On the Wind Turbines Assessment by Real Options Technique in Israel

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***Abstract*— The limitation factor for using of the local energy resources in Israel is the persistent one that causes different economics participants to develop the 'green' technologies. The wind turbines installation constitutes undoubtedly an important trend of their efforts in this area. Many methods are elaborated for assessment of the investment projects in the industry and energetics. One of them, extensively applied to the investments evaluation, presents the standard discounted cash flow method, using the net present value criterion. Yet, this method is unsuitable for the fast altering investment environment, and for the consequent need of the managerial decisions flexibility. The technique of real options analysis is broadly used nowadays in many investment projects of renewable energy for their efficiency estimating. The current research develops the real options analysis facilities for evaluation of the wind turbines efficiency and profitability, as a part of the wind energy economic potential in Israel.**

Keywords-wind energy; energy market; renewable energy; investment decisions; real option analysis

I. INTRODUCTION

Nowadays, considering the Israeli energy market, even when such plentiful sources of traditional nonrenewable energy as the prominent gas fields discovered in the Mediterranean Sea off the coast of Israel: the Tamar [1] and the Leviathan [2] gas fields with the estimated stocks of 356 and 450 billion cubic meters respectively, - the perspective of their exhaustion still forces the state, as other numerous countries, to devote various efforts to the 'green' energy research and development. These efforts are undertaken primarily in the area of solar energy, but also last period in wind energy installations. Yet the wind power amount produced in Israel is diminutive comparing to the continuously growing world global market, however, the last steps undertaken by the state are designed to improve the situation.

Israel currently operates one wind farm in Asanyia Hill in the Golan Heights, with an installed capacity of 6 MW (10 turbines at a height 50 meters including blades, each with a capacity of 600 kW), consumption of about 5 thousand families. The duty cycle of the wind farm operating reaches 97%, and electricity selling consists 1 million US $ a year. Indeed, wind energy potential of Israel is restricted due to moderate- or poor-wind velocities' areas, and is limited to the areas with sufficiently high average wind speed, some of which are being opposed by green groups on landscape conservation grounds. Anyhow, in accordance with the Israel Ministry of Environmental Protection (IMEP) directions, the state continues efforts for the development of two more farms with a 50 MW capacity [3].

As it is emphasized in a document of the Israeli Knesset (Parliament), an improved estimate, based on the wind turbines' technological development, gives a value higher than 500 MW for the Israeli potential wind energy capacity [4].

The main goal of this paper is the study of the influence of energy price fluctuations on the assessment of the feasibility wind turbine installation using the real option analysis tool.

The economic output of wind turbine field is a function of its electric power output and market energy prices, when the electric power output is a function of the equipment used and wind velocity statistics.

The equipment can be chosen to have an optimal *cut-in speed* (the wind speed level at which the turbine begins to generate electricity), and the *cut-out speed* (the speed level at which the turbine hits its alternator limit and intermits to produce increased power output following increases in a wind speed) [5]. For a more detailed discussion, we refer the reader to results of our previous investigations of the wind energy use, devoted to the technical appropriateness and environmental relevance questions [6]-[9].

While the annual power output of the field can be known to a high certainty degree, the prices of energy may vary indeterminately, and thus should be considered as a prominent investment risk. To evaluate the influence of risk correctly we suggest the real option analysis which is the subject of this paper.

In this context, our purpose is to contribute to the way where, following Grossman's conception of risk allocation, "decentralized economy allocates risk and investment resources when information is dispersed" [10, p. 773].

Thus, in Section II, we describe the results of our preliminary statistic survey and the estimation results based on the investigated area's data. In Section III, we outline and apply the methods of the wind energy exploitation's estimation using the real options technique. Section IV is devoted to the analysis of energy prices' volatility in general and in Israel particularly. In Section V, we complete the use of the real options analysis for the wind turbines assessment in a case of high variability applying to the given data, and in Conclusion, we summarize the main obtained results.

