A Technology Opportunities Analysis Model: 
Applied to Dye-Sensitized Solar Cells for China

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ABSTRACT
We devise a multi-level framework to support and systematically identify technological opportunity. Patent data as a product of technology innovation is used to implement opportunity analysis under the framework. At the research and development level, we anticipate the directions of technology development based on technology morphology. Countries’ development emphases can also be investigated in order to help identify their research and development strengths and weaknesses and seek possible, efficient development pathways. At the level of competition, we devise the assignee-technology analysis to obtain insight into competitive participants’ technical emphases and intents. It is also used to explore possible collaboration opportunities among them. At the market level, we apply family patent analysis to understand countries’ target market and assess prospects for the commercialization of their technology. Under the framework, we pursue technology opportunities analysis to explore China’s opportunities and challenges in Dye-Sensitized Solar Cells. The empirical case analysis supports the effectiveness of the technology opportunity analysis model. We believe it can be adapted well to fit other emerging technologies.

Keywords:
Technology opportunity analysis; patent analysis; technology morphology; dye-sensitized solar cell
1. Introduction
As globalization advances continuously, technology changes fast and improves each passing day. This has led to the frequent emergence of new technologies and, subsequently to their fast development. Compared to traditional technologies, the new and emerging sciences and technologies (NESTs) are newly invented, fast changing and developing, and have relatively limited applications in the marketplace (Propp, unpublished), which provides a wealth of technical opportunities. A promising NEST may profoundly impact the global industrial and economic structures and alter future competition. It drives the need of competitive participants to identify and grasp the potential opportunities for technological innovation based on self-recognizing in order to enhance their technological innovation capability and international competitiveness.

The development of intelligence information, such as patent data, scientific and technological journals, and technical reports, provides a possibility to tap the potential opportunities of technological innovation. However, opportunities for technological innovation are not presented in a pre-packaged form and need to be searched and mined with some effort. Alan Porter and Michael Detampel proposed Technology Opportunity Analysis (TOA), which combines monitoring and bibliometric analysis to generate effective intelligence on emerging technologies (Porter and Detampel, 1995). It provides us with an approach to exploit patent and publication resource concerning NESTs to identify technology opportunities. Based on the TOA approach, we devise a multi-level framework to support and systematically identify technological opportunity. The framework set up is based on Technology Delivery System (TDS), which is a socio-technical systems model used to identify the pivotal elements involved in innovation (Wenk and Kuehn, 1977). According to the framework, we perform patent analysis and augment this analysis with expert opinion in order to anticipate and identify technology development opportunities and challenges for technology innovation. In contrast to publication data, patents imply more information about the competitive environment, application prospects, and marketing interests. From the perspective of technological competition, patents can yield insight into competitors’ developmental trajectories and help to forecast others’ upcoming technology-based products and services (Porter and Cunningham, 2005). From a market perspective, patents can reveal promising applications and prospective competitors’ potential strengths.

Based on patent analysis, the Technology Opportunities Analysis (“TOA”) model provides an efficient and effective way to monitor the development of a technology and evaluate the position of potential competitors (Trappey et al., 2011). The paper starts with an introduction of our research background and then follows with a review of the concepts, theory and application of technology opportunity analysis. Section 2 develops the methodological framework and introduces the data we mainly used in our research. In this section the research questions are formulated. In Section 3, we model Dye-Sensitized Solar Cells (DSSCs) and China’s opportunities and challenges in this area. Analysis results are explained in this section. In last section conclusions are given and policy implications are future discussed.
2. Data and Methodology

In this research, we strive to offer a systematic approach to better exploiting patent resources concerning NESTs to identify technology opportunities. The analysis model is devised based on the Technology Delivery System (“TDS”) approach (Wenk and Kuehn, 1977), which reflects dynamic development processes from R&D to the market (Figure 1). A complete technology innovation process is rooted in R&D activity, developed by one or more organizations, and then delivered a product, process, or such to the market. Distinguishing the key contextual factors affecting the success of that innovation process can suitably guide our opportunity analysis.

the relation between the framework description and figure 1 is not always very clear
Based on the TDS approach, we have devised a three level analytical framework to support TOA modelling. At the research and development level, we implement component technology analysis based on technology morphology, in order to anticipate the directions of technology development. It can also help to forecast the most promising technology portfolio which can be used to guild China’s development orientation in near future. The R&D analysis mainly focuses on technological aspect. At the level of competition analysis, we do analysis which links
technology to player. Player can be a country or an organization which participates in research and industry. Technology-Country analysis is implements here to investigate countries’ development emphases. Through comparing China with other countries, we can identify China’s research and development strengthens and weaknesses, which can support seeking possible efficient development pathways. We also devise the assignee-technology analysis at this level to obtain insight into competitive participants’ technical emphases and intents as well as to explore competitive possible collaboration opportunities among them. At the market level, we emphases on analyzing players’ market opportunities. We apply family patent analysis to understand countries’ target market and assess prospects for the commercialization of their technology. Furthermore, we investigate top assignees who applied patents in international markets.

