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INVESTIGATION OF THE RELATIONSHIP BETWEEN SOLAR AND WIND POWER DEVELOPMENT IN ELECTRICAL GRIDS AND COST CHANGES IN THE RELATED TECHNOLOGIES

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Abstract- Renewable energy sources are known to have significant advantages especially in terms of availability, accessibility, greenhouse gas emissions and public perception. The use of renewable energy resources, especially solar and wind are increasing remarkably within most power grids in the world. There has been immense growth in the installed renewable energy generation capacity last two years. Most developing countries are gradually planning to add significant amounts of renewable power to their electricity grids. Additionally, the cost to generate electricity energy from solar and wind has remarkably declined in last years. The aim of this study is to investigate the effect of the progress and cost decreases in wind and solar technologies on the amount of installed power in the grids. This study evaluates wind and solar power projects in terms of engineering economics and provides experience gained from global investment projects.

Keywords: Wind, Solar, Installation Costs, Renewable Energy, Energy Management.

1. INTRODUCTION

Renewable energy investments are a significant element of many global strategic plans related to sustainable economic growth. Therefore, electricity markets have developed various incentive mechanisms to provide future renewable energy investments for the past two decades. The use of renewable energy can provide benefits to countries such as contributing to energy security, reducing energy imports, reducing price volatility, reducing fossil fuel use, protecting against price increases and improving national employment [1-4].

Solar and wind power plants are dissimilar from conventional plants. Because, they provide electricity when the sun shines and wind blows, however cannot be switched on based on demand. Further, they are frequently built far away from high demand regions, which may require additional grid investments. System cost in renewable power plants is basically calculated by the total cost of the power system. A separate grouping is not required for the cost components and new or old equipment of the power system. The main difference between these approaches relates to the need to connect costs to specific parts of the power system. Calculating total system cost merely requires the first step, making categorization and feature unneeded [5, 10].

Wind and solar power have emerged as the most purchasable energy source for many countries and markets, with cost decreases set to continue into the next decade. Nowadays, solar photovoltaic (PV) and onshore wind power generation have almost cost less than the marginal operating cost of existing conventional coal fired plants [6-9] .

In this study, the second section describes the main components of solar and wind power plants. The third and fourth sections examine the cost changes in solar and wind investments. And the conclusions of this study are presented in the fifth section.

2. SOLAR AND WIND POWER TECHNOLOGIES

2.1. Solar Photovoltaics Systems

Solar photovoltaics (PV) convert sunlight into direct current (DC) electricity. Photovoltaics are used in the generation of electricity from solar energy. The current produced by photovoltaics is the direct current (DC), and the output voltage of each module is between 12- 1000 V, the power is between 180-250W. The output voltages of the electricity produced by solar power plants are designed according to the voltage level of the grid to which they will be connected. If the grid's voltage is over 400 V, the connection is made using step-up transformers such as 400V/31.5kV. DC current and voltage are converted to alternating current (AC) by an inverter [1, 11].

Photovoltaic cells are produced in many sizes, but most are 15 cm by 15 cm. In order to make the appropriate voltages and current outputs available for dissimilar applications, single solar cells are interconnected (wired together in parallel and in series) to form larger units, namely PV modules and arrays (Figure 1). Moreover, cells are sometimes cut into smaller pieces. There are three kinds of PV cell technologies that have control over the global market: polycrystalline silicon, monocrystalline silicon, and thin film [1, 12].

In the calculation of energy production from a solar panel system, the sunbathing time of the region, the efficiency of the panel and the installed power of the panel are important.

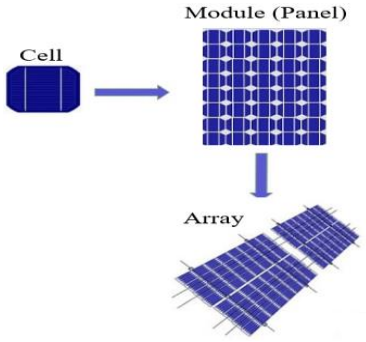


Figure 1. Cell, module (panel) and array

2.2. Wind Systems

Essentially, wind energy that can be transformed to electricity using wind blades. The quantity of electricity that wind power turbines generate depends upon the quantity of energy in the wind passing through the area scanned by the blades in a unit of time. Wind power density also depends on air density.

