Analysis of Generations of Wind Power Technologies Based on Technology Life Cycle Approach

M. Dehghani Madavar[1], *M.H. Ghodousi Nezhad*[1],
Alireza Aslani[1,2] *and Marja Naaranoja*[2]
[1]Department of Renewable Energy,
Faculty of New Sciences and Technologies, University of Tehran
[2]Department of Industrial Management,
Faculty of Technology, University of Vaasa, Finland

ABSTRACT

Utilization of renewable energy technologies is one of the strategies of the governments in order to increase the level of energy security. One of the main renewable energy resources with fast utilization growth is wind power. However, development of wind power is highly depended on its related technolog°ies. Therefore, wind power technology forecasting is an indispensable requirement to understand how each of the wind energy domains will improve in the future. This research is to focus on the analysis of wind power technologies based on the technology life cycle approach. The contributions can help researchers, technology futurists, and policy makers to focus better on the related R&D and utilization policies.

Key words: Wind power, Technology Life Cycle, Forecasting, Patent

INTRODUCTION

Fossil fuel along with increasing global challenges of climate change has increased the importance of renewable and domestic energy sources. One of the main renewable energy sources is wind power. Wind energy is driven by one of the fastest growing technologies generating electricity, charging batteries, pumping water, and grinding grain. Wind power technology forecasting is an indispensable requirement to understand how each of the wind energy domains will improve in the future.

This helps policy makers and researchers to focus better on the policy and researches in this field. However, it is rather challenging to forecast emerging technologies as there is not historical data available. In such cases, the use of patent analysis has provided useful data. Patents provide one of the most significant ways to enhance competitive strategy of enterprise's business concept and technology strategy. Patent statistics are used as indicators of the inventive activity of companies, industries and countries. Increasingly researchers in technology management are using patent citations as an indicator of companies' innovation performance and the measurement of knowledge flows or spillovers. Monitoring of patenting activities helps identify the status of a technology in its life cycle; and determine competitive or collaborative relations among companies in certain areas, which provides valuable information to develop strategies of R&D and marketing activities. Technology life cycle (TLC) predicts the direction and rate of technology change, and thus, facilitates decision-making process to reduce the risks of technology development.

This research focuses on patent analysis of wind power technologies based on TLC approach. First, basic concepts of renewable energy and wind energy technology are reviewed in the sections 2.1 and 2.2. Then, a brief literature review about technology management and patent analysis is presented in the sections 2.3 to 2.5. A review of previous researches in this area is presented in the section 2.6. Technical concepts of onshore and offshore wind energy technologies are covered in the section 2.7. The methodology of the research is presented in the section 3. Finally, results and analytical data of the research are presented thoroughly.

LITERATURE REVIEW

Importance of Renewable Energy Utilization

Through the recent decades, and due to the highly-increased economic growth of world and consequently the growing need for energy, there have been numerous reasons for countries to develop the technologies related to renewable energies and broadening the share of RE based energy production, including improving the energy security, increasing the variety of sources in energy supply chain, reducing the greenhouse gases emission, reducing the dependency on fossil fuels, lowering the environmental impacts of energy harvesting and consuming, etc.

The very first sparks led to paying more attention to renewable energies (REs) was after the 1970s oil crisis followed by eight-year war of two major oil exporting countries in 1980s, i.e. Iran and Iraq. The tendency to renewable energies extremely descended as the oil prices decreased highly in 1990s. By the 21st century starting with war on Iraq in 2003 and global catastrophic economic breakdown in 2008, many countries were again persuaded to develop RE-based energy production.

Renewable energies are more compatible with sustainable development than fossil fuels. The main sources of REs in the business levels solar, wind, geothermal, biomass, and hydropower. They are green, job-generating, inexhaustible and indigenous sources of energy, which are often free and just need an effective method to be harvested. Due to technology improvements and market penetration, renewable energies are rapidly evolving. Moreover, fossil fuel resources are limited while renewable energies are abundant, so that in future, there would be an increase in costs of fossil fuels as well as a decrease in renewable energies costs. These respective upward and downward cost trajectories will lead to the convergence of price of renewable and conventional generation in future[1-3]. Historical data, recorded by credible energy agencies, seal this fact. The U.S. Energy Information Administration (EIA) estimates that the share of renewable energies in world marketed energy consumption is about 11% today with an estimation of 15% by 2040. EIA estimates that about 21% of world electricity generation was from renewable energy in 2011, with a projection for nearly 25% in 2040[4].

Wind Energy Technology

Wind energy is one of the most competitive and high potential energies that can be a good alternative for conventional energy production methods. Wind energy is one of fastest-growing energy sources, as the world overall wind energy installed capacity had extended more than five-fold, between the years 2000 to 2007, which is a great rate of growth[5]. This significant growth has been continued within the following years and even intensified, as the world installed capacity has been increased from less than 50GW to more than 250GW, from 2004 to 2012[6]. It is represented in Figure 3, as the Global Wind Energy Council reports [7]. This impressive rate of growth can be likely a result of technological improvements in the area of wind turbines in the recent decades. Although wind energy is not a new source of energy and has been used by human for centuries, but the recent advances in technology of wind turbines and plants, carried out by leading countries and companies, has led to expanding its application. Patents, as stated previously, are one of the most prominent indicators of technological growth in a specific area. Technological improvements and patent applications are inseparable phenomena, therefore as the technologies related to wind turbines are developed, the associated patent applications increase. This fact is presented clearly in Figure 1, which illustrates the annual patent application of wind turbines up to end of 2014.

Wind energy conversion system is comprised of several subsystems, among which the wind turbine is the most prominent part[8]. Wind turbine technologies can be broken into several categories, considering different aspects of its operating procedure, including horizontal-axis wind turbines (HAWT), versus vertical-axis wind turbines (VAWT), fixed-speed versus variable-speed turbines and stall versus pitch aerodynamic control of blades[6]. Meanwhile, as a result of technological improvements leading to development of offshore wind farms, a new classification has been established in the area of wind technology. While onshore wind farms have been the conventional approach for harvesting wind power, offshore wind farms emerged in early 1990s, providing some new advantages in wind-based energy production.