To operationalize the three level analyses, we devised 5 steps (Figure 1). Patent data from the Derwent World Patents Index (DWPI), which collects public patent documents that was applied by 43 countries or areas (include USA, Japan, Europe and China etc.) from 41 patent institutions, are selected to support technology opportunity analysis.

Step 1 is to design our searching strategy. Here we use a multi-stage Boolean search strategy to acquire patent documents. It involves four major steps. First, we create search terms to capture a variety of technical terminology. This shows high retrieval and is defined as our main search term. Second, we enrich those search terms according to different expressions of this technology and closely related technical structures. Third, we check retrieval results of those complementary search terms by excluding their retrieval overlap with the main search. We revise the terms by adding limitations – such as adding restriction to select records only if they also appear in certain International Patent Classifications (IPCs) for the DWPI database. We add exclusion terms for the publication databases. Finally, we combine the terms and evaluate them by randomly testing and assessing retrieval results, and then further revise our search terms. Using search term, we download patent data, and then use filter to import those raw data into VantagePoint software\(^1\), which will be used later to help clean the data, tabulate patent activity, extract text phrases occurring in abstracts and claims, and visualize findings.

In Step 2, data cleaning methods, as described in Porter et al. (Porter and Youtie et al., 2008), are applied. We mainly clean data at three aspects in order to support our analysis in next steps.

- **Key terms extraction, cleaning and classification**

In order to support our analysis in Step 3 and Step 4, we need to prepare technical key terms which represent specific component technologies. Although the Vantagepoint software can provide extracted phrases, there are too many noisy data either too general or not relate to component technologies. So we devise a systematic methodology to obtain the various technical key terms from patents pertaining to each component technology. Here we take DSSCs technology as a case to explain it.

- First, the technical experts will be involved to define the structure of such a morphology (Yoon and Park, 2005), so as to identify component technologies. As we distinguished four key DSSCs components: semiconductor film, sensitizer, electrolyte, and counter-electrode.
- Second, we need to determine which phrases refer to these component technologies. For example, the phrases “dye,” “dyes,” “pigment,” “pigments,” and “sensitizers” all refer to sensitizer aspects.

\(^1\) www.theVantagePoint.com
Third, nearby phrases to those component-related phrases are extracted from the patent abstracts and claims. They are used to explore various shapes of each component technology.

Fourth, experts check these nearby phrases and select those actually technically related and maybe supplement some important phrases that were missed up to that point. Phrases that refer to the same thing are merged, such as “TiO2,” “titanium oxide,” and “titanium dioxide.”

Based on those cleaned and classified key terms, we can continue R&D analysis in next steps.

- Patent assignees extraction and cleaning
  We clean patent assignees in two steps. First is to use the VantagePoint List Cleanup function to reduce or cleanup a list. Second, we check the cleaned assignee list in terms of Derwent Assignee Codes and Google knowledge. The cleaning process can exclude some mistakes which cause by misspelling, different expression and name varying etc. The assignee list is prepared to support analysis in Step 4 and Step 5.

- Cleaning countries of patent assignees
  In DWPI database, only small part of patent data provides assignees’ country, which requires further cleaning process to complete the information. So we acquire those missed information by recognizing the country of assignees or inventers manually with help of Google, and then clean it. The patent assignees’ country can be used to implement analysis both in Step 4 and Step 5.

Step 3, R&D analysis is the first step to implement technology opportunity analysis, which mainly keeps eyes on profiling R&D activities in order to examine a technology of interest. “R&D profiling” is an important part of TDS modelling. Here we employ the theory of keyword-based morphology analysis (Yoon and Park, 2004), of which the basic idea is that the subject is broken down into several dimensions, through which the subject can be described as comprehensively and detailed as possible (Wissema, 1976). Basically, technology is treated as a system that is composed of a number of subsystems, wherein each subsystem can be shaped in a number of different ways. Any technical change of a subsystem may advance the whole technology system. Based on that principle, we devised keyword-based component technology
analysis. First, the morphology structure of selected technology is defined to manifest the properties of the technology. And then, Step 2 is applied to process key terms and to identify candidate technologies for each subsystem. Base on the data prepared in Step 2, we profile those technologies by analyzing corresponding key terms, which can help researchers and policy makers understand the “research landscape” to identify what are the hot topics and promising sub-technologies, to help ascertain the best opportunities for one’s own research and support policy formulating.

