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Network Topology of Renewable Energy Sector in Stock Exchange

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ABSTRACT

In today's global economy, the most prominent position clean energy is basically viewed as the highest-speed growing branch. Sustainable energy, perpetual climate change, and technological advancements are the reasons from which this foreground position results from. Regarding the debate of effects of pollution and the importance of the alternative fuels, the more awareness people improve, the more interested they are to invest in clean energy. This paper brings to a focus the inspection of clean energy and the way any market would analysis the influential stocks which have an effect on the other. In this regard, correlation network approach has extensively applied to explore the financial markets properties. In econophysics, technical topology network is defined for analyzing the interaction between stocks to find significant implications to optimize the portfolio. Network topology shows the physical layout of a network. It refers to the way in which per stock is located and interconnected to other stocks. This study analyse the topological properties of network on a set of 62 stocks in renewable energy companies from 30th February 2015 to 3th March 2016 to aid to the interpretation of relationships in the network structure and find influencing stocks.

INTRODUCTION

A group of alternative markets, settled in varies industries like renewable energy, constitute the global financial system through which wide-ranging financial products are being traded. These markets are various and multiple, though; index movements are primarily toward the same economic report that reveals the corresponding, correlated characteristics (Andersen, et al., 2007; Balduzzi et a., 2001). This fact shows there are identical characteristics among financial time

series which may be correlated as well. Renewable energies play substantially a crucial in order to reinforce the Regional development policy.

On the basis of the renewal penetration, the principal obstacle is mainly high-up front costs and related inadequate cost effectiveness. Subsequently, this fact necessitates the introduction of financial support mechanism alongside with approving promotion scheme, to be specific the one that evokes private finance for energy sector and reduces the financial burden. Markets all around the world are indeed various members of a unit multiplex system (Bukarica and Vrhovcak, 2006; Nalan, Murat and Nuri, 2009). Consequently there is a need to highlight the analysis of structural interactions on a global based, indeed. This unit complex system is defined as a network. With regard to the investment theory and risk management, correlation among stock markets is the predominant factor which plays a paramount role with respect to the optimization problem in the Markowitz Portfolio Theory (Markowitz, 1952).

With reference to the paramount role of Network Analysis which provokes the representation of financial markets, the network topology essentially improves the understanding of structural. Stock markets have performed Innumerable analysis of stock markets (Mantegna, 1999; Bonanno et al., 2004; Coelho et al., 2007). Moreover, in accordance with the growth of renewable energy, multiple companies involved in these sectors have emerged. Their presence on stock exchanges worldwide has fueled the creation of indices that aims to track the performance of renewable, allowing us to analyze how this sector performs compared to other assets. However, the branch of the renewable energy has not been highlighted yet. Therefore, the present research considers the 62 renewable energy stocks from 30th February 2015 to 3th March 2016 to the analysis of the renewable energy exchange market by using network theory. This approach helps us to analyze the interaction between stocks and the performances of them that determine the level of importance to find significant implications in stock market structure.

1. RENEWABLE ENERGY SECTOR IN STOCK MARKET

Policy measures and financial supports extensively support the renewable energies in order to lessen the given expenses. On the basis of technological and infrastructural renovations, the cost of the reliable and abundant renewable energy, such as solar, wind, geothermal, hydropower, tidal energies, and biofuels, is basically going to be diminished. Unsustainable energy (coal and petroleum), demanding a greater and further effort of exploration, will be substantially costly and seriously hazardous regarding mining and drilling. Whereas, it only takes a minute that renewable energy leads to Carbon dioxide emissions. Climate changes, which actually caused by fossil fuel usage, have been essentially fortified in support of sustainable energy (Yanine et al., 2014).

Over the past decades, overall growth in the global economy has been expanded based on the sustainable energies (Katsaprakakis and Christakis, 2016; Lu et al., 2016; Rafindadi and Ozturk, 2016). As table (Bürer and Wüstenhagen, 2009) suggests, competent merchandiser and investors tend to view policy environments as the leading factor based on which technologies of clean energy may be supported (Boyer and Filion, 2007). Previous studies have illustrated the effects of energy and prices of stock markets, though the researchers do not identify any kind of substantial relationship between price and stock markets.