Rotors in wind power plant come in a wide variety of types. Each one is planned to transform the aerodynamic impacts of the wind into a torque turning a mile [1, 12].

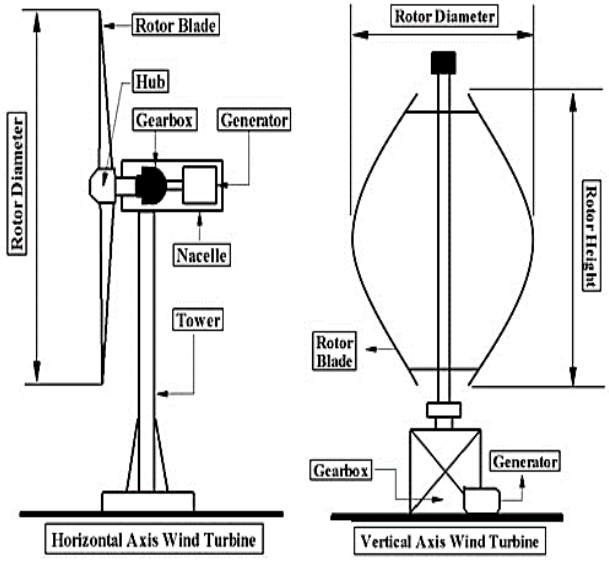


Figure 2. Schematic of horizontal and vertical axis wind turbines

Figure 2 indicates general horizontal and vertical axis constructions of a wind turbine system. Though there is no regular system for classifying wind turbine components, the turbine subsystems may be divided into four basic subsystems: Rotor, a nacelle, a tower and auxiliary equipment (cabling and electrical controls) [1, 12].

3. COST CHANGES IN SOLAR PHOTOVOLTAICS POWER INVESTMENTS

The investment costs of a solar system are generally measured in price-per-peak-watt (peak watt, for instance Euro/Wp). The prices for all solar photovoltaic systems are very different and depend on a variety of factors including grid connection, system size, location, technical specification and others.

By taking photovoltaic for building applications as an example the major factors influencing the investment costs of PV turn-key systems are briefly outlined:

Investment costs in solar photovoltaic systems are quite low (per kWp) at large capacities. However, it is seen that small capacity systems have higher production costs [1, 10-11].

Basically, the proximity or distance of the installation site to the grid in solar systems affects the investment cost. Likewise, the investment cost of solar rooftop systems is particularly based on the needs of the static structure on roofs [1, 10-11].

The declared costs include maintenance costs for generators in outlying solar systems, as well as great reserve costs because of environmental factors such as vandalism situations and utmost temperatures. Some works declare that maintenance and operation costs are thoroughly correlated to the system dimension, therefore approximately 2% or 3% of total hardware costs is expected to be a reasonable estimation of operation and maintenance costs [10-14].

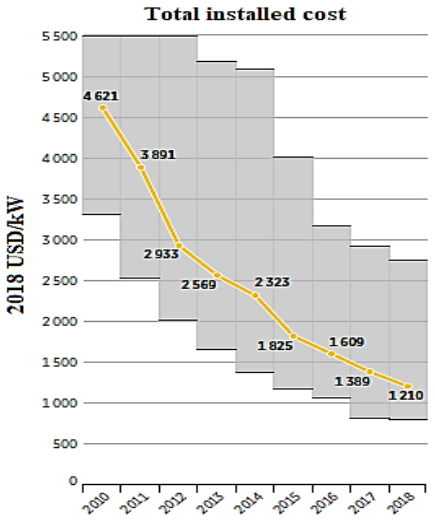
94 GW of new solar power capacity was added in 2018 year. This amount is almost 55% of total new renewable power capacity additions. In 2018 year, some major markets announced new power additions in solar PV. For example, China (approximately 44 GW), India (approximately 9 GW), the United States (approximately 8 GW), Japan (approximately 6 GW), Australia and Germany (approximately 4 GW), and the Turkey, South Korea and Mexico (each country approximately 2 GW each) [10].

In 2010 year, the global weighted-average levelized cost of electricity (LCOE) of utility-scale solar system was 0.371 US Dollar/kWh, while by 2018 this had dropped to 0.085 US Dollar/kWh, 77% lower than in 2010. The decrease in 2018 was 13%.