II. STATISTIC ESTIMATION RESULTS

In the general framework of our research, we concentrated on the wind velocity distribution at the Golan Heights region, using the data of the Meteorological Service of the Israel Ministry of Transport and Road Safety [11], collected by the Merom Golan meteorological station, one of the 84 Israeli stations which is situated at the given area [12], for the 2014 year. The data include 52,066 observations during this period of time, the sample values of the wind speed, one observation for every 10 minutes, 144 values per day (except some non-significant missing values) [13].

We used the Weibull distribution function as the common accepted most appropriate function describing the wind speed statistical frequencies at a given location in most of the world. This information is essential for the planning of the wind turbine optimal configuration [6].

Generally, the Weibull probability distribution function (PDF) is defined, concerning a random variable of the wind speed *X*, by two parameters. They are a *shape parameter k* (dimensionless) and a *scale* parameter λ (m/s for the wind speed), which together determine the PDF form, as follows:

$$f(x;\lambda,k)=\begin{cases}\dfrac{k}{\lambda}\left(\dfrac{x}{\lambda}\right)^{k-1}e^{-\left(\frac{x}{\lambda}\right)^{k}}, & x\geq 0\\ 0\,, & x=0\end{cases}. \tag{1}$$

The PDF parameter values in (1) are significant for choosing the optimal location for the wind turbine, as well as for selecting most efficient turbine, which imply the wind farm efficiency [14].

For fitting the observed data of the given location to the PDF [15], we used the method of the maximum likelihood estimators [16]. The corresponding Weibull PDF for the wind speeds distribution at the Merom Golan site, together with their distribution histogram, is shown below in Figure 1.

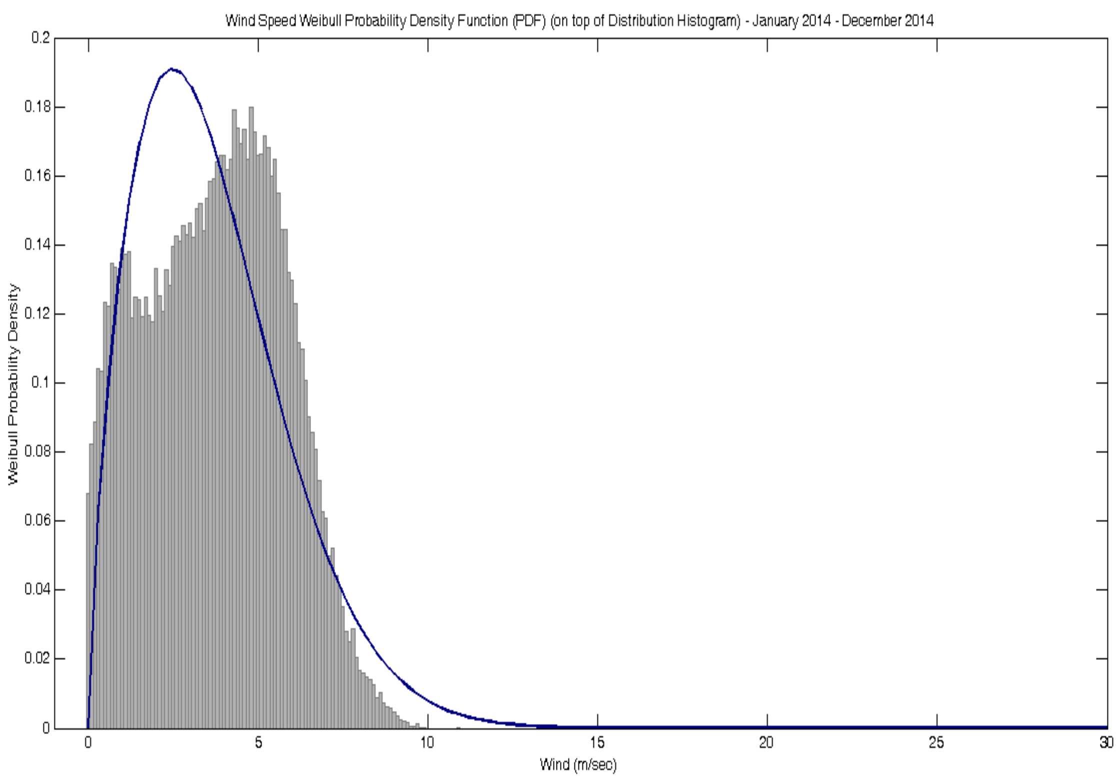

Figure 1. The Weibull PDF diagram for the Merom Golan wind speeds distribution (on top of distribution histogram).