2. CORRELATION NETWORK CONSTRUCTION

The existence of the relationships among stocks as a complex structure is a known fact. Since the behavior of each stock in stock market are influenced by the others, the relationships among all stocks seems to be complicated system. The interrelationship or, equivalently, similarity among stocks is customarily measured by using Pearson correlation coefficient (PCC) among the logarithm of returns in which stocks are characterized by univariate time series of its price. Logarithmic vola-

tility refers to the changes of the logarithm of closing price $Z_i(t)$ at time t, which is defined by, $V_i(t) = \ln Z_i(t+1) - \ln Z_i(t)$, for $i = 1,2,\dots,p$(number of stocks).

Therefore, The correlation coefficient between the i-th log price of stock i ($V_i(t)$) and j-th log price of stock j ($V_j(t)$) is $r_{ij} = \frac{\sigma_{ij}}{\sqrt{\sigma_{ii}\,\sigma_{jj}}}$ for all $i,j = 1,2,\dots,p$ where the σ_{ij} is called covariance of stocks i and j. The level of linear association between stocks i and j, is quantified by the coefficient r_{ij}. Correlation coefficient r_{ij} for all stocks form a matrix C in which C is a 62-by-62 symmetric matrix. This correlation matrix plays a significant role since it shows the degree of interrelationship as the main source of economic information and it provides an overall conception of system's behavior. However, it cannot tell us anything which we would not in principle obtained readily from the large matrix C itself. Therefore, we initial need to transform the similarity into dissimilarity among all pairs of stocks by using the nonlinear mapping d_{ij}; $d_{ij} = \sqrt{2(1 - C_{ij})}$. The correlation structure by transforming the r_{ij} to appropriately defined distances d_{ij} form a distance matrix D or, equivalently, a weighted complete graph. The graph is considered as a network of 62 stocks. However, by concerning with all connections in the network, it would not be interpretable even for small networks. In this regard, a more applicable approach is Minimum Spanning Tree (MST) related to its aptitude in providing the meaningful information from network. MST is used to reduce and simplify this network from $62 * (62-1)/2$ connections of complete graph to only 61 connections. The MST constructs the network topology of 62 stocks which is determined by Kruskal's algorithm.

The information contained in MST is summarized by using centrality measures (Borgatti, 2005). From network analysis view point, the importance of per stock can be determined in terms of a measures of centrality to provide the result of role played for each specific stock. Centrality measure is known as a fundamental concept in the network analysis and help us to find the influential stocks in the network (Espino and Hoyos, 2010) as recommended by Borgatti (2005; Sieczka and Hołyst, 2009). In the area of centrality measure, many interesting research issues are investigated. Borgatti et al. (2006) explored robustness of betweenness centrality measure in random graphs. To the aid of interpretation of information contained in network, we conduct analysis based on betweenness centrality measure formulated in (Ibid.) which is defined based on shortest paths. This measure is useful to know the importance and influence of particular stock relevant to the other stocks (Ibid.).

3. DATA COLLECTION

As a case study of renewable energy sector, 62 popular companies in the stock markets are chosen in terms of some information provided in websites (http://www.renewable-energy-industry.com/stocks and http://www.investorideas.com/Companies/RenewableEnergy).

The historical data collection of the stock price are taken from http://finance.yahoo.com based on the daily close price of stocks for the period of 30th February 2015 to 3th March 2016. Table 1 shows a set of 62 stocks, corresponding sectors and regions.

Table 1. A set of 62 stocks in renewable energy and corresponding stock symbols, sectors and regions

#	*Company and Symbol*	*Sector*	*Region*
1	Acciona, S.A. (ACXIF)	General	Americas
2	ALEO SOLAR(AEORF)	Solar	Americas
3	Alterra Power Corp. (MGMXF)	General	Europe

