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Patent intelligence analysis to support technology roadmap on the sector of renewable energy

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Abstract. Managing the unpredictability of the market, the complexity of innovative systems and its technological development is crucial for the management branch of a company; to do this, it is necessary to coordinate all the efforts of commercial, production and innovation groups towards a common goal. However, aligning all the different departments is challenging, then the collaborative creation of a roadmap can help to overcome this obstacle. Thanks to its flexibility, the method adapts to any scenario, managing the complexity of strategic planning. However, the effectiveness of developing a roadmap depends largely on the information the development team has. In this paper a road mapping method is presented, in particular to demonstrate how high level patent intelligence can complement and support roadmap workshops. The focus of this paper will be on an in-depth IP analysis of the wind power generation sector. The innovation is contained in the methodology of extraction of information from the patent pool, which uses semantic analysis tools to speed up the process by automating it, being able to increase the level of depth of the information extracted.

Keywords: Roadmap, patent intelligence, renewable energy, Wind power generation

1 Introduction

Interest in planning tools such as roadmapping has grown considerably over the last two decades at both government and company level, and the real advantage over other methods lies in the power to support communication between teams and the consolidation of consensus within the company. Through the visual representation of a strategy, it is possible to bring together different perspectives and add value to any corporate project [1].

Ikos consulting is the leading consulting company in railways in Europe; its R&D department, IKOS Lab, is constantly focused on expanding and improving the areas in which it operates with a particular focus of energy sector. One of the key tools used to make decisions about the future strategy of the group is the roadmap. Over the years Ikos has developed a model based on TRIZ theory, in particular the system operator (multi-screen) tool, used as a template for group visioning and scenario creation. The

main part of the roadmap similar to the multi-screen tool is the component-system-super system and its evolution over time. Usually a roadmap is focused on the present and the future, but in this way fundamental information is lost if you are trying to predict the future.

For this reason, the roadmap created works on a time horizon that starts about 10/20 years in the past, looks to the future in the next 10/15 years and finally sets a long-term goal to further stimulate the vision to the future. Looking at the structure, the main events that have influenced or will influence the energy sector over time are displayed vertically at the top, followed immediately by the market objectives and the company position.

In the middle we find the system operator (multi-screen) "component-system-super-symbol" structure, which contains the systems and subsystems needed to achieve the set market objectives. Finally, at the bottom are the technologies and resources that Ikos has developed or will need. Such a structure is focused on highlighting trends in the sector of interest.

The objective of the work is to develop a methodology based on an in-depth IP analysis to support the development of a company roadmap on the renewable energy sector in order to assess possible future areas of interest. This work, as in other occasions [2] was conducted in collaboration with the experts of the University of Bergamo.

The article is defined as follow: in section 2 the proposal of the methodological approach, while in section 3, an example of the methodology through a case study related to wind turbine is defined. In closing, section 5, the conclusion.

2 Proposal

The aim of this paper is to show how a patent analysis can be a useful tool to support the drafting of a roadmap [3-6]. With patent analysis [7] it is possible to derive a source of information that can provide a broad view of aspects of a given technology.

One of the strengths of this work is based on the automation of critical steps of patent analysis such as the extrapolation of key concepts within patents and the output phase of the final results. Through automated lexical analysis [8-10] it is possible to focus on technical/engineering features in a way that has not been possible until now except through manual procedures. These tools make it possible to find lexical connections between specific aspects of a given technology, thus identifying and creating niches of terms that allow to generate much more specific and high interest groupings characterising the technology in a much more accurate way.

The methodology presented in this article is based on 4 steps, as shown in Figure 1.