The capacity factor is one of the basic parameters that show the effectiveness of a power plant in the electricity grid. In this study Figure 3 shows the costs and capacity factor of PV systems from 2010 to 2018.

The total global power capacity of Concentrated Solar Power (CSP) at the end of 2018 year was almost 5.5 GW. In spite of this development, CSP is a solar technology with the lowest total installed capacity.

Higher capacity factors and lower total installed costs are utilizing the decrease in the cost of electric energy produced from CSP technologies. The LOCE of CSP dropped by 28% in 2018 year. The cost of CSP decreased from approximately 7200 US Dollar/kW in 2017 to 5200 US Dollar/kW in 2018. On the other hand, the capacity factor of CSP technologies is 39% in 2017 and 45% in 2018 year (Figure 4). Also, this increase rate is quite significant for CSPs.



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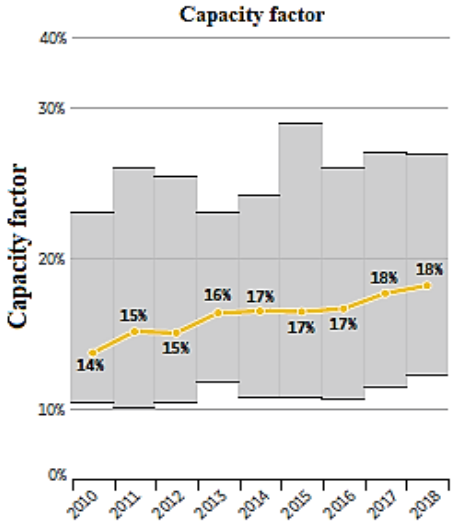

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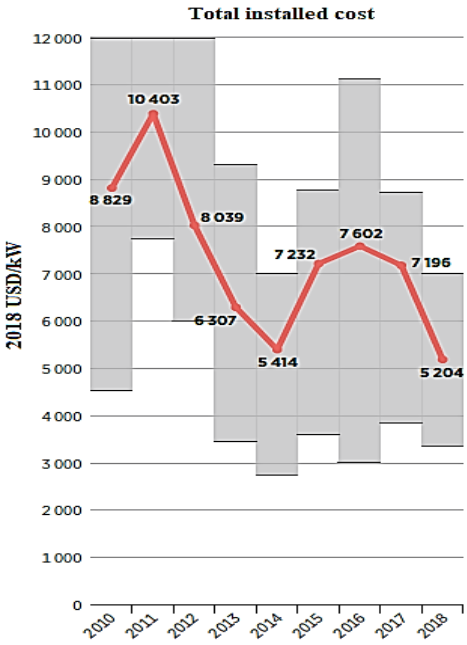
Figure 3. (a) Costs and (b) Capacity factors for solar photovoltaics between 2010 year and 2018 year



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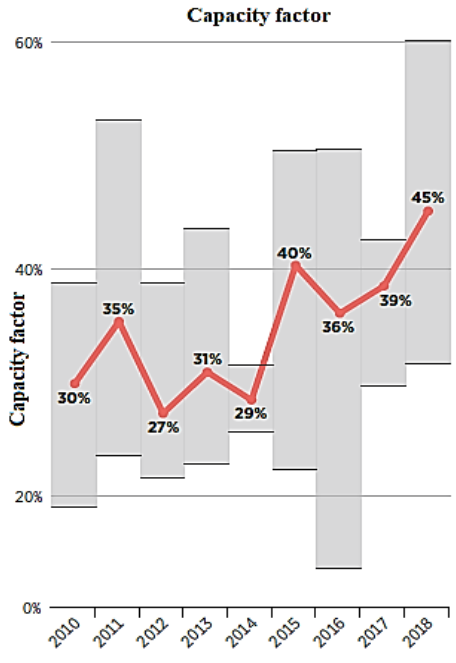

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Figure 4. (a) Weighted average total installed costs in global and (b) capacity factors for CSP between 2010 and 2018