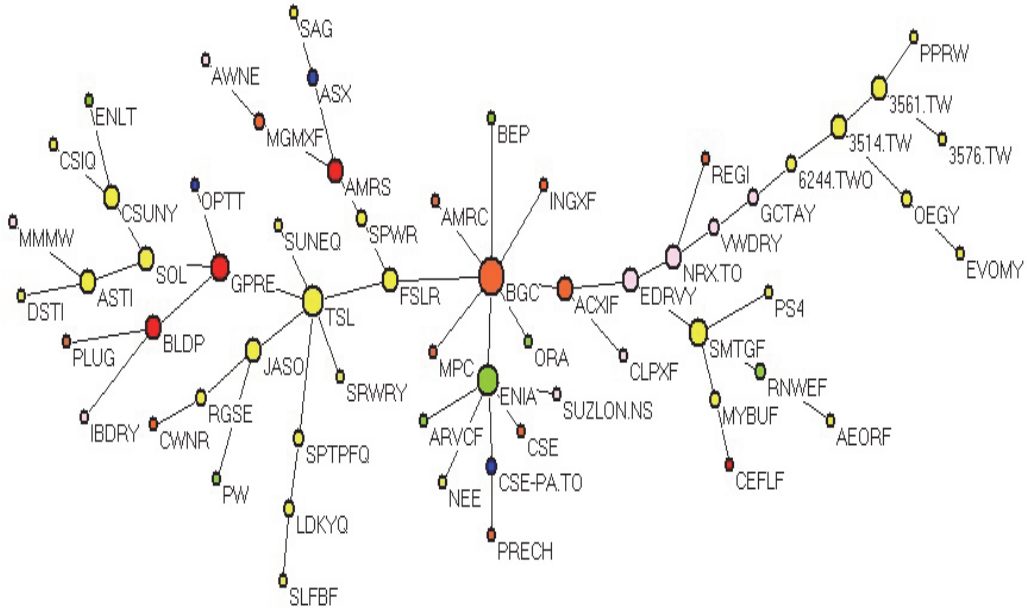
4	Ameresco, Inc. (AMRC)	General	Americas
5	Americas Wind Energy Corporation (AWNE)	Wind	Asia
6	Amyris, Inc. (AMRS)	Fuel cell	Americas
7	APPLIED SOLAR, INC. (OEGY)	Solar	Europe
8	AREVA SA (ARVCF)	Nuclear & Renewable energy	Americas
9	Ascent Solar Technologies, Inc. (ASTI)	Solar	Australia
10	Ballard Power Systems Inc. (BLDP)	Fuel Cell	Australia
11	Brookfield Renewable Partners L.P. (BEP)	Hydroelectric, Solar& Wind	Asia
12	Canadian Solar Inc. (CSIQ)	Solar	Americas
13	Capstone Infrastructure Corp (CSE)	General	Asia
14	CAPSTONE INFRASTRUCTURE CORP PR (CSE-PA.TO)	Wave	Asia
15	Ceramic Fuel Cells Limited (CEFLF)	Fuel Cell	Asia
16	China Longyuan Power Group Corporation Limited (CLPXF)	Wind	Australia
17	China Sunergy Co., Ltd. (CSUNY)	Solar	Europe
18	Crosswind Renewable Energy Corp. (CWNR)	General	Americas
19	DAYSTAR TECHNOLOGIES INC (DSTI)	Solar	Americas
20	EDP RENOVAVEIS ADR (EDRVY)	Wind	Asia
21	Enel Américas S.A. (ENIA)	Electric power	Americas
22	Enlight Renewable Energy Ltd (ENLT)	Solar and Wind	Americas
23	ENVIROMISSION LTD SP (EVOMY)	Solar	Asia
24	First Solar, Inc. (FSLR)	Solar	Asia
25	Gamesa Corporacion Tecnologica (GCTAY)	Wind	Asia
26	General Cable Corporation (BGC)	General	Australia
27	Gintech Energy Corporation (3514.TW)	Solar	Europe
28	Green Plains Inc. (GPRE)	Fuel Cell	Europe
29	Iberdrola, S.A. (IBDRY)	Wind	Americas
30	Innergex Renewable Energy Inc. (INGXF)	General	Americas
31	JA Solar Holdings Co., Ltd. (JASO)	Solar	Europe
32	LDK Solar Co., Ltd. (LDKYQ)	Solar	Europe
33	Mass Megawatts Wind Power Inc. (MMMW)	Wind	Americas
34	Meyer Burger Technology AG (MYBUF)	Solar	Europe
35	Motech Industries, Inc. (6244.TWO)	Solar	Europe
36	Muenchmeyer Petersen Capital AG (MPC)	General	Europe
37	Neo Solar Power Corp (3576.TW)	Solar	Europe
38	NextEra Energy, Inc. (NEE)	Solar	Australia
39	Norex Exploration Services Inc. (NRX.TO)	Wind	Americas
40	Ocean Power Technologies, Inc. (OPTT)	Wave	Asia
41	Ormat Technologies, Inc. (ORA)	Geothermal	Asia
42	Phoenix Solar AG (PS4)	Solar	Europe
43	Plug Power Inc. (PLUG)	hydrogen and fuel cell	Asia
44	Power REIT (PW)	General	Americas
45	Premier Power Renewable Energy, Inc. (PPRW)	Solar	Europe
46	Real Goods Solar, Inc. (RGSE)	Solar	Americas
47	REC Silicon ASA (RNWEF)	Solar & Electronic	Americas
48	ReneSola Ltd (SOL)	Solar	Europe
49	Renewable Energy Group, Inc. (REGI)	General	Americas
50	Renewable Energy Holdings Corp. (PREHC)	General	Americas
51	SAG Solarstrom AG (SAG)	Solar	Americas
52	SMA Solar Technology AG (SMTGF)	Solar	Americas
53	Solar-Fabrik AG (SLFBF)	Solar	Americas
54	Solartech Energy Corp (3561.TW)	Solar	Americas
55	SolarWorld Aktiengesellschaft (SRWRY)	Solar	Americas
56	Solco Limited (ASX)	Solar	Europe
57	SunEdison, Inc. (SUNEQ)	Solar	Europe
58	SunPower Corporation (SPWR)	Solar	Europe
59	Suntech Power Holdings Co Ltd (STPFQ)	Solar	Americas
60	Suzlon Energy Limited (SUZLON.NS)	Wind	Americas
61	Trina Solar Ltd (TSL)	Solar	Europe
62	Vestas Wind Systems ADR (VWDRY)	Wind	Asia