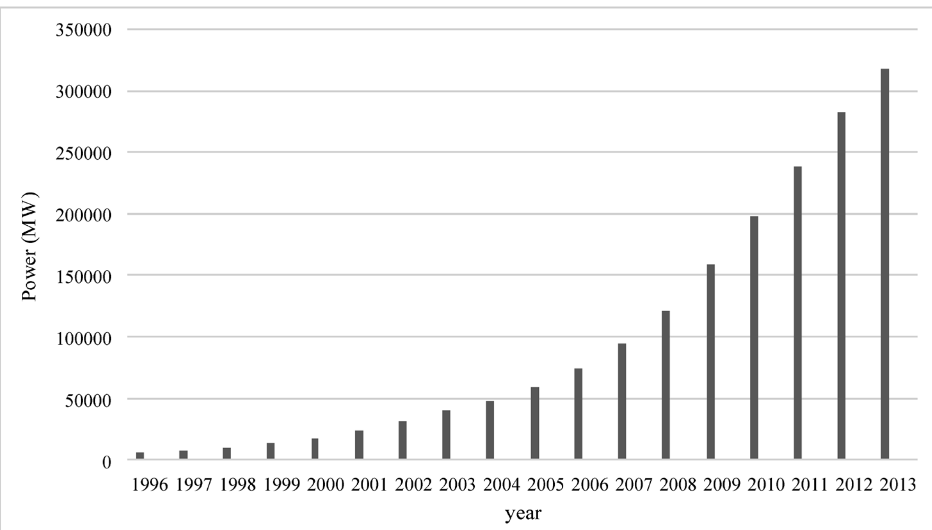

Figure 1. Global cumulative installed wind capacity 1996-2013 [7]

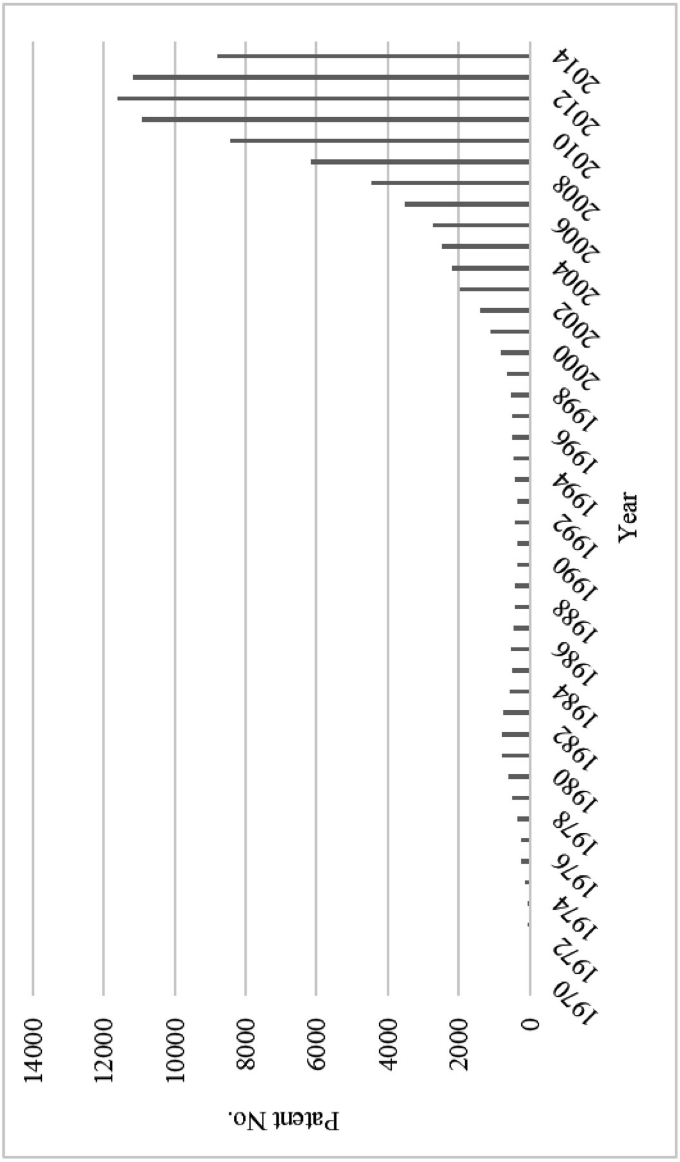

Figure 2. Wind energy technology patent application trend.

Technology Management

Today, companies are increasingly trying to increase their competitive advantages compared with competitors in the markets. One of the key approaches utilized by companies is Management of Technology. Management of Technology (MOT) involves a wide range of disciplinary including engineering, management, different branches of sciences, etc.[9]. In other words, MOT has an interdisciplinary nature, as illustrated in the Figure 3. The main objective of MOT is to maximize the R&D and innovation activities to commercial markets for companies[10].

Technological development and innovation are inextricably intertwined and these two terms, finally, lead to the development of new products and services. In a competitive market, firms are highly under pressure to develop new products to response properly to the needs of costumers[11]. Moreover, new product development (NPD) plays an important role in building competitive advantage and can be a significant factor for a firm's economic growth and profitability[12]. Hence, efforts in NPD would lead to increasing the revenue of firms while broadening the range of welfare and prosperity in a society.

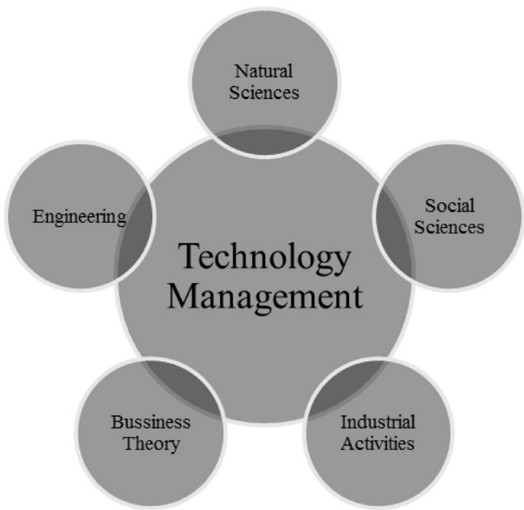

Figure 3. Interdisciplinary nature of technology management

Intellectual property is a key factor during the process of new product development to protect the R&D efforts and activities. It comprises of patents, registered designs, copyright law and trademarks[9], which all help the firms in many areas including being fast enough to compete in a fast-growing technological market, defending the self-designed products and concepts against illegal copying and counterfeiting, taking advantage of academic technologies, etc. Patents are generally known as the most common form of intellectual property and play a major role in technology commercialization. Considering efficiency issues and revenue objectives, firms are well interested in accessing new technologies as soon as possible after their invention[13]. Moreover, commercializing the technologies developed in universities by firms is increasingly growing[14]. Here, the prominent role of patents attracts significant attention and it can be said that patents are as linking chain of the technological knowledge and efforts and the market.

Patent Analysis

Since patents can provide exclusive rights and legal protection for the inventions of individuals and enterprises, they have an important role in the development of technology. Patents have been always analyzed in the R&D project management to estimate competitive position to avoid infringement. Patent analysis is used for extracting information about a specific industry or technology, which can be used in forecasting activities. Patent document analyzing is considered to assess various aspects of technological change. Most studies have used patent statistics as a tool for either studying the relationship between technological development and economic growth (Penrose, 1951[15]; Taylor and Silberston, 1973[16]), or to assess the research and innovation process in a national and international context (Bosworth, 1984[17]; Schiffel and Kitti, 1978[18]; Paci and Sassu, 1997[19]).