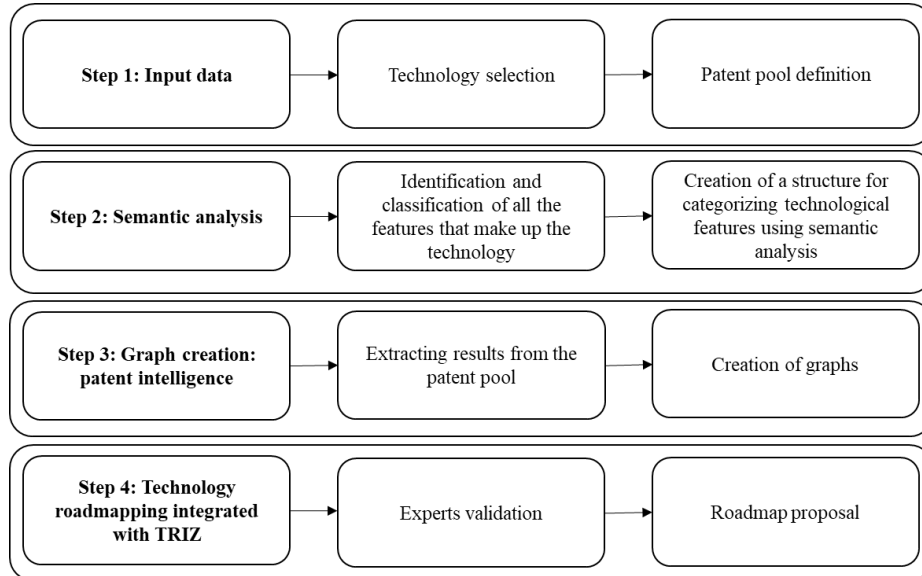


Fig. 1. Suggested methodological approach

2.1 Technology selection and patent pool definition

This phase has, as objectives, the definition of the starting technology, object of the search and the creation of an initial pool of descriptive document sources of the technology. As far as the definition of the technology is concerned, scouting surveys are required to choose the macro-categories on which the search is based on which to focus for subsequent patent result search analyses. This collection consists of a large set of documents to gather most of the state of the art on the targeted topic.

2.2 Creation of a structure for categorizing technological features using semantic analysis

Starting from the patent pool, the objective of this phase is to arrive at the creation of a structure based on the engineering characteristics of the technology. To do this, it is necessary to create a classification mechanism for all features that would qualify the contents of the entire pool. This type of work is based on automatic tools that allow to perform an advanced text analysis facilitating the extraction of the single terms necessary to characterise the micro-areas of interest.

This type of analysis was possible using a tool based on the TRIZ methodology that allows, through an analysis built on the semantic structure of the patents, to extrapolate descriptive parameters of the technology. The software is developed by the university spin-off TRIX and, proceeding with the analysis of the terms found, particular attention was paid to the section related to the problems and all those terms that are semantically related to the concept of improvement, overcoming a problem or an unwanted feature within the technology analysed. Dependency patterns and technological feature

recognition based on neural network are combined in order to provide list of potential related concepts. At this stage of software development, the final result of categorizing the patent pool is not yet fully automatic but requires to manually clean up the raw list. The cleaning process involves a validation and reorganisation of the entries found, and although this phase involves additional work, it allows us to drastically reduce the time compared to the classic methodology.

The system is first launched on the patent databases, from which the main patent players are then extracted as input for the subsequent market analysis phase.

2.3 Graph creation: patent intelligence

After the creation and refinement of the terms that make up the semantic scheme, the final phase involves the extraction of data from the patent pool and their representation by means of graphic examples. In this part of the work, graphs are created to represent the numerosity according to the previously created categorisations.

These graphical representations are useful to estimate the level of maturity of the system. Maturity can be distinguished into technical maturity, which is extracted from the extrapolation of patent information, and economic maturity, which is extracted from graphical representations from databases that collect economic and financial information for companies in a sector.

2.4 Integration into technology roadmapping with TRIZ methodology

The aim of the analysis is to provide a new tool to support the drafting of the roadmap. By studying the data, it is possible to analyse comparative trends between different aspects of the technology. By looking at a few key parameters it is possible to have a qualitative assessment of how the technology is evolving and at what point in its useful life it may be. In Figure 2 there is a schematic representation of a technology roadmapping integrated with TRIZ methodology.