Step 4, Competitive Analysis is located here to link technologies to competitive actors. Competitive actors are the most important players in technology development and act to deliver technology from R&D to the market. Based on an R&D profile, we devise the technology-country analysis to obtain a macro sense of R&D emphases and capabilities of top countries or areas. A spider map is a good choice to graph leading DSSC countries’ R&D activities on important component technologies. Each axis in spider map represents an important component technology in a technology system. The scales along each axis represent the percentage patent shares of each country on corresponding technology. The percentage is calculated as the ratio of the patents applied by assignees that belong to a country to the total patents on each technology. If a country has more shares on a technology than other countries, we can anticipate that the country has relatively strong capability. Or for a country, if a technology occupies more shares comparing to other technologies, this means that the technology may draw more attention by the country. What we should mention here is that because differences in legislation and practice between the regions and patent institutions (e.g. some argue that in China more patent applications are filed per invention than is the case for other countries in the world), The analysis results may have biases. How to reduce it is our future we restrict the sample to patents filed in more than a single, local patent office to reduce biases.

Furthermore, we also devise the technology-assignee analysis to get insight into competitive participants’ technical emphases and intents. Network map is applied here to graph relationship between technologies and assignees. If an assignee has more patents on certain technology, the linked line is thicker. Since we can anticipate if two organizations have similar research interests, they more possible have the chance and intents to collaborate with each other, this analysis can be also used to explore possible collaboration opportunities.

And in addition, co-assignee analysis is also applied to find out assignees that have already co-applied patent. Vantagepoint extracts assignees’ names from each patent document, and then creates a co-occurred matrix. The column and row both list assignees’ names, and the numbers in the matrix show the number of records containing both the row item and the column item. From the matrix, we can discern if any national or international collaboration opportunities present themselves for those potential assignees.

In Step 5, we mainly focus on players’ market analysis. In a TDS, the market is the “downstream” destination of technology development. Exploring market interests is an important part of TOA modelling. As a major revenue source, patents provide rich market information. We apply family patent analyses to understand the target market. As we know, when applicants want to protect their inventions in different countries, a patent application needs to be filed in each patent office where protection is sought. As a result, the first patent filing made to protect the invention (the priority filing) is followed by a series of subsequent filings, and together they form a patent family (Martínez, 2010). Along these lines, the recently published OECD Patent Statistics Manual defines patent families as “the set of patents (or applications) filed in several countries
which are related to each other by one or several common priority filings” (OECD 2009). Thus, patent family data can be well paired to analyze the international technology markets. In this analysis, we create a home countries/family countries matrix to support market opportunities analysis. We use home countries to identify the patent applications submitted by local applicants. We use family country to identify the patents that are protected in a specific country no matter if the corresponding application was submitted by local applicants. By using the home countries/family countries matrix, we can establish:

1) How assignees do from a given country consider their market opportunities?
2) In what ways do those assignees relate their technological assets to international markets?

This knowledge can help decision makers employ Competitive Technical Intelligence (“CTI”) to forecast market opportunities and assess prospects for commercialization of their technology.

The paper yields a multi-level analysis for profiling an emerging technology of interest. We implement it in five steps to help China identify DSSCs opportunities and recognize challenges.
3. Case Study: Dye-sensitized Solar Cells (DSSCs)
As a third-generation solar cell solution, DSSCs were invented by O’Regan and Grätzel in 1991 (Oregan and Grätzel, 1991). They are gradually drawing the industry’s attention because of their high conversion efficiency, low cost, and easy production compared to other solar cells. We pursue technology opportunities analysis (TOA) to explore China’s opportunities and challenges in DSSCs based on patent analysis. Using Step 1, We download 3091 records of DSSC patents for the time period from 1991 to 2010 from DWPI database.

3.1 R&D Technical Analysis
A dye-sensitized solar cell is generally composed of four components: the photoanode, sensitizer, electrolyte, and counter-electrode. With DSSC experts’ (Jud Ready and Chen Xu) involvement, we pursue Step 2 and get 9 corresponding key term lists for the four subsystems. Table 1 lists selected keywords related to the four components.