The rate of the patent growth generally follows a similar trend that can be similar to S-curve growth. In the early stages of a technology, the number of patents issued is very limited, next a fast-growing period follows when the number of field and issued patents increases and finally a plateau is reached. [20]

Technology Life Cycle

The attractiveness of a technology as an investment object depends on its life cycle stage. The technological life cycle (TLC) of patent applications over time generally follows a trend which resembles an S- curve growth. The S-curve, which is also known as the logistic curve, is helpful for estimating the level of technological growth at each stage in the life cycle to predict a specific technology. Figure 2 illustrates the S-curve of a technological life cycle. Corresponding to product life cycles we can differentiate emerging, growth, maturity, and saturation as technology life cycle stages.

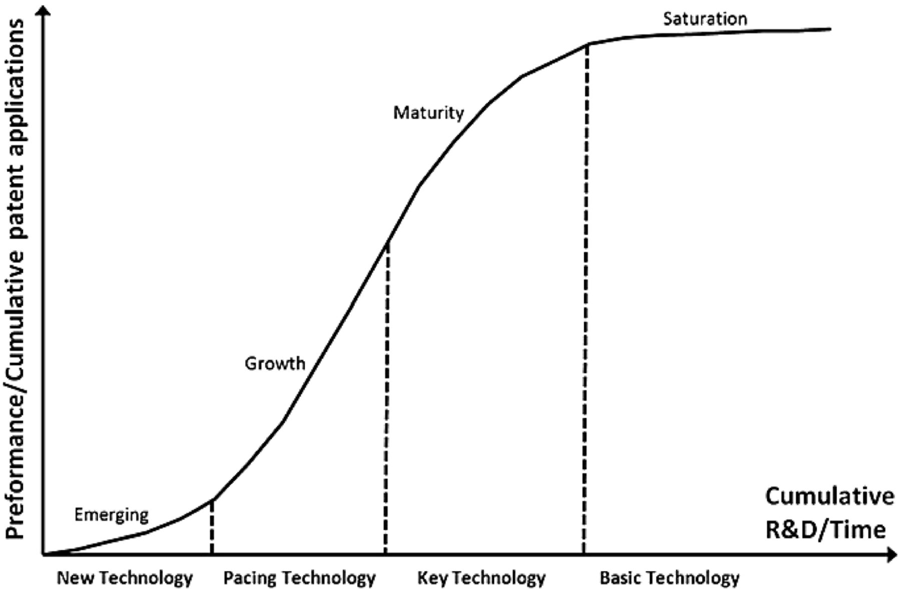

Figure 4. The S-curve of a technological life cycle

The first stage of the technological life cycle coincides with the emerging of the earliest, pioneering applications into the market. When it ever materializes, the demand does not show high growth rates in this stage, even though it is rapidly accelerating. Technological opportunities are very high. Next stage is characterized by sustained and highly accelerated market growth, while technological opportunities are still very high. In maturity stage the market grows once again, but at a considerably lower rate. Finally the saturate phase is marked by the exhaustion of the innovative potential of the technological trajectories and the contraction of the market, bringing the life cycle of the industry branch to a close.

Researches Related to Patent Analysis

Different researchers have worked on patent analysis of technologies related to wind energy. These researches have covered the subject from different aspects of view and have used various methods, techniques and approaches for patent analysis to provide a functional means of wind energy technology forecasting and a roadmap for future trends of this technology. Benson and Magee (2014) selected two leading renewable energies (solar PV and wind energy), as well as two methods of electricity storage (batteries and capacitors), to provide a comparative study of their rate of improvement in a quantitative approach. The approach was based on number of patents as well as energy generation and storage per unit costs in each domain[21]. Karvonen et al. (2012) considered some leading actors in wind energy technology such as VESTAS, REpower, Siemens Wind, GE energy, etc. and discussed their patent count as well as their financial performance in the market to analyze the emerging offshore wind power market technologies[22]. Again, Karvonen et al. (2012), considering the leading firms in wind power market, applied the technology cycle time (TCT) and its trend for each of these firms to measure their technological innovation progress[5]. Daim et al. (2012) applied the Patent Alert System (PAS) method and used two different variations of PAS, i.e. Linear Regression PAS and Fuzzy Logic PAS, to provide a comparative study of horizontal and vertical axis motor control trends[23]. Kapoor et al. (2012) used Data Envelopment Analysis (DEA) to measure the efficiency of leading firms in wind power market. Given the R&D expenditure of firms as input and different patent value indicators as output, the efficiency of each company was derived[24]. Dubaric et al. (2011) provided the patent application number and S-Curve for F03D class in patents classification which represents "wind motors"[25]. Liu Fengchau et al (2009) made a comparative analysis on regional distribution and technical distribution of patent application between VESTAS, GAMESA and GOLDWIND[26].

Onshore vs. Offshore; Technology Approach

As early as the industrial scale of energy production by wind energy emerged, large on-land wind farms have been the traditional method of wind energy harvesting. Onshore wind farms can be constructed easily and located near the energy grid or transmission lines. They also offer low maintenance costs. These reasons can be adequate to lead to the rapid growth of onshore wind farms through the last decades[8]. By the year 2007, wind energy achieved 1% of overall generated electricity, which almost all of that represented the onshore wind farms; because there were only 2000 MW offshore wind energy installed by 2009, which is a small share of wind energy capacity[27].

As the advantages of offshore wind farms stated within the 1990s, a strong tendency was formed gradually to shift the wind farm activities toward offshore[28]. Due to technological developments in offshore wind farms and various advantages than onshore, it is rapidly growing, as it reached from approximately 2000 MW in 2009 to 3000 MW in 2010, about 1.5% of worldwide wind capacity[29]. The increasing growth is shown in the Figure 5.