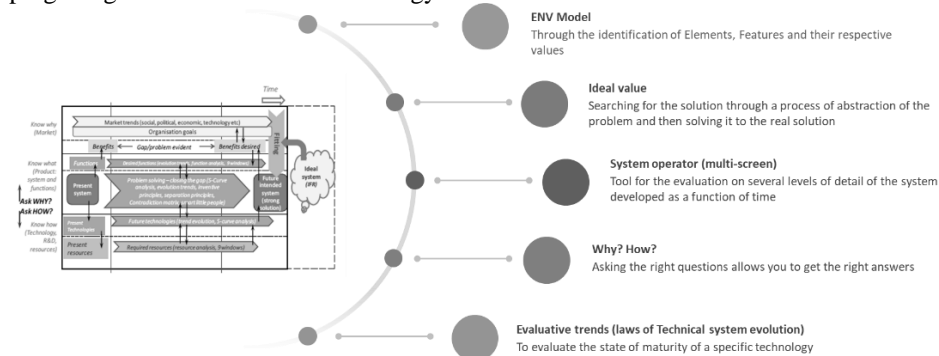


Fig. 2. Technology roadmapping integrated with TRIZ methodology

3 Case study

The research, starting with renewable energies, focused on the wind power generation sector. The focus was on this technology in particular as the wind power sector is considered by Ikos to be one of the most interesting for their future business. The analysis aims to understand which subsectors, technologies or components are the focus of patenting and thus of company research and development.

3.1 Technology selection and pool definition

The work started with an analysis of the technology, quick searches were carried out to create a knowledge base on the topic and decide which features were most interesting for the analysis. Once the main information was gathered, a patent pool was created to do an initial technological scouting.

Once the first technology scouting phase was completed, the next step was to create the patent pool for the wind energy sector. The FAMPAT patent database was used to perform the search. In the first search attempt, an attempt was made to use the widest possible filters in order to avoid losing any information and to assess the popularity of the technology in terms of patents. The results led to a relatively large number in the order of 200,000 patents. This size, although not huge in absolute terms, is very large depending on the type of analysis to be carried out.

The processing time and all subsequent steps are directly proportional to the size of the pool. In order not to have processing steps that take longer than a few days, it is necessary that the pool has a size of about 10,000 patents. With this first extracted pool, neither of the two required characteristics is met.

Part of the problem lies in the method of filtering the patents, many of which do not really contain information related to wind power generation [11] but are patents where it is simply mentioned as an example or as a comparison. It was necessary to narrow down the starting pool in order to arrive at a lower but more reliable result. To do this, stricter filters were chosen for various patent aspects.

Table 1. Query used for the retrieval of “wind turbines” patents from FAMPAT database

Retrieval query	Number of patents identified
((WIND OR WINDS OR (AIR 1D CURRENT+)) 2D (TURBIN+))/TI/AB/CLMS/DESC AND ((PRODUCT+ OR OUTPUT+ OR YIELD+ OR GENERAT+) 3D (POWER+ OR ENERG+ OR ELECTR+ OR CURRENT+))/TI/AB/CLMS/DESC AND (Y02+ OR F0+)/CPC AND (WO OR US OR EP)/PN AND EPRD >= 2015	7500

Where D is an operator that is used to group adjacent terms, regardless of the order, separated by a maximum of n words inside the same sentence. TI/AB/CLMS AND DESC are respectively title, abstract, claims and description of a patent text, while EPRD defines the earliest priority date.

3.2 Creation of a structure for categorising technological features using semantic analysis

Starting from the restricted pool, in order to arrive to the creation of a structure based on the characteristics of the technology, it was necessary to create a classification mechanism for all the features qualifying the contents of the entire pool. To do so, we relied on semantic analysis tools, automatic and based on TRIZ theory, which allow to perform an analysis of the text that greatly facilitates the extraction of individual terms necessary for the characterisation of the micro-areas of interest [12-13]. The categorisation of the scheme including all the collected items was carried out according to a list of characteristics such as: type of turbine (Figure 3), axis of rotation, type of generator, geolocation, problems and aspects related to the improvement of a parameter.