The figure demonstrates visually that low and moderate winds are widespread, with a tight condensation at the primary segment, which means that storms are just rare. It should be noticed that the distribution approximation by a Weibull PDF in this case is not perfect, though we could however obtain approximately based on it, the wind principal statistical parameters.

Estimated annual parameters of the wind Weibull distribution were found to be: k =1.7228 and λ =4.1206 m/s. In addition we calculated (excess) kurtosis (a measure of the PDF sharpness) to be 2.1757, and skewness (a measure of the PDF asymmetry) as 0.0574, were calculated to demonstrate the specific type of the Weibull PDF.

The main meaningful statistical parameter for planning of the wind turbine installation, the speed mean, was obtained of 3.73 m/s, with Standard deviation of 2.03, during the given period, with a positive right-skewed tail. This finding, in accordance to the Israeli Cooperative for Renewable Energy conclusions [17], indicates the possibility of wind energy exploitation in the investigated region.

III. Using of the Real Options Analysis for the Wind Energy Exploitation's Estimation

While the standard discounted cash flow (DCF) method using the net present value (NPV) criterion is extensively adopted to evaluate investments, the standard DCF method is inappropriate for a rapidly changing investment climate (Dixit and Pindyck [18]; Herath and Park [19]; Lee and Shih [20]) and for the managerial flexibility in investment decisions (Hayes and Abernathy [21]; Hayes and Garvin [22]; Trigeorgis and Mason [23]; Trigeorgis [24]).

In recent years, the real options analysis technique is widely applied in many studies for valuation of renewable energy investment projects, for example Lee and Shih [20], Kumbaroğlu, Madlener and Demirel [25], Boomsma, Meade and Fleten [26], Menegaki [27]. Hence, we apply in this study the real options analysis approach for the valuation of wind energy turbines. In particular, we capture the value of the follow-on investment opportunities which add value to the investment.

We found in our study on the basic Black-Scholes model of a financial market [28], because we focus on the missing value of the option to abandon in an environment where it is impossible to estimate the standard deviation by the numerical tools.

We analyze in the current study the feasibility of installing an additional turbine field in the Asanyia Hill in the Golan Heights, in order to extract value from wind. We have partly based our investigation on the achieved results of the wind turbines construction and exploitation in Israel [29], while some of the numbers presented here are rough estimates. The decision to build the field which encompasses many turbines can be divided into two stages: in the 1st stage, we build one unit. After building and operating which may take few years, the 2nd decision on building the turbine field is taken based on electricity price at this stage.

We model the uncertainty over future electricity prices as a price of an underlying asset of a real option using Black-Scholes formula (2) as in [28]:

$$C = S_0\, N(d_1) - K\, e^{-rT} N(d_2)\,, \tag{2}$$

where

$$d_1 = \frac{\ln(S_0 / K) + (r + \sigma^2 / 2)T}{\sigma\sqrt{T}},$$
$$d_2 = \frac{\ln(S_0 / K) + (r - \sigma^2 / 2)T}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T}. \tag{3}$$

The notations in (2), (3) above are as follows:

C is the call option value, S_0 is the price of the underlying asset, K is the exercise price, r is the annual risk free return, T is the duration of the period (the number of years) till exercising the option, and σ is the annualized standard deviation (StD) of the return of the underlying asset. N stands for the normal distribution cumulative density function (CDF).

All the used figures were elaborated in accordance with a proposed scenario as in a Table I below, where the real figures can be introduced according to the data of each project (all costs are given in millions $US).