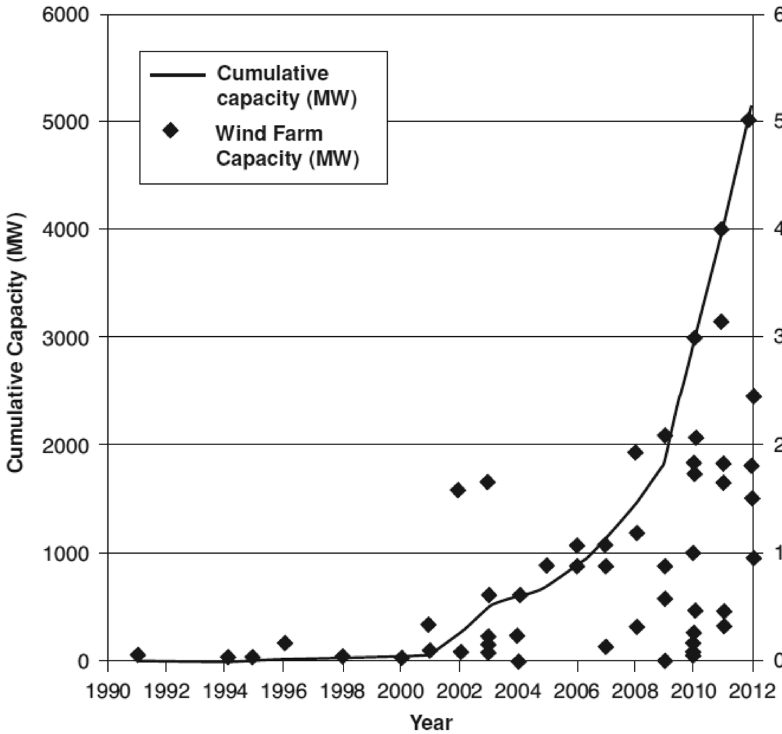

Figure 5. Global offshore wind capacity 1991-2012 [29]

There are different advantages of offshore versus onshore. One of the most important is lack of suitable wind resources on land[8]. On-land wind resources are mostly far from energy end-users, i.e. cities and residential areas, while coastal areas are often inhabited, offering a great potential of harvesting sea winds' energy for generating electricity and feeding the coastal areas and cities. On the other hand, in some countries, there are serious limitations on land usage for constructing onshore wind farms, which in turn stimulates the governments to develop offshore wind farms. UK government, for instance, has set a goal of 15-20 GW offshore wind capacity by 2020[29]. In Europe, Denmark and the UK possess the largest share in offshore constructed wind capacity and there are some operational but not constructed projects in the continent[30]. Another important reason is the preferable features of offshore wind, which is higher in speed and steadier in flow. Considering the wind velocity, for example, at a distance of 10-15 m away from the shore, wind speed is about 20-25% higher, resulting in higher energy production. More uniform breeze also leads to less turbulence, less consequent fatigue and finally increased lifetime of offshore wind turbine generator. Moreover, sea environment provides less wind shear due to its less roughness than lands, which leads to potential usage of shorter towers, on which the wind turbine is to be mounted[27, 28]. In addition to aforementioned facts, audible noises, visual impacts and aesthetic concerns are minimal, in offshore wind farms compared with onshore cases[8].

On the opposite side, there are some disadvantages for offshore wind farms that should essentially be addressed. These includes more expensive and complex foundations for towers, higher costs of grid integration, more difficult maintenance procedures due to limited access to facilities, and finally more expensive installation procedures of equipment due to tougher environmental situations[31].

Methodology

The methodology of this research is an applied research and a descriptive one. Figure 6 shows the research framework. The first step for mapping intellectual property landscape of any technology is to create a complete database of patents within the technological domain. This step is to extract a relevant and nearly complete set of patents in order to curve the life cycle of technology for technological domain. To identify relevant records in the database, CPC (Cooperative Patent Classification) symbols are used (Table 1).

According to the table, offshore and onshore towers are classified to classes Y02E 10/727 and Y02E 10/728 respectively. To identify a firm's technological domains, the observed CPC codes in the firm's patent records were identified and classified into technology fields representing the firm's major technological domains. Therefore, the keywords of the domain were searched and analyzed for the most representative to find related codes. The source of the patent data was the "Acclaimip online database"*. Acclaimip is a subscription-based patent search and analysis platform which offered as a "paid software-as-a-service (SaaS) product

Table 1. Cooperative Patent Classification (CPC) of Offshore and Onshore towers

Code	Definition
Y	General tagging of new technological developments; general tagging of cross-sectional technologies spanning over several sections of the IPC
Y02	Technologies or applications for mitigation or adaptation against climate change
Y02E	Reduction of Green House Gases emission, related to energy generation, transmission or distribution
Y02E10	Energy generation through renewable energy sources
Y02E10/70	Wind energy
Y02E10/727	Offshore towers
Y02E10/728	Onshore towers

and the platform allows users to search through the following patent data sets:

- US Patents
- US Applications
- Japanese Patent Abstracts
- World (PCT) Applications
- European Patents

All patents were collected in the period from 1970 to December 2014.

ANALYTICAL DATA

Onshore vs. Offshore; patent analysis approach

Since the initial data is in the form of raw data, the researchers plotted it in various forms of graphs to ease the analysis job. Each set of data and therefore each graph, is provided simultaneously for onshore and offshore wind turbines to enable a useful means of comparison.

Annual Count of Patents

The first and basic graph extracted from research data is clustered

*http://www.acclaimip.com/

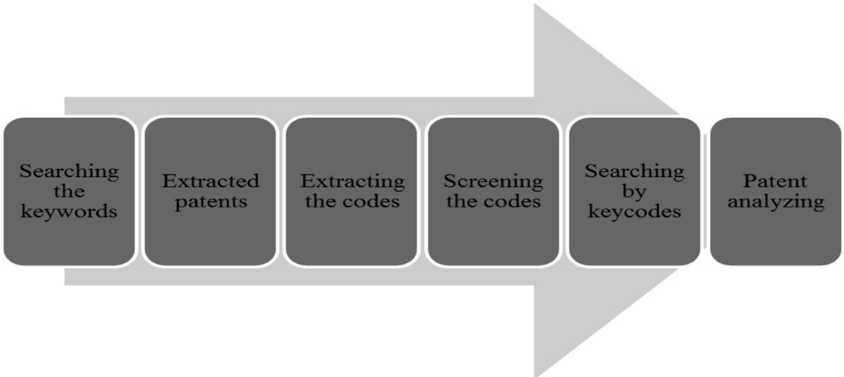

Figure 6. Research framework.

column chart of annual number of patents in both onshore and offshore technologies (Figure 7). The rising point of the chart in patenting numbers, which is mid 1970s for onshore while late 1990s for offshore, asserts the precedence of onshore technology.

Another important fact that can be extracted from these charts is the effects of world challenges and events on energy markets and so the patent activities. The clashes of 1973 in the Middle East and the later oil crisis led to increase in patenting activities of onshore technology, which was the only wind technology on that time, and intensified by 1979 revolution in Iran and Iran-Iraq war. As the oil prices decrease in late 1980s and 1990s, the number of patents stays in a low level in comparison with previous decade. This rising and falling clearly shows the inseparable relationship between oil prices and interests in renewable energies technological activities.