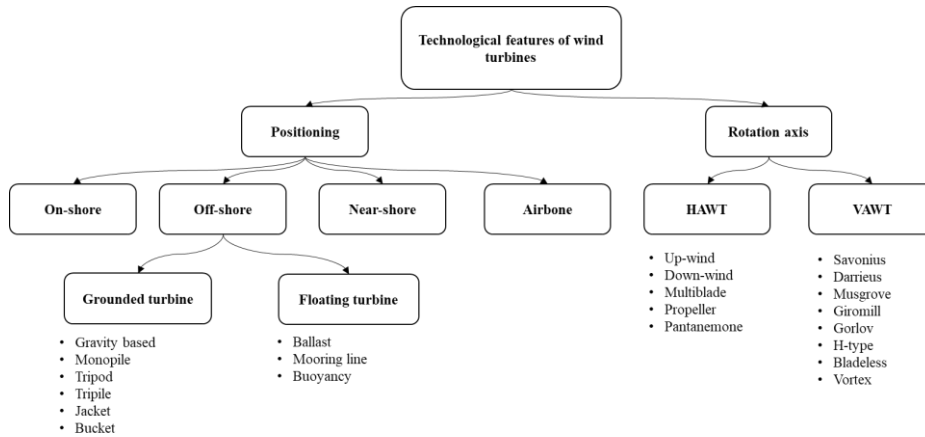


Fig. 3. Type of wind turbine, technical parameters and components

From the technology classification obtained from the analysis of the patent pool, it is possible to estimate the growth of the sector. This analysis is divided into two strands: technical, through patent analysis, and economic, through estimates on economic databases.

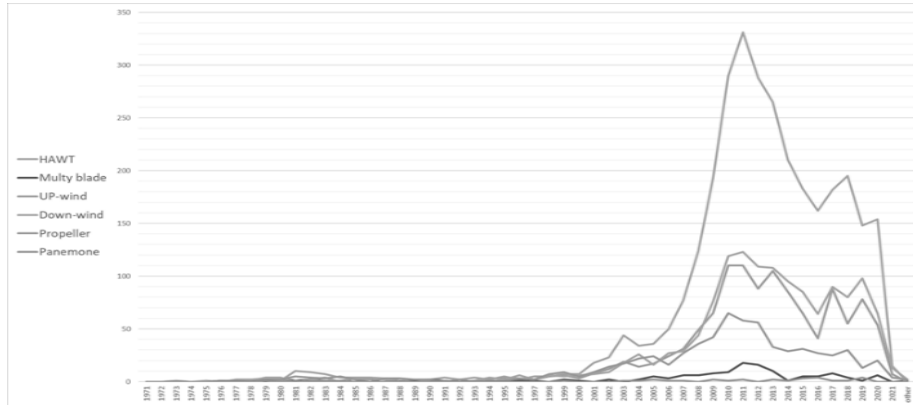


Fig. 4. Comparison of patent trend from 1971 to present for the wind turbines identified. Source: FAMPAT patent database.

As it can be seen in Figure 4, all technologies follow the same general patenting trend, have a similar trend, which indicates that there are no prominent emerging technologies that differ from others. From this technological analysis, it could be assumed that the sector is in its infancy, in the early stages of maturity, as there are so many different technologies behaving equally.

In figure 5, instead, some of the capabilities of the semantic analysis tool used can be seen. By excluding the first parameters, all related to performance, no parameter stands out from the others, except for those related to costs and maintainability, two secondary parameters.