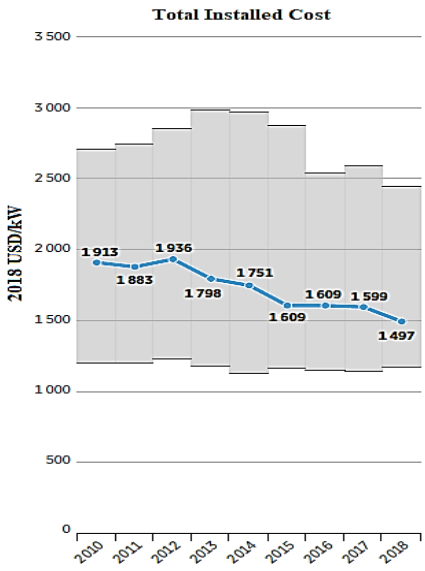
4. COST CHANGES IN WIND POWER INVESTMENTS

The major factors leading wind power economics include the investment and auxiliary system costs, grid connection costs, average wind speed/electricity generation, the lifetime of a wind turbine and manufacture of wind turbines and the investment costs.

Because electricity generation is extremely linked to wind conditions, choosing a suitable location is crucial to reaching economic applicability.

In recent years, grid-connected (integrated) wind turbines have dominated the developing renewable energy markets. During this period, the size of the wind turbines has grown considerably, and also its efficiency has increased steadily, and its investment costs per kW have declined in general.

Basically, major costs of wind power investments are mostly the cost of the wind turbine itself. Another cost elements are characteristically electrical system installations, grid-connection, construction of connection roads of power plant facility, size of the turbine and location/country of installation.



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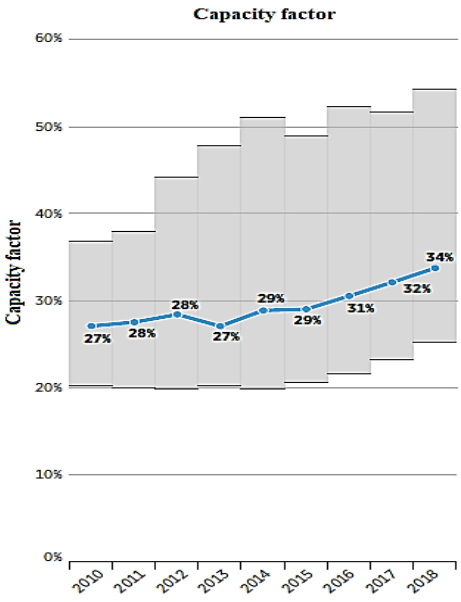

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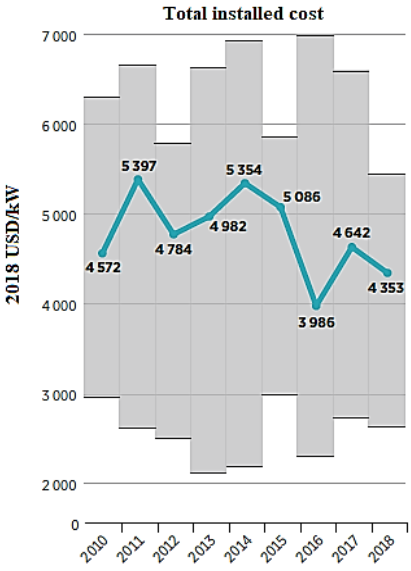
Figure 5. (a) Weighted average total installed costs in the world and (b) capacity factors for onshore wind between 2010 and 2018



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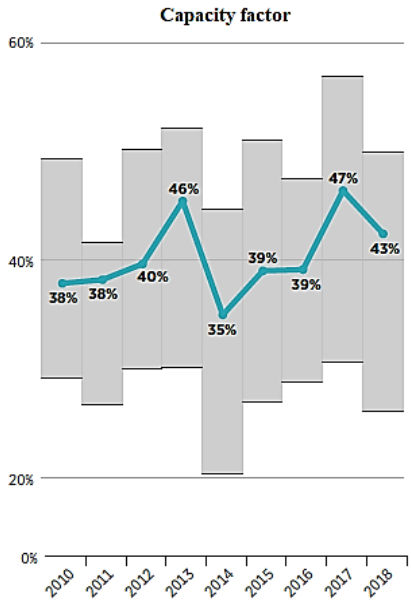

(b)

Figure 6. (a) Weighted average total installed costs in the world and (b) capacity factors for offshore wind between 2010 and 2018

In 2018 year, the United States and China had most of the enlargement in onshore wind facilities, with increments 6.8 GW and 18.5 GW respectively. This deployment was continued by GW or higher new capacity additions in France (approximately 1.6 GW), Germany (approximately 2.7 GW), India (approximately 2.4 GW) and Brazil (approximately 2.1 GW) [10].