The golden era of wind energy technology as it obvious in Figure 7, is commenced by the beginning of 21st century. As the global awareness about renewable energies and impacts of fossil fuels on environment increased, there can be seen a considerable rise in onshore technology patents number starting by 1999-2000. Besides, the technological improvement in offshore technology during the 1990s has led to growth increasing in patenting on 2000s.

Due to the longer technology life of onshore turbines, the mean number of patents in offshore technology is about one-fourth of onshore which is reasonable. However by the advantages of offshore wind turbines and interests for offshore wind energy a potential rise in this technology is predicted.

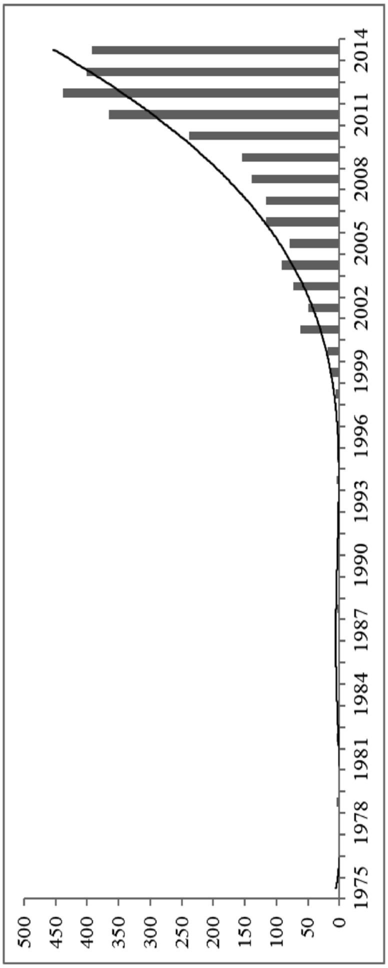

Figure 7. Temporal distribution of offshore patents

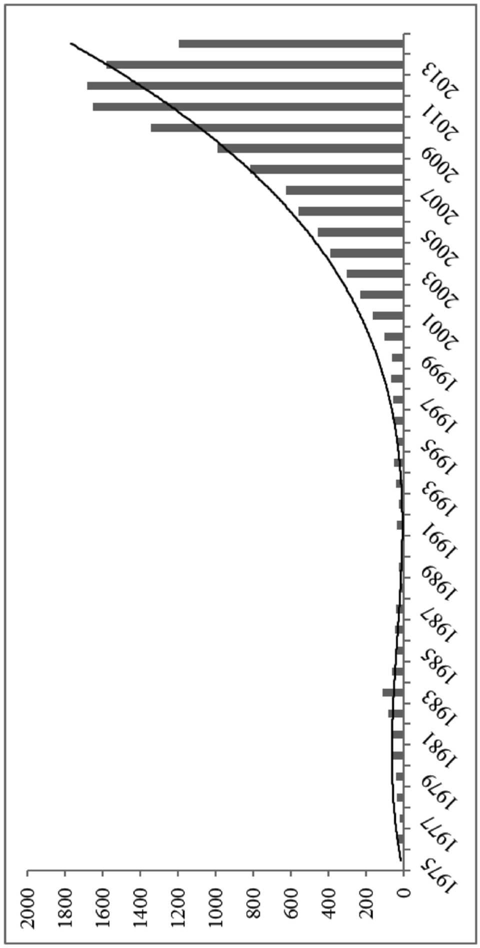

Figure 8. Temporal distribution of onshore patents

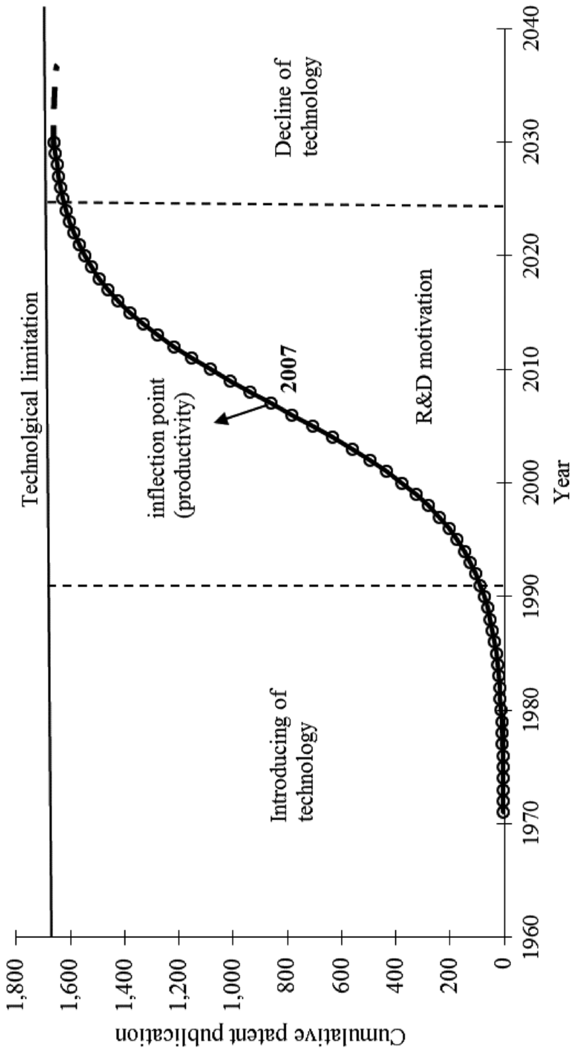

Figure 9. The growth curve of onshore technology

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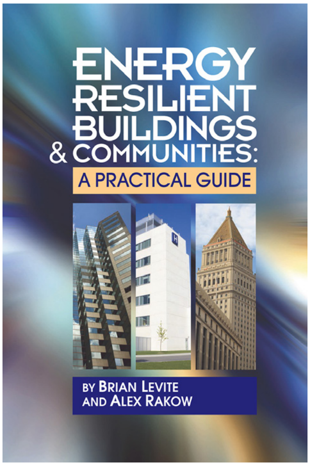
Brian Levite and Alexander Rakow



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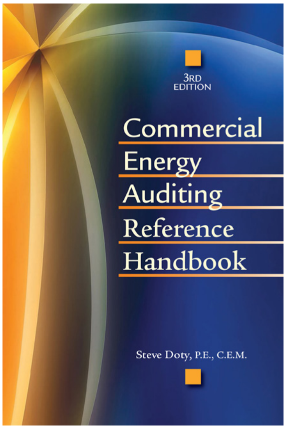