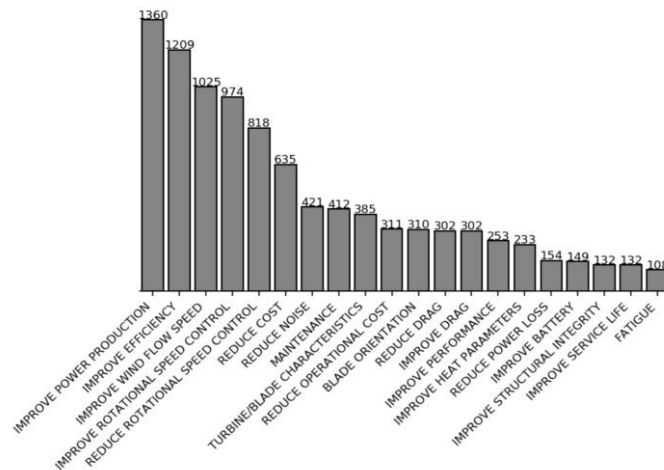


Fig. 5. Patent trends for major issues/improving parameters/worsening parameters - reduced patent pool (7500 patents). Source: FAMPAT patent database.

3.3 Graphs creation: patent intelligence

The first part of the analysis focused on the general patenting trend in order to try to understand the market situation and in particular whether there were technologies with higher growth in terms of innovation. From the integration of the patent trend with external market analyses, it quickly became clear that this sector is strongly influenced by factors not related to patents.

Some of the strong growths as well as the declines are in fact consequences of the policies of the world's major powers such as the USA and China, which, depending on the allocation or withdrawal of funds for research and development in the sector, result in a growth or decline in patenting over the same periods. This influence can be seen, for example, in the globally installed annual power, where the cut in US funding led to a drop in 2012. Another major influence comes from one of the main competitors of renewable energies, namely oil (Figure 6). By superimposing the price trend over time in qualitative terms, it can be seen that periods of rising oil prices lead to a fall in patenting, and vice versa.

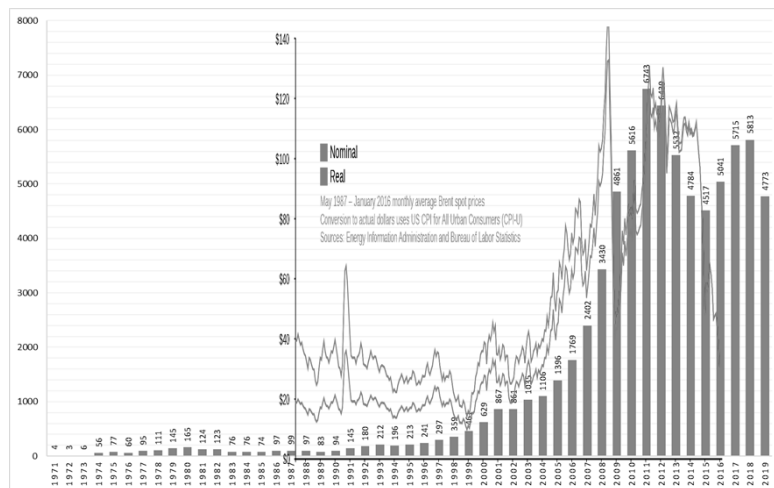


Fig. 6. Trends in the cost of oil per barrel in January between 1987 and 2016- compared with publication patent trend (blue columns). Source: Energy information administration and Bureau of Labor Statistics.

The results for the top player applicants were then analysed, and from the data obtained it can be assumed that the market is in a saturation phase with medium-large players in terms of turnover owning most of the patents developed. Focusing in particular on 5 of them (in terms of installed power per year, in this case for 2018). It can be seen that revenues have increased for almost all of them in recent years, but this is not reflected in profits, a further indicator of a market with a high level of competitiveness. Patenting for the two largest players follows the trend seen above, with Goldwind peaking in 2016 due to Chinese state aid. The small ones remain little influential in terms of overall patenting.

Increasing the level of analysis further, it was possible to analyse the technology parameters for Vestas by cross-referencing them with the company's annual reports. As mentioned above, we observe a saturated market with lower and lower percentage revenues due to competition, especially in the on-shore sector. One sector that is little affected by this general trend is the services sector. These trends are also confirmed at patent level, where we can start to see an interesting increase in the macro-topics relating to costs, service life and maintenance (Figure 7).