4. TOPOLOGICAL ANALYSIS

To elaborate the findings more clearly, based on the MST, we present its network topology in order to analyze the topological properties with respect to degree of connections. The degree of connection for node k refers to the adjacency matrix. The adjacency matrix A_{ij} of network (C) is a symmetric matrix consists of 62×62 elements of 0 and 1. $a_{ij} = 1$ indicates the existence of relationship between a pair of i and j stocks in MST.

We use Pajek software to visualize the topological network in the form of graphical representation (De Nooy et al., 2011; Batagelj and Mrvar, 2004). It helps us to understand the complex network in a simple structure. Figure 1 shows the correlation–based MST for a set of 62 renewable energy stocks in which size of nodes is based on degree of connections. Each stock is labeled by its symbol and colored by its corresponding sector include solar (yellow), general (orange), wind (red), wave (blue) electric power which is the main source of the other stocks (green).

Figure 1. The topological network of 62 renewable energy stocks



This section discusses the results of topological network analysis obtained by using centrality measures. Betweenness stock-level centrality measure capture the interaction between the stocks of the network. In this network, General Cable Corporation (BGC) with highest score of betweenness centrality measure (0.662) and 8 links is located in central position. BGC has directly relationship and influence to First Solar, Inc. (FSLR), Ameresco, Inc. (AMRC), Brookfield Renewable Partners L.P. (BEP), Innergex Renewable Energy Inc. (INGXF), Muenchmeyer Petersen Capital AG (MPC), Enel Américas S.A. (ENIA), Ormat Technologies, Inc. (ORA) and Acciona, S.A. (ACXIF).

After BGC in general sector, FSLR and Trina Solar Ltd (TSL) in solar sector play important roles in network. This MST shows the situation where the FSLR and TSL are dominated by BGC. In terms of centrality also Acciona, S.A. (ACXIF) and EDP RENOVAVEIS ADR (EDRVY) have the highest scores, respectively. Therefore, the most influential and dominant stock in renewable energy is General Cable Corporation. The top five stocks based on betweennees centrality measure score are classified in Table 2.