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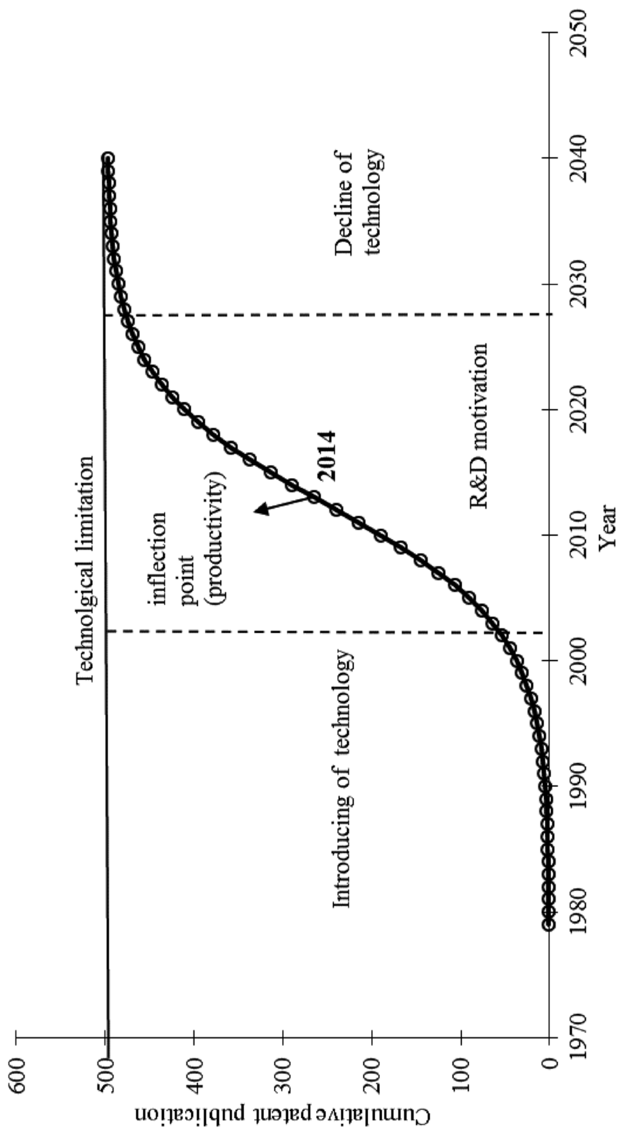

Figure 10. The growth curve of offshore technology

S-Curve

Given the annual count of patents, the s-curve for onshore and offshore technologies can be plotted. Figure 8 illustrates these s-curves.

Figure 8a shows the S-curve of onshore wind technology. Here we can see that this curve traces technological life cycle presented in Figure 2. According to the Figure 9, the onshore wind technology passed the inflection point that start productivity in this technology in 2007. Indeed, the figure shows that the onshore wind technology is being mature until 2025. Onshore wind already plays a leading role in the generation of renewable electricity that has the advantage of being one of the most affordable renewable energy sources. Onshore wind power has an impact on the environment chiefly in the forms of noise pollution, visual pollution and harm to birds [32].

In addition, the noise and visual pollution that may result from onshore wind turbines make a compelling case in favor of offshore wind turbines. It is likely that offshore wind power will increase more than onshore wind power because of the practicality and because of the space issues that many coastal areas face. On the other hand, the technological developments to make wind turbine production more efficient will continue to develop[33], perhaps eventually cancelling out the difference in environmental cost between onshore and offshore wind power. As it presented in Figure 8b, the inflection point of offshore technology s-curve is on 2014. The seven years delay between onshore & offshore technology is because of current estimates based partly on European experience since 1991, and offshore wind energy costs of under 6 cents per kWh. Offshore capital costs are around 30-50% higher than onshore, due to larger machine size and the costs of transporting and installing at sea. This is partially offset by higher energy yields as much as 30%. However, as happened onshore, these prices are expected to drop as technology improves and more experience is gained. Finally, the added efficiency of offshore wind power over onshore wind power result in an environmental cost that is roughly equal, and the added efficiency of floating wind turbines over those on offshore platforms result in an environmental cost that is essentially equal[34].

Leading Countries

Figure 9 shows the top ten countries in patenting by extracting the patents numbers by country. As shown in the figure, the countries in both on and offshore are the same except one. Norway owns the third place in offshore patenting, while it is replaced with China in onshore list at the fifth place. Comparing the countries with cumulative installed wind power provides the fact of the technological improved countries in the wind industry and patenting and installed capacity. Table 2 shows the leading countries in offshore and total installed capacity by 2014, as the GWEC reports[7], and their ranking in patenting activities. Due to the low share of offshore capacity in the total capacity, the onshore is corresponded with the total capacity. This may cause a slight change in the list.

As the Figure 11 and Table 2 shows, the two leading countries in technological and patenting activities are Germany and United States. The energy policy of United States has been formed by different factors including federal tax incentives, and national laws and acts. One of the most important acts, is the "Energy Independence and Security Act of 2007" which has a significant effect on U.S. Energy Policy[35, 36]. As a result, the American Wind Energy Association (AWEA) reports that the wind power capacity of U.S. has reached from about 4000 MW on 2001 to more than 60000 MW by 2014, which is a great growth. Renewable energy policy in Germany began in 1974 following the first oil crisis. Since then, Germany has been a leading country in EU and the world broadening renewable energies. Different incentives, such as feed-in law and tax breaks, low-interest loans to investors and facilitating state acts and plans (e.g. Renewable Energy Act (EEG) of 2001), have derived the German use of wind energy[35, 36]. All these together with technological advances of German companies have led to an impressive growth in German wind industry. The German Wind Energy Association, for instance, reports that the installed wind capacity of the country has increased from about 6000 MW in 2000 to more than 31000 MW in 2012[37].

Leading Firms

To have a better insight of wind turbines patent analysis, it is good to analyze the leading companies in patenting in this area of technology. With huge research and development expenditure and facilities, firms are the linking chain between the technology and the industry and market. In other words, successful firms are those that play an active role in commercialization of their technology. This can be done through patenting activities. Regarding wind power industry, there are some leading companies, mostly located in leading countries. This confirms that there

