. The sustainable incentive mechanisms for ensuring the increase of wind energy in the share of electricity consumption are inevitable [15]. In this study, electricity prices were analyzed in the scope of realistic scenario with incentive mechanisms of wind power plants in the Electricity Market of Turkey being analyzed through the APLUS Computer Program.

IV. APLUS COMPUTER PROGRAM

The APLUS Computer Program is comprehensive software and the algorithms of software were developed by APLUS Energy Company. The program enables the modeling of the Electricity Sector of Turkey, the carrying out of analysis, the analysis of predictions for the future, and dual analysis for following the market. With the APLUS Computer Program, sector analysis, estimation modeling of electricity prices, estimation modeling of electricity demand, power optimization models of power plants, and portfolio optimization models can be analyzed [16].

The methodology of the program was developed on the fundamental model understanding and facilitates the determination of the spot market electricity price based upon the marginal price foundation at the point where supply and demand are crossed at the relevant time. In this context, annual electricity demand predictions are made primarily. After electricity demand are predicted annually and divided to hourly profiles, the electricity generation estimation is made for the supply side. In this scope, taking the capacity factors of electricity importing-exporting and renewable power plants like wind, geothermal, river-type hydro, and biomass with capacity factors into consideration makes electricity generation estimations. After this, the predicted generation from publicly owned corporations that are Build Operate Transfer and Build Operate power plants and the estimated production of reservoir-type hydro plants assumed to produce at peak hours are calculated. These generation estimations predicted for coming years are collected and taken from estimations of electricity demand. The remaining electricity demand amount is matched with the capacity at disposal that

thermal plants ordered according to marginal price basis offer to the market at relevant times. In this manner, the marginal cost of the relevant plant at points when supply crosses demand creates the spot market price for that hour [16]. Fig. 2 shows the working mechanism of APLUS Computer Program.

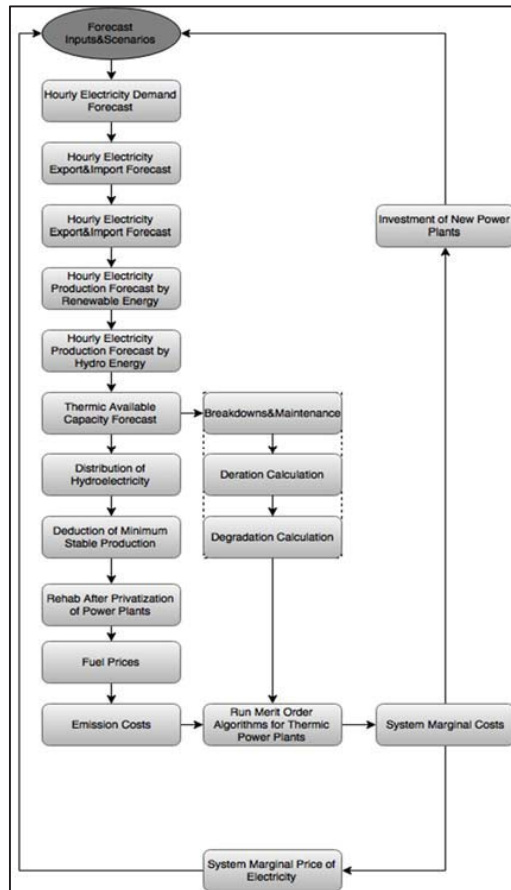


Fig. 2 APLUS Computer Program working mechanism

The APLUS Computer Program uses the Dynamic Engaging Algorithm for power plants that will go into operation in the future. By means of this algorithm, the investment costs of electricity from power plants that are in the investment process are compared with the estimated spot electricity market price. As a result of this comparison, if the unit electricity investment cost is less than the estimated spot electricity market price, the power plant is commissioned, while if it is above, the going into operation of the plant is evaluated with the same method the following year. Thanks to this method, the real market conditions are reflected and price forecasting can be calculated in this direction [16].

As a result of the use of the APLUS Computer Program, the annual electricity demand forecasting can be taken for specified periods of time. With the estimation of the electricity demand, electricity generation values and total installed capacity values can be obtained according to previously indicated bases. By using this data, the distribution of power

plants of the years and electricity production amounts can be obtained according to energy sources.