We apply here the technique of real option valuation as illustrated in Brealey et al. [30, p. 584], where we have replaced:

TABLE I. INPUT DATA FOR THE BLACK-SCHOLES OPTION VALUE CALCULATION

Data for the Black-Scholes Option Value	
Cost of the 1st stage's one turbine building	50
Annual turbine's profit in the 2nd stage	0.2
Present value of 50 turbines' profit over 20 years = Stock Price now (S_0)	114.7
Cost of the 2nd stage's for each turbine construction	1.2
Number of turbines in the 2nd stage (entire field)	50
Cost of the 2nd stage's 50 turbines building = Exercise Price of Option (K)	60
Number of Periods to Exercise in years (T)	2
Compounded Risk-Free Interest Rate (r)	0.02
Standard Deviation of prices of energy or electricity (annualized σ)	0.031

- the stock price with the current value of the field, S_0=114.7 million \$US, which is the present value of 20 years future operation with annual profit of 0.2 million \$US per turbine for a field of 50 turbines, discounted with 6% annual cost of capital;

- the number of periods to exercise in years (T) with the number of years between confirmation of 1st stage (one unit) to the decision on the 2nd stage (the field).

We have therefore calculated firstly the call value, based on the annual StD estimation of 0.031, as 57.05 million \$US. This StD estimation of 0.031 is based on the data of the Electric Power Monthly report of the U.S. Energy Information Administration (EIA), Table 5.3 "Average Retail Price of Electricity to Ultimate Customers" [31].

Our assumption of the 1st unit's building cost is equaled, as above mentioned, to 50 million \$US, where such high expenses of the first turbine's launching include, among others, research and development to adapt the turbine to the specific area under consideration and the cost of connecting it to the power grid, subtracted by the profit from operation.

Hence, the results indicate that the investment in the 1st turbine stage is warranted, and that there is the option to follow on, which adds significant value to the investment. It follows that the net profit of the 1st stage is 57.05-50 = 7.05 million \$US for the standard deviation value of 0.031, accordingly to the following data of a Table II (in a column for the StD = 0.031 case), which includes the intermediate values and the option to follow-on.

For comparison with a scenario lacking an option to abandon, the project value is estimated as the present discounted value of a difference between (i.e., the earnings from) the future cash flow raised from the 2nd stage realization subtracted by the 2nd stage building cost, which subtracted additionally by the 1st stage building cost.

Applying to our numerical example, this yields just the negative benefit, meaning merely loss, of the
$(114.7\text{-}60)/1.06^2 - 50 = -1.3$ million \$US.

However, using StD of 0.031 yields a profit of 7.05 million \$US, as was calculated above. This is so because one can make a choice to abandon the project in its midst. This is the economic meaning of the real option.

TABLE II. INTERMEDIATE AND OUTPUT DATA FOR THE BLACK-SCHOLES OPTION VALUE

Intermediate and Output Data		
StD	0.031	0.40
$\sigma\sqrt{T}$	0.0438	0.5657
d1	15.7146	1.4990
d2	15.6707	0.9333
Delta *N(d1)* Normal CDF	0.5123	0.9331
Value of the Call Option to Follow-On	**57.05**	**59.48**

IV. ESTIMATING THE VOLATILITY OF ENERGY PRICES

It is difficult to determine the direction and intensity of energy prices in the future. For example, the U.S. Energy Information Administration in its "Independent Statistics & Analysis" publication "The Availability and Price of Petroleum and Petroleum Products Produced in Countries other than Iran" states:

"The uncertainty on both the supply and demand side of the market could result in large future price movements [underlined by the authors]. The possible lifting of sanctions on Iran could move additional supply on to the world market and reduce prices, while an unexpected supply disruption at a time of low surplus production capacity may push prices higher" [32]. Such irregular fluctuations in supply and demand can be observed in the graph from this report in Figure 2, where the spread between production and consumption is widening since July 2014.