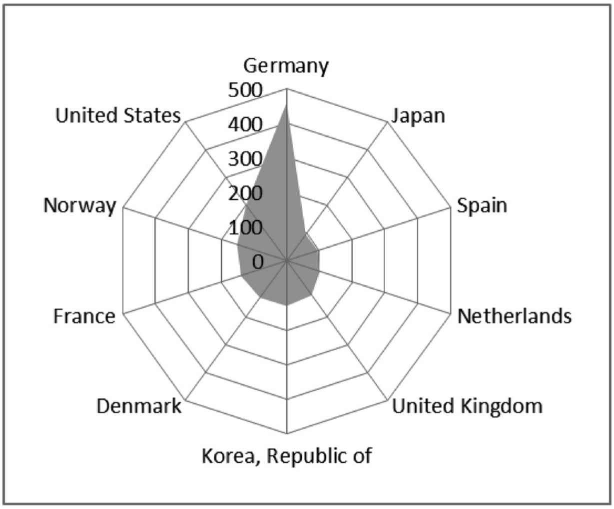

Figure 11. Leading Countries in offshore patent application

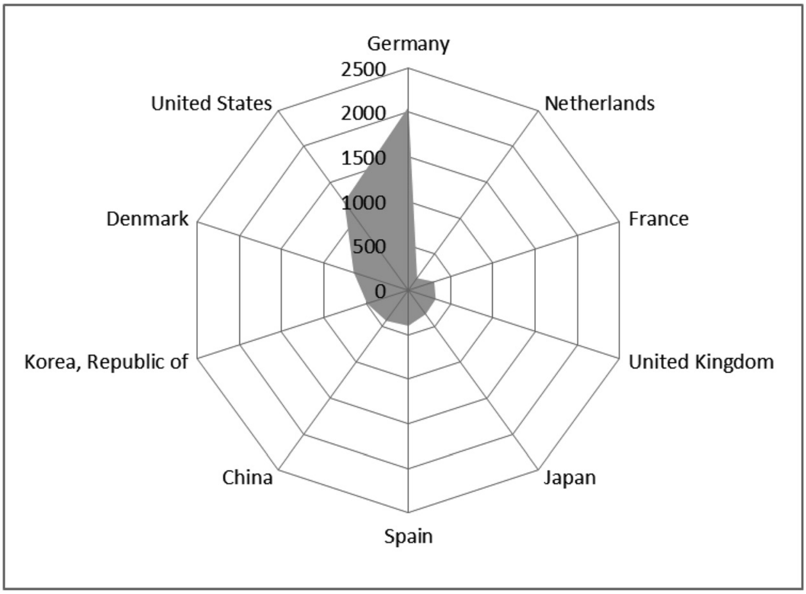

Figure 11. Leading Countries in offshore patent application

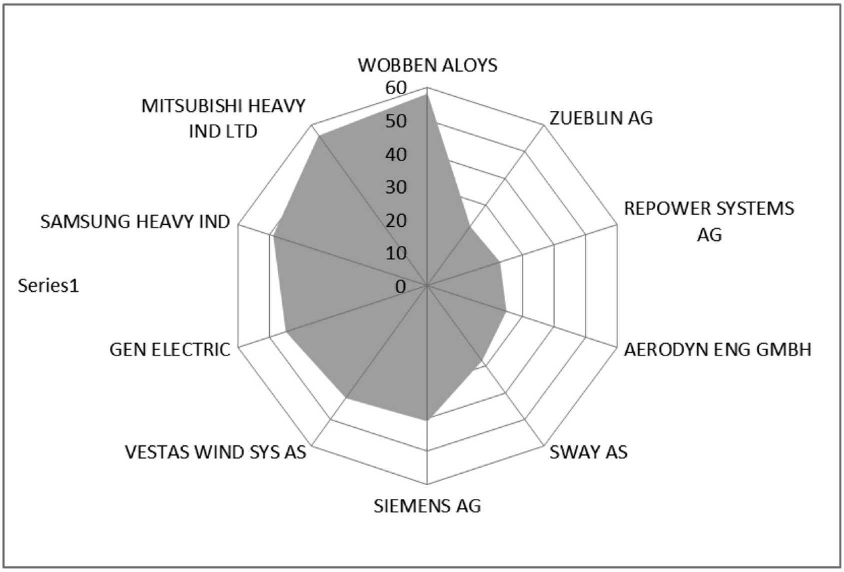

Figure 13. Leading firms in offshore technology.

Table 2. World top ten countries in offshore and total installed wind capacity [7]; numbers in brackets show the country ranking in the patents number list.

Rank	1	2	3	4	5	6	7	8	9	10
Offshore wind capacity	UK (7)	Denmark (5)	Germany (1)	Belgium (--)	China (--)	Netherlands (8)	Sweden (--)	Finland (--)	Iceland (--)	Japan (10)
Total wind capacity	Chi na (5)	USA (2)	Germany (1)	Spain (6)	India (--)	UK (8)	Canada (--)	France (9)	Italy (--)	Brazil (--)

is a close relationship between technological and industrial improvement. Figure 13 illustrates the forerunner firms in the wind industry, which are the top ten in the number of patents whether in offshore or onshore. The firms in these lists are mostly the same.

Deriving the countries in which these firms are located, a good understanding of relationship between leading firms in patenting and leading countries in installed capacity can be obtained. Table 3 provides these facts, i.e. number of active firms, patent applications and installed capacity.

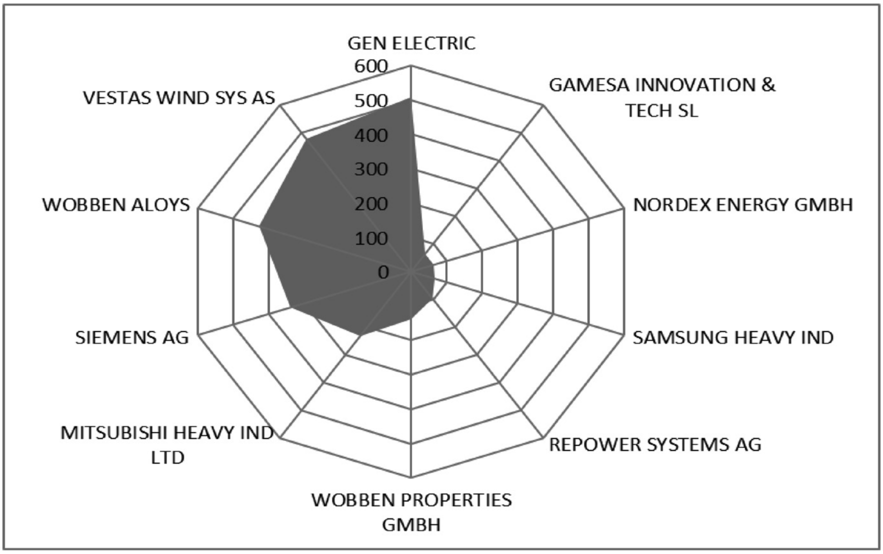

Figure 14. Leading firms in onshore technology.