V. RESULTS AND DISCUSSION

Legislative regulations have been enacted for enhancing the use of renewable energy in Turkey and improving energy efficiency. For wind power plants that are commissioned before 2020, 10-year purchase guarantee of 73 \$/MWh starting from the date the plant commences operation is being given. Furthermore, if the mechanical and/or electromechanical parts to be used in the wind turbines are made domestically, additional incentives are being implemented for a 5-year period on the fixed purchase price.

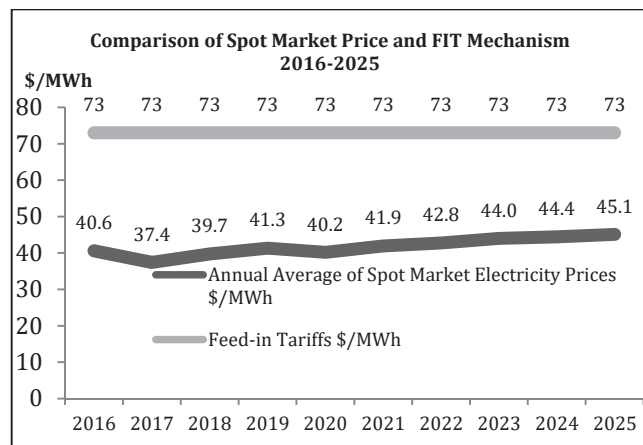


Fig. 3 Comparison of spot electricity prices and FIT mechanism prices between 2016- 2025

With the aim of examining the effect of the supporting of electricity production from wind energy on the electricity market, growth rate of the wind energy installed capacity between 2016 and 2025 is being predicted and it has been observed in the forecast that the purchase guarantees incentive of 73 \$/MWh for wind energy power plants that are being commissioned is to continue that spot electricity market prices are low. Considering the scenario in Fig. 3 that the TRY/\$ parity is 3 TRY, an approximation of the spot electricity market prices between the years 2016 and 2025 has been given and comparisons have been made for the incentive given for electricity produced from wind energy.

In the scope of the FIT support mechanism, the increasing of the share of the installed capacity of wind energy in the total installed capacity shows a suppressing effect in lowering spot electricity market prices. With regards to clean, quality, cheap, and sustainability of electricity, the increase of renewable energy sources in electricity generation can be received positively. However natural resources such as wind and the sun are fluctuating loads for security of supply. If days when the sun shines and winds blow do not match days when the demand for energy in the country is high, unexpected power cuts can be happened. For this reason, it must be planned for the role of renewable energy to support base load

electricity plants in a continuous and sustainable energy portfolio.

The availability of base load power plants is highly important for energy security. The necessity to instantaneously meet the electricity demand is the most influential of the parameters that lead policies on energy. Therefore, with regards to the sustainability of the supply of electricity, base load power plant investments need to continue with regards to meeting the demand for continuous electricity.

Energy investments are long-term investments made in accordance to the market, technology, supply, and demand. The feasibility of long-term investments is determined according to the current conditions in the market. Investors in the electricity market take the decision to invest by taking spot electricity prices as a base. Spot electricity market prices being seen as low can have a negative effect on investments that are to be made in base load energy plants in the liberalized Turkish Energy Market.

As a result, so long as the purchase guarantee incentives given for electrical energy produced from wind energy continue in the Turkish Energy Market, it has been simulated with the APLUS Computer Program that electricity prices in the spot market will be seen as low between the years 2016 and 2025. A dynamic mechanism is needed for the sustainable support mechanism for renewable energy. The giving of an extra premium according to spot electricity market prices instead of a fixed price purchase guarantee for wind energy plants that are becoming more productive with the development of technology and whose capacity factor is increasing will contribute to the formation of a sustainable electricity market. Otherwise by encouraging electricity produced from renewable energy sources, a disruption may be seen in investments to be made in base load electricity plants that have an important share in meeting demands for electricity.