In addition to the world energy price uncertainty, there are at least four other sources for price uncertainty in Israel: (a) the possibility of military conflict; (b) the discovery of gas in Israel's shore; (c) the adoption of gas by the industry; For example, Foenicia – a glass manufacturer that was recently close to bankruptcy due to luck of gas turned to be a profitable [33]; and (d) the discovery of oil in the Golan Heights [34].

While it is still difficult with all these sources of uncertainty to determine the direction and intensity of the change of energy price, we must consider thus the possibility of high volatility in price. To this end, we will consider hereafter the possibility of high volatility taken to be StD=40% per annum.

V. USING OF THE REAL OPTIONS ANALYSIS FOR THE WIND ENERGY EXPLOITATION'S ESTIMATION WITH HIGH VOLATILITY

Calculating the call value, based on the annual StD estimation of 0.4, yields 59.48 million \$US (compared to 57.05 million \$US based on StD of 0.031).

It follows that the net profit of the 1st stage increased to 59.48-50 = 9.48 million \$US (see Table II, a column for the StD = 0.40 case).

It would be worth to notice here that the main statistical parameters of the wind speed at the Merom Golan area, the mean and StD, are observed with a tendency to stability, without any significant divergence over the period of last years 2009-2014, as it follows from the calculated at the Table III data.

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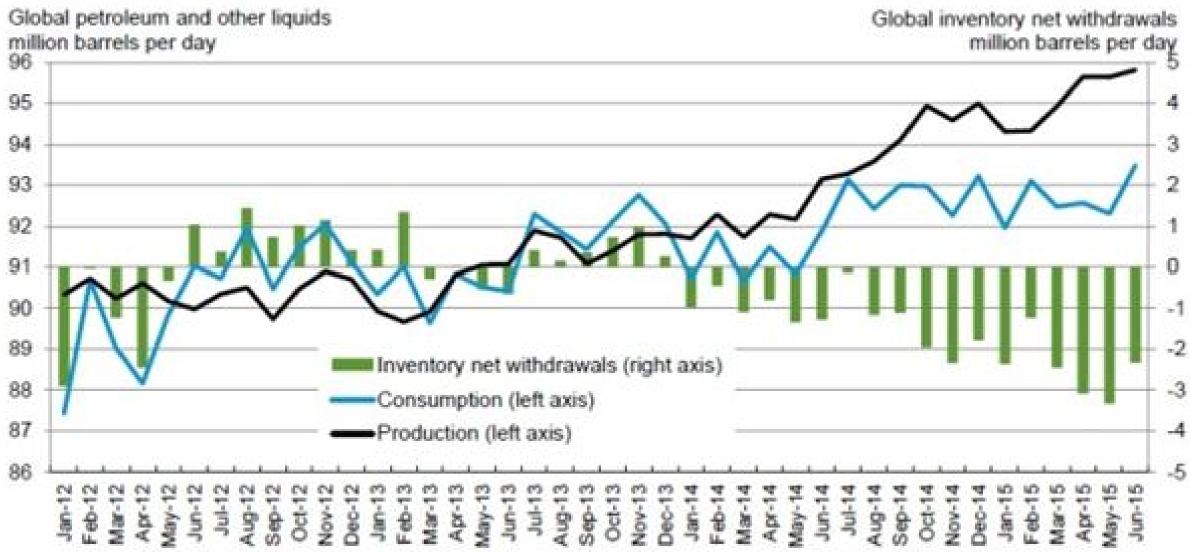

Figure 2. Global Petroleum and other Liquids Production, Consumption and Inventory Net Withdrawals, January 2012-June 2015 [32].

The expectation value of an annual average is the same as the expectation value for one sample but the standard deviation of the annual average is equal to the standard deviation of one sample divided by the square root of the annual number of samples. Thus, the standard deviation of the annual average of wind speed is between 0.6%-1.1% and can be further reduced by more sampling. A six year average based on 24327 samples will be 3.72 m/s with only 0.4% standard deviation.

The standard deviation of average power for all turbines investigated is much lower than the mentioned above standard deviations. Hence, a long term project can ignore the risk connected with the standard deviation of wind speed.