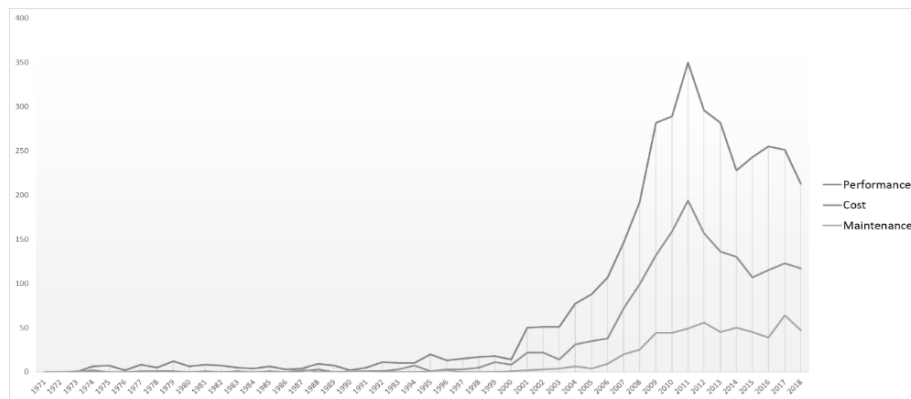


Fig. 7. Performance, cost and maintenance graph describing how mature the wind turbine system is today. Source: FAMPAT patent database.

Extending the analysis to the whole market, it can be observed that, more generally, patents on maintenance are affected by the above mentioned fluctuations in a lesser way than those on performance and costs, indicating a more stable and strong market, which makes it a possible field of interest for future analyses. The results are summarised in Figure 7, where patents are grouped into technical parameters and Figure 8, where the market is analysed to determine whether companies are growing or not. Economic revenues are distorted by the oil fluctuation trends.

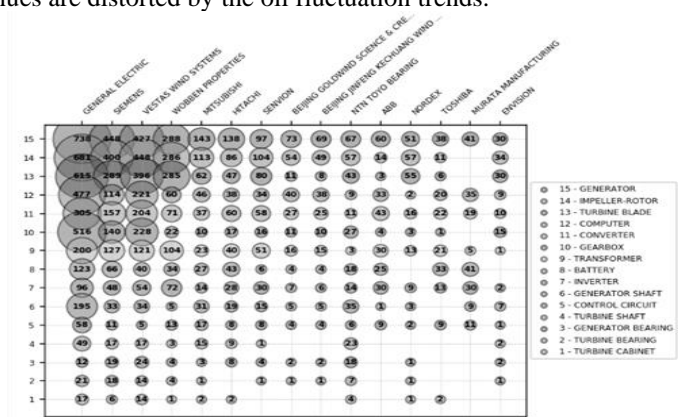


Fig. 8. Bubble graph of components in relation to top players. Source: TRIX software developed by University of Bergamo Spin-off based on the patent pool of 7500 patents.