Table 2. most important stocks and centrality measures

Symbol	*Stock*	*Degree of connections*	*Betweenness*
BGC	General Cable Corporation	8	0.662
FSLR	First Solar, Inc.	3	0.577
TSL	Trina Solar Ltd	6	0.532
ACXIF	Acciona, S.A.	3	0.446
EDRVY	EDP RENOVAVEIS ADR	3	0.445

Figure 2 shows the number of stocks in each sector. From 62 companies of renewable energy, solar with 28, general with 11 and wave with 9 companies have the highest rank among other sectors, respectively. In Figure 3, the number of regional stocks are classified. As can be seen, America with 28 and Europe with 21 have the most companies of renewable energy sector in the world.

Figure 2. Companies' distribution for each sector region

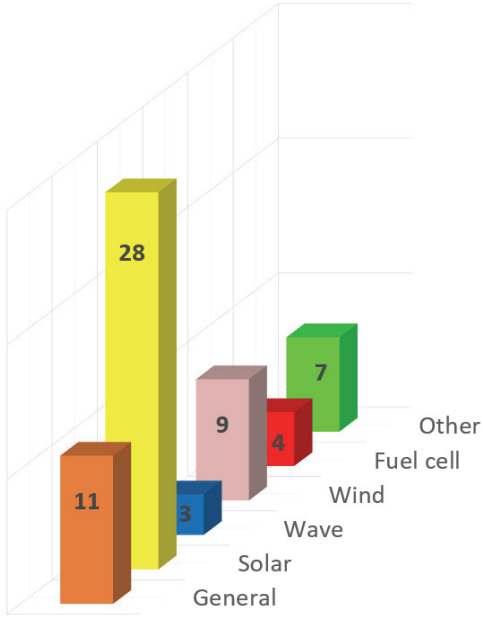
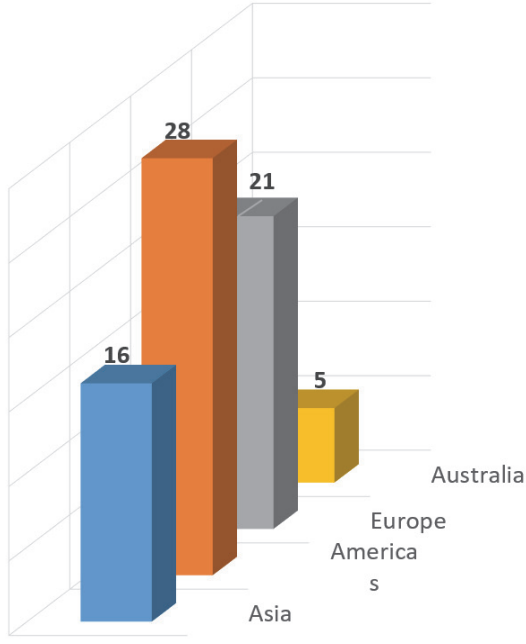


Figure 3. Companies' distribution for each



5. CONCLUDING REMARKS

However, in todays' world the growth of global economic has peaked while environmental pollution and the crisis of energy deficiency will surely broaden the burgeoning problem. In case the dispute has not been managed efficiently, it would influence the human beings' lives in such a way that any human community will not support the sustainable developmental issue which have an effect on their living quality, moreover. Thereupon, taking serious issues of energy and environment into account and accelerating the renewable energy sources may be considered quite compelling.

The stock market considered as an extremely complex network of the relationships between time series of stock price therefore, they are particularly worth of analysis. The purpose of this re-

search is to examine the 62 major stocks behaviour in stock market and find affecting stocks associated with renewable energy sector. In order to determine the most influential stocks, this research considered the similarity measure among stocks by using Pearson correlation coefficient. After that, the network visually constructs the interaction among stocks, which is extracted a topological influence map for stocks by the MST. We discussed the results obtained from topological network analysis by using centrality measures. These measures are useful to know the importance and influence of particular stock relevant to the other stocks. Based on those findings, study can conclude that the most influential stocks are General Cable Corporation (BGC) from general sector, First Solar. Inc and Trina Solar from solar sector in renewable energy stock market.

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