REFERENCES

- [1] Huesemann MH. The limits of technological solutions to sustainable development. *Clean Technology Environment Policy* 2003;5(1):21–34.
- [2] British Petroleum Inc. (BP). Statistical Review of World Energy London: BP, June 2015, Retrieved January 2016, from <<http://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html>>.
- [3] Energy Information Administration (EIA). International Energy Outlook 2011, Washington, DC: EIA, 2011, Retrieved March 2016, from <<http://www.eia.gov/forecasts/ieo/>>.
- [4] Renewable Energy Policy Network for the 21st Century, Renewables 2015 Global Status Report, 2015.
- [5] International Energy Agency (IEA), Medium-Term Renewable Energy Market Report, 2015, Retrieved March 2016, from <https://www.iea.org/bookshop/708-Medium-Term_Renewable_Energy_Market_Report_2015>.
- [6] US Environmental Protection Agency, Global Greenhouse Gas Emissions Data, 2016, Retrieved March 2016, from <<http://www.epa.gov/climatechange/ghgemissions/global.html>>.
- [7] Gökçek M, Erdem HH, Bayülken A. A techno-economical evaluation for installation of suitable wind energy plants in Western Marmara, Turkey, *Energy Explore Exploit* 2007b;25:407–28.
- [8] Global Wind Energy Council (GWEC), Global Wind Statistics, February 2016, Retrieved March 2016, from <http://www.gwec.net/wp-content/uploads/vip/GWEC-PRstats-2015_LR.pdf>.
- [9] Turkey Electricity Transmission Company (TEIAS), Annual Energy Market Report, 2015.
- [10] Turkish Wind Energy Association (TWEA), Turkish Wind Energy Statistics Report, January 2016.
- [11] Republic of Turkey Ministry of Energy and Natural Resources, Turkey National Renewable Energy Action Plan, December 2014.
- [12] Frankfurt School-UNEP Centre/BNEF, Global Trends in Renewable Energy Investment 2016, March 2016, Retrieved April 2016, from <<http://fs-unep-centre.org>>.
- [13] Turkish Energy Market Regulatory Authority (EMRA), The Renewable Energy Law, 2013.
- [14] Blanco, M.I., The Economics of Wind Energy. *Renewable and Sustainable Energy Reviews*, 2009.
- [15] Sawin, J.L., Sverrisson, F., Chawla, K., Lins, C., McCrone, A., Musolino, E., Riahi, L., Sims, R., Skeen, J., Sverrisson, F., Renewables 2014 Global Status Report, Technical Report, Renewable Energy Policy Network for the 21st Century, 2014.
- [16] APLUS Energy Investment Technology Consultancy, AVIEW-MarketSim Fundamental Energy Price Forecast Model, İstanbul, 2015.



Tugrul, A. Beril was born in Bursa. After finishing Bursa College, she graduated Istanbul Technical University (ITU) in 1973 as Mechanical Engineer. She also graduated from ITU Institute for Nuclear Energy (INE) in 1975 and gained MSc degree on nuclear safety. She worked in Turkish Atomic Energy Authority as Expert and Group Leader for site selection

of the first nuclear power plant between 1974 and 1977. She moved to ITU Institute for Nuclear Energy as Research Assistant in 1977. She gained PhD degree in 1984 She became Assistant Prof. in 1987, Assoc. Prof. in 1988 and lastly Prof. in March 1995. She was Vice Director at ITU-INE in 1988 – 1999 and Head of Nuclear Applications Division in 1997- 2001 and head of Nuclear Researches Division in 2009-2015. She was consulting member of Turkish Airlines in 1993-1996 on NDT. She has directed many of research Project and has been Professor in ITU Energy Institute as head of Nuclear Researches Division and has been lecture in Gebze Technical University also Military Academia on energy policy.

Prof. Tugrul was a member of Turkish Atomic Energy Commission 2011-2015. She was Vice President Turkish Atomic Energy Authority - Nuclear Safety Committee in 1998-2000. She was also member of Turkish Atomic Energy Authority – Consulting Committee between 1997 and 2003. She has over 250 publications. 48 of them have in international indexes. 53 MSc students and 14 PhD students have graduated under her supervising. She gained many publication awards from ITU, Turkish Scientific and Technology Council and Turkish Scientific Academy. She gained an Energy-Scientific Award from ICCI in May 2011 and also gained a women Scientist Award in March 2012.



Kilic, I. Halil was born in Gaziantep. After finishing of the Hatay College, he graduated Istanbul Technical University (ITU) in 2014 as a Metallurgical and Material Engineer. He will be also graduated ITU Energy Institute and will be gained MSc degree on Energy, Science and Technology. He is working in a private company as a power trader.