This circumstance determines the fact of non-relevancy of the speed variance, during prolonged period of time, for the wind turbine economic value; this should be compared to the significance of the energy prices for the turbine economic value.

TABLE III. WIND SPEED MEAN AND STD AT MEROM GOLAN FOR THE LAST PERIOD

Year	2009	2010	2011	2012	2013	2014
Speed mean (m/s)	3.89	3.69	3.63	3.70	3.80	3.62
StD (m/s)	2.10	2.12	2.00	2.03	2.05	1.99
Number of Samples	2919	2920	2920	9774	2896	2898
StD/$\sqrt{n}$ (m/s)	0.039	0.039	0.037	0.021	0.038	0.037

VI. CONCLUSION

Traditional calculation for an uncertain cash flow applies just the expected values of the cash flow from the project without the possibility to abandon. Given our empirical assumptions, this yields a loss of 1.3 million $US instead of any profit, meaning the project becomes not worthwhile.

Contrariwise, applying the proposed real option analysis, which reveals the value of the option to abandon the 2nd stage running as well, we turn the project just to become profitable and worthwhile. The value of the real option increases depending volatility to be either 57.05 million $US or 59.50 million $US depending on future volatility, and the profit is either 7.05 million $US or 9.48 million $US, respectively.

REFERENCES

[1] "Tamar gas field," Wikipedia. Retrieved: May, 2016, from http://en.wikipedia.org/wiki/Tamar_gas_field.

[2] "Leviathan gas field," Wikipedia. Retrieved: May, 2016, from http://en.wikipedia.org/wiki/Leviathan_gas_field.

[3] "Renewable energy," Israel Ministry of Environmental Protection. [Electronic version]. Retrieved: April, 2016, from http://www.sviva.gov.il.

[4] O. Lotan, "Wind energy power generation," Background paper, 21.09.05 (in Hebrew). Jerusalem: Knesset, Research and Information Center, 2005.

[5] P. Gray and L. Johnson (1985). Wind Energy System. Upper Saddle River, NJ: Prentice Hall, 1985.

[6] M. Byalsky and A. Yahalom, "Modeling of the Wind Energy Use Efficiency", The 4th Annual International Conference on Qualitative and Quantitative Economics Research (QQE 2014), GSTF, Phuket, Thailand, 28-29th Apr., 2014, pp. 91-93.

[7] Y. Ditkovich, A. Kuperman, A. Yahalom, and M. Byalsky, "A Generalized Approach to Estimating Capacity Factor of Fixed Speed Wind Turbines", IEEE Transactions on Sustainable Energy (2012), Vol. 3 (3), pp. 607-608, doi:10.1109/TSTE.2012.2187126.

[8] Y. Ditkovich, A. Kuperman, A. Yahalom, and M. Byalsky, "Site-Dependent Wind Turbine Performance Index",

International Journal of Renewable Energy Research (2013), Vol. 3 (3), pp. 592-594.

[9] Y. Ditkovich, A. Kuperman, A. Yahalom, and M. Byalsky, “Alternative Approach to Wind Turbine Performance Index Assessment”, Journal of Energy Engineering (2014), Vol. 140 (4), 06014001, pp. 1-4.

[10] S.J. Grossman, “Dynamic Asset Allocation and the Informational Efficiency of Markets”, The Journal of Finance (1995), Vol. 50 (3), pp. 773-787.

[11] “The Israel Meteorological Service Site”. Retrieved: May, 2016, from http://www.ims.gov.il/ims/all_tahazit/.

[12] “The Israel Meteorological Stations’ Characteristics”. Retrieved: May, 2016, from https://data.gov.il/sites/data.gov.il/files/metadata10minutesIMS7.XLSX.

[13] “The Government Information Data Bases’ Site”. Retrieved Retrieved: May, 2016, from https://data.gov.il/ims/7.

[14] “Weibull statistics,” Reliability Engineering. Retrieved: April, 2016, from http://www.weibull.nl/weibullstatistics.htm.