Table 3. Leading firms in wind power patent application by country

Country	Firms	Country Installed capacity (MW) by Dec. 2014	Patents count (offshore and onshore)
Germany	Wobben Aloys (Enercon) Siemens AG Aerodynamics Engineering GmbH Zueblin AG Wobben Properties GmbH Nordex	39165	2518
United States	General Electric	65879	1428
Spain	Gamesa	22987	496
Denmark	Vestas	4883	778
Japan	Mitsubishi Heavy Industries	2789	427
S. Korea	Samsung Heavy Industries	609	618
Norway	SWAY AS	819	268
Switzerland	REPOWER	---	71

Sentiment Analysis

Textual content streams generated many publicly or privately. Many of these content streams contain text information relevant to identifying the best patent as per technologies need. extracting relevant keywords from abstracts, descriptions and claims can help to enhance the reliability and validity of research. using text-mining for patent analysis, the automatic extraction of major keywords from patent documents has been applied in technology management contexts[38]. Whereas some researchers are still skeptical about the effectiveness of patent analysis based on this keyword-based approach[39], others have emphasized its value and potential.

In keyword-based studies, researchers have commonly tried to achieve their study goals through analyses using sets of keywords extracted from patent documents. Analysis results will thus depend on the keyword set that is selected—if it does not represent the characteristics of the entire document well, the reliability and accuracy of the subsequent analysis may be affected, which in turn will make it difficult to draw reliable insights from the results. Thus selecting and processing keywords that represents the patent's key technological concepts accurately is critical but challenging in patent analysis.

Figure 16 illustrates the text mining results in this research. Clearly from the figure, words "turbine" and "tower" are the most used words in patents' related texts. Following these, the combination and percentage of words usage differ for onshore and offshore patents. While there are common keywords in both texts, exclusively related words to each technology can be found in text mining results. Improving efficiency is a crucial concept in onshore technology, so that the words "rotor" and "blade" totally own about 23% of the words usage; a fact which is only 9% for offshore technology. On the other hand, a good foundation is an inevitable necessity for offshore turbines. Therefore, the word "foundation" is a major keyword in offshore related texts.

CONCLUSION AND REMARKING

Patent analysis is widely used to understand and analyze the current situation of a technology. This research analyzed the development and future of onshore and offshore wind energy technologies based on the patent analysis approach. As patenting activities are in a close rela-

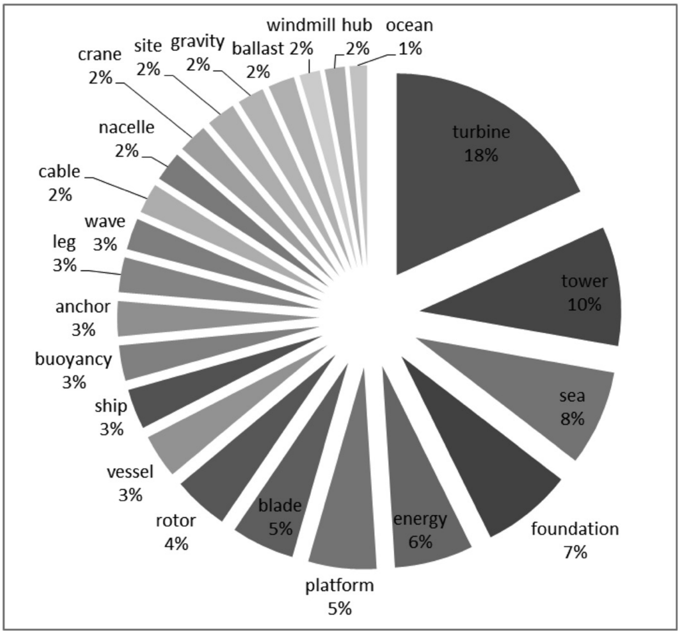

Figure 15. Text mining results for offshore technology.

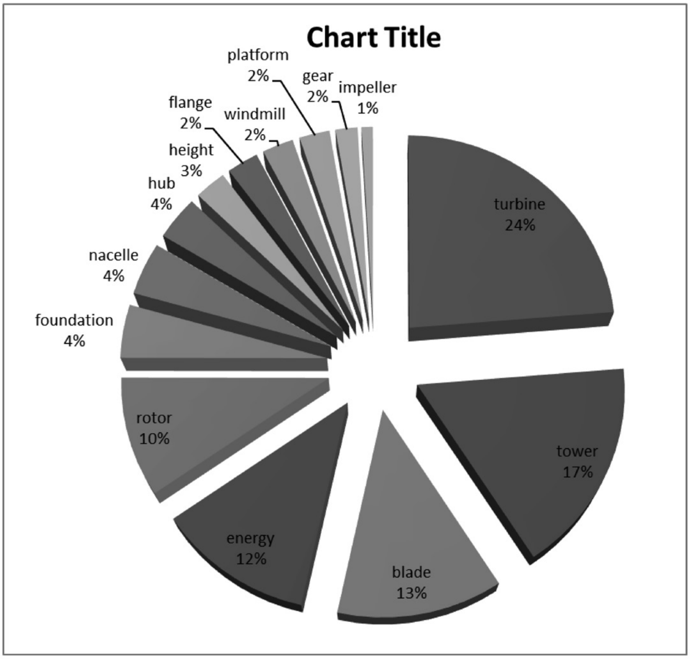

Figure 16. Text mining results for onshore technology.

tionship with industrial, commercial and economical activities, it can be strongly affected by harsh external incidents. We analyzed these issues in section 4.

Another application of patent analysis is facilitating tracking technology trend, as the S-curve is calculated and plotted. This brings wind energy technology has faced a blooming growth whether in offshore or onshore. As shown, wind technology has entered the productivity phase in its TLC. It has happened on 2007 and 2014 for onshore and offshore technologies, respectively. This fact may provide the decision makers a wide insight about the state-of-the-art in wind technology and motivate firms to increase the investments on R&D activities in this area.

Generally, patent analysis can play productive role in different areas. It can be used to conduct the funds and investments to the right place. Policy making and road mapping would be more efficient and clear as the patent analysis is applied. Scientific societies, knowing the technology edge by patent analysis, may act better to make the technology more mature. Therefore, patent analysis can be implemented for various applications in energy policy making, investments, energy technology commercialization, technology growth and different socio-economic purposes.

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ABOUT THE AUTHORS

M. Dehghani Madvar is an MSc. student of the energy system engineering at the University of Tehran, Iran. He has a BSc. in chemical engineering. His research interests include energy technologies, and technology assessments.

MH Ghodousi Nezhad is an MSc. student of the energy system engineering at the University of Tehran. He has a BSc. in chemical engineering. His research interests include feasibility studies of energy systems, and energy conversion.

Dr. Alireza Aslani, corresponding author, is an assistant professor of the renewable energy and environment department at the University of Tehran. He is also researcher at the University of Vaasa in Finland and adjunct faculty member of Maastricht School of Management in Netherland. His research interests include energy modeling, energy economics, and security of energy supply. E-mail: alireza.aslani@uva.fi

Dr. Marja Naaraonja is an associate professor of the University of Vaasa, Finland. She is an expert in the fields of innovation and technology management. Her research interests include, knowledge management, innovation management, and energy future centers.