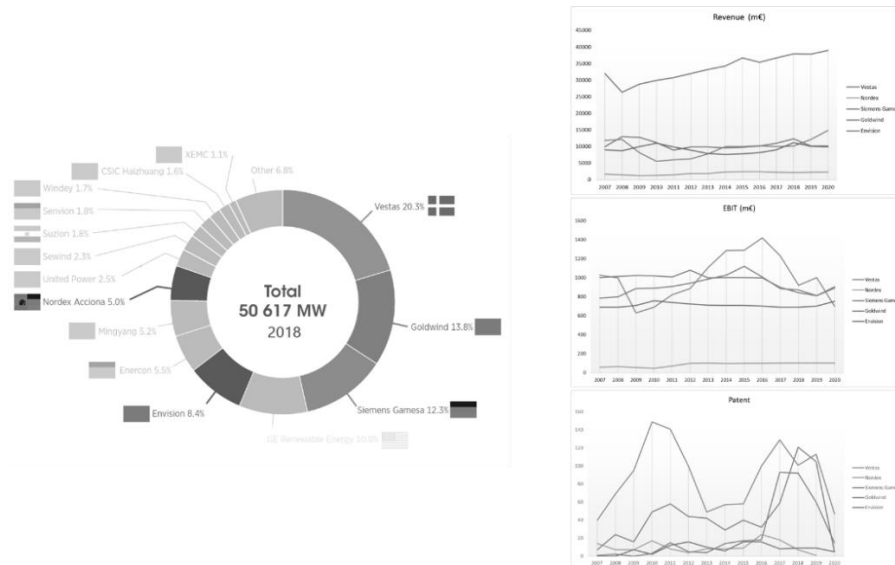


Fig. 9. Top player applicants and economic value of profits, margin and EBIT. Sources: TRIX software developed by University of Bergamo Spin-off based on the patent pool of 7500 patents and Orbis software (<https://www.bvdinfo.com/>) for the economic evaluations.

On the basis of these considerations, putting together all the information obtained in particular from the world of patents, and through this new methodology, it was possible to define an interpretative framework supporting choice of the sector to analyse further in collaboration with experts. This consideration has led to the actual proposal, identifying the predictive maintenance systems sector as an excellent candidate on which to intervene in order to develop innovative solutions; the market for UAV systems and inspection services is expected to exceed 6 billion by 2024.

3.4 Integration into technology roadmapping with TRIZ methodology

By assessing the different aspects related to patents, it is possible to observe a parallelism between priority and investment in R&D, while in the case of publications, the correlation is more related to what are thought to be the potential markets in the future; nevertheless at this level it is possible to obtain useful information on how the market is evolving and what are the main issues on which the top players are working. By studying the data, it is possible to analyse comparative trends between different aspects of technology. By looking at some key parameters, it is possible to have a qualitative assessment of how the technology is evolving and at what point in its useful life it may be. An example is the comparison of the cost and performance parameters, where the curves show the maturity index of the technology.

Depending on the performance of more specific parameters, it is possible to identify key issues that allow an assessment of the individual aspect of the technology, whether a given problem has been solved or not. A strong increase in patenting over time for a

technical problem or factor would potentially mean that high interest, if growth does not slow down, would indicate that no solution capable of meeting all market requirements has yet been found.

From the in-depth observation of each aspect gathered in the analysis it will be possible to determine the direction to take in order to draw-up the roadmap and to define the preferred type of market to work-in or to decide on complementary analysis to be developed.

4 Conclusions

Depending on specific interests, it is possible to cross-reference any kind of data, to analyse the trends over time or to assess how much the major players have invested in patenting; therefore, with these cross-referencing the graphs obtainable are potentially infinite. The advanced capabilities of this method lie in this specific aspect, allowing the analysis of a pool of data in a semi-automatic way and providing results on cross information that could never be obtained in such a short timeframe.

Possible developments of the work could be related to the application of the found classification to the general starting pool or other types of pools. The results of the work are not limited to the extrapolation of the final data; if this proves to be effective, the real potential lies in semantic categorisation, which would become the tool to reprocess in a much shorter timeframe ideally any pool of any type (provided the starting pool is consistent) with minimal adjustments.

Once the results for the wind sector have been integrated, the development of the roadmap will continue with a new project for the other energy sources that Ikos wants to integrate. Thanks to the work carried out, the new methodology will also be usable by an inexperienced user to build a new set of scenarios, suggestions or interpretations.

This functional analysis phase of the roadmap allows a non-expert user to create an interpretative scenario which then requires a confrontation with an expert to discuss the doubts raised during the study (influence of oil trends). The criticality of the work lies in processing the huge number of patents that concern these technologies. The starting pool could be re-analysed to find a new pool with high value but higher numbers than the one used for the analysis in order to improve recall. On the other hand, more attention should be paid to the 'quality' of the pool to avoid inconsistent data.

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