[15] P. Bhattacharya and R. Bhattacharjee, “A study on Weibull distribution for estimating the parameters”, Journal of Applied Quantitative Methods (2010), Vol. 5 (2), pp. 234-241.

[16] “Weibull Parameter Estimates”, MathWorks Documentation Center. [Electronic version]. Retrieved: May, 2016, from www.mathworks.com/help/toolbox/stats/wblfit.html.

[17] H. Levy, “Installation of small wind turbines for the electricity generation,” Israeli Cooperative for Renewable Energy (in Hebrew). [Electronic version]. Retrieved: May, 2016, from http://ecoop.org.il/index.php?option=com_content&view=article&id=88&Itemid=135.

[18] A.K. Dixit and R.S. Pindyck, “The options approach to capital investment”, Harv. Bus. (1995), Rev. 73 (3), pp. 105-115.

[19] H.S.B. Herath and C,S. Park, “Economic Analysis of R&D projects: an options approach”, Eng. Econ. (1999), Vol. 44 (1), pp. 1-35.

[20] Shun-Chung Lee and Li-Hsing Shih, “Renewable energy policy evaluation using real option model — The case of Taiwan,” Energy Economics (2010), Vol. 32, (S1), pp. 67-78.

[21] R.H. Hayes and W.J. Abernathy, “Managing our way to economic decline”, Harv. Bus. (1980) , Rev. 58 (4), pp. 67-77.

[22] R.H. Hayes and D. Garvin, “Managing as it tomorrow mattered”, Harv. Bus. (1982) , Rev. 60 (3), pp. 70-79.

[23] L. Trigeorgis and S.P. Mason, “Valuing managerial flexibility and strategy in resource”, Midl. Corp. Financ. J., (1987), Vol. 5 (1), pp. 14-21.

[24] L. Trigeorgis, “Real Option: Managerial Flexibility and Strategy, Resource Allocation”, 2nd ed., Parager Publisher, Westport, 1997.

[25] G. Kumbaroğlu, R. Madlener, and M. Demirel, “A real options evaluation model for the diffusion prospects of new renewable power generation technologies”, Energy Economics (2008), Vol. 30 (4), pp. 1882-1908.

[26] T.K. Boomsma, N. Meade, and S.-E. Fleten, "Renewable energy investments under different support schemes: A real options approach", European Journal of Operational Research (2012), Vol. 220 (1), pp. 225-237.

[27] A. Menegaki, "Valuation for renewable energy: a comparative review", Renewable and Sustainable Energy Reviews (2008), Vol. 12 (9), pp. 2422-2437.

[28] F. Black and M. Scholes, “The pricing of options and corporate liabilities,” The Journal of Political Economy (1973), Vol. 81 (3), pp. 637-654.

[29] “Wind Energy Golan” [Electronic version]. Retrieved: May, 2016, from http://www.wind-golan.com/.

[30] R. A. Brealey, S. C. Myers, and F. Allen. “Principles of corporate finance,” 10th ed., New York: McGraw-Hill/Irwin, 2011.

[31] "Electric Power Monthly Report of the U.S. Energy Information Administration (EIA)", Electricity. Retrieved: May, 2016, from http://www.eia.gov/electricity/?fm&t=epmt_5_03.

[32] ’The Availability and Price of Petroleum and Petroleum Products Produced in Countries Other Than Iran”. No. 23 in a series of reports required by section 1245(d)(4)(A) of the National Defense Authorization Act for Fiscal Year 2012. Retrieved: May, 2016, from http://www.eia.gov/analysis/requests/ndaa/pdf/ndaa.pdf.

[33] “Finally: Phoenicia factory from Nazareth Illit is connected to the natural gas” ,Globes, February, 3, 2015 (in Hebrew). Retrieved: May, 2016, from http://www.globes.co.il/news/article.aspx?did=1001006735.

[34] “Huge oil discovery on Golan Heights,” Globes October, 7, 2015. Retrieved: May, 2016, from http://www.globes.co.il/en/article-huge-oil-discovery-on-golan-heights-1001071698.

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