In 2018 year, the generation cost of electricity for onshore systems decreased with ongoing declines in total installed costs, as well as by developments in the capacity factor (average). The factors ongoing this trend contain continuous reforms in manufacturing and design of turbine projects; more competitive areas in the world, and growing series of turbines intended to minimize LCOE value in operating conditions [10-15].

In 2018 year, the overall installed cost of onshore system decreased by almost 6% in 2018 year. While its cost was nearly 1600 US Dollar/kW in 2017, it went down to approximately 1500 US Dollar/kW in 2018 year. Also, turbine cost in a wind power plant proceeded to drop (Figure 5).

In offshore power plants, approximately 4.5 GW of extra capacity was added in 2018 year. Especially, the People's Republic of China represents a large proportion in global (almost 40% of total extra capacity). The other countries leading the increase in power are England (approximately 29%) and Federal Republic of Germany (approximately 22%) (Figure 6) [10-15].

5. CONCLUSIONS

In wind and solar energy, the high potential, environmental concerns and incentives applied by countries increased the investments on a global scale. Instant change of wind and solar data also affects the formulas used for energy and cost calculations. It is very important to analyze the feasibility studies correctly because the investment prices for these resources are very high.

In order to make correct and timely renewable investment decisions, it is important to examine price formations and make future analyzes.

The prices of solar photovoltaics module have dropped almost 90% since 2009 year. In 2018 year, solar module prices in Europe were between USD 0.22 US Dollar/W (modules with low cost) and 0.42 US Dollar/W (black modules). Between 2010 and 2013, the prices in solar modules dropped quickly, also average prices by country proceeded to drop until 2018 year, with reductions between 34% and 61% for large (gigawatt) scale markets (Table 1).

In solar photovoltaic investments, a sharp cost decrease was observed between 2010 and 2012. However, a sharp cost reduction is not expected in the next 5 or 6 years period. On the other hand, it can be thought that the CSP investment costs in the next years will show a variable trend apart from the capacity factor.

There is a linear relationship between the total cost and the capacity factor of onshore wind power plants. However, there is a completely opposite situation in offshore power plants. Because the investment priorities of each country related to offshore wind power plants are different and there are many criteria in determining the costs of these technologies.

Between 2010 and 2018, almost all leading wind markets in the world have seen a substantial growth in the capacity factor. Depending on the market, sales prices of wind turbine have declined by between to the level of 64% since their peak level in 2007 and 2010.

It is considered that wind and solar production costs will decrease further with the effect of technological development and competitive approaches.

Table 1. Renewable electricity costs on a global scale in 2018 year

Type of Power Plant	Weighted average cost of electricity (US Dollar/kWh)	Generation cost of electricity (US Dollar/kWh)	Change in the cost 2017-2018
Solar PV	0.085	0.058-0.219	-13%
CSP	0.185	0.109-0.272	-26%
Wind (Offshore)	0.127	0.102-0.198	-1%
Onshore Wind (Onshore)	0.056	0.044-0.100	-13%

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BIOGRAPHIES

Fazil Kaytez received his B.Sc. degree from Department of Electrical and Electronics Engineering, Faculty of Engineering and Architecture, Omer Halisdemir University, Nigde, Turkey in 2000. He received the M.Sc. and Ph.D. degrees from Department of Electrical and Electronics Engineering, Gazi University, Ankara, Turkey. He worked in different departments of many private and public companies such as Metropol Audit Co., TREDAS, BEDAS Ministry of Environment and Forestry, and EnerjiSA & Eon between 2002 and 2012. He is in the Energy Policies and Technology Department of the General Directorate of Energy Affairs, Ministry of Energy and Natural Resources. He is currently Co-Chair the Infrastructure and Sector Coupling Working Group at the German-Turkish Energy Forum. His research interests include electricity generation, transmission and distribution, high voltage engineering, electricity facilities, optimization in power plants, optimal design of renewable energy sources, machine learning and artificial intelligence algorithms, load forecasting algorithms, smart grid architectures, risk-based energy management, Power to X transformation technologies and electricity market configurations.

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