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We see that various nano-structured materials are used as a semiconductor layer in DSSCs photoanodes, such as TiO2, ZnO, SnO2, ZrO2, Al2O3,WO3,NiO, Nb2O5, and SrTiO3 (ordered by number of patents containing related keywords). TiO2 and ZnO show leading numbers as two major nano-structured materials. Out of the whole 3097 records, 566 involve TiO2 or ZnO. In Figure 2, their development trend is analyzed to determine which the most promising technology is. Trends show the accumulated numbers of patents containing the keywords that refer to TiO2 photoanode or ZnO photoanode, or both of them, by application years; columns show the annual numbers. We see that both TiO2 and ZnO show increasing development, while TiO2 has recently attracted more attention and grown more quickly than ZnO. The numbers demonstrate a reduction in 2009 because the collection of such recent patents in the DWPI database is incomplete. However, it is worth mentioning that ZnO shows an increasing ratio of semiconductor research in comparison with TiO2 materials in recent years. The ratio of patents noting ZnO divided by those noting TiO2 began with 0.08 in 2001, grew to 0.24 in 2004, and then culminated at 0.54 in 2008.

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We extract sensitizer keywords from patent abstracts and claims. Experts classify many of them as metal complex dyes or organic dyes; 270 patents involve those two classes of dyes. In Figure 3, lines show the numbers of patents that involve these two classes of sensitizers by application years; columns show the annual numbers. What we see is that metal complex dyes and organic dyes show similar development by 2005. In 2006, organic dyes show a downswing, but have rapidly developed since 2007. From 2008, organic dyes have developed faster than metal complex dyes.

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The physical form of electrolytes is an important characteristic that can greatly affect the performance of DSSCs. So we classify them into three types: liquid, gel, and solid electrolytes. There are 258 patents involving those electrolytes. In Figure 4, lines show the numbers of patents that pertain to these three types of electrolytes by application years; again, columns show the annual numbers. We see that liquid electrolyte attracted the most attention before 2006. But since 2006, the attention given to liquid electrolytes has continued to decline annually, and gel type electrolytes caught up in 2007. In recent years, both gel electrolytes and solid electrolytes have continued to increase. But gel electrolytes grow more quickly in terms of patent applications than solid electrolytes.

From the keyword analysis, we can tell that the two major counter-electrodes for DSSCs are platinum and carbon; 89 patents involve those two types of counter-electrodes. Figure 5 shows that in the most recent years, carbon counter-electrodes have drawn slightly more attention than platinum. However, in 2009, an obvious growth of platinum counter-electrodes took place; although it must be noted that the data for 2009 are incomplete. From further analysis, we find that this growth is largely due to attention to platinum counter-electrodes in China.

In-depth component analysis supports our effort to draw the technology portfolio map. Figure 6 depicts the most popular portfolio of DSSCs in recent years. As the most used semiconductor material for photoanodes, TiO2 has the advantage of being relatively cheap, abundant, and nontoxic (Jose, and Thavasi et al., 2009). DSSCs utilizing TiO2 demonstrate good photovoltaic performance when compared to others. Organic dye is becoming more popular because of its low cost, tunable absorption, and electrochemical properties, through suitable molecular design (Grätzel, 2009). As the most used electrolyte form, the gel electrolyte shows better stability than the liquid electrolyte and better conductivity than the solid electrolyte. It is the transitional form since producing a solid electrolyte with high conductivity is the final object. Platinum, as compared to carbon, has good conductivity. According to experts (Chen Xu), although it is more expensive than carbon, it will remain popular in the near future.

In order to look into China’s development of these technologies, Figure 7 shows China’s patent shares for the two most recent periods (2006–2007, 2008–2009). In 2006 and 2007, China showed a very low count of patent shares in each technology. But a big growth occurred in
2008–2009. Actually, although the data in 2009 are incomplete, China’s patents show a big growth in 2009 when others’ patent counts decreased. We can clearly see that, in each component, TiO2, organic dye, the gel electrolyte, and platinum counter-electrodes draw more attention in China than the alternative component types. China demonstrates a similar orientation as the global development in this regard (recall Figure 6).

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3.2 Competitive Analysis
To better understand China’s DSSCs technology emphases and capability, we apply technology-country analysis. Figure 8 shows the percentage patent shares of Japan, China, South Korea, the United States, and Europe on each technology. Japan held for the highest share of countries on most of the technologies, while China claimed for the highest share on platinum electrodes. We also can see that China is in the second position on gel type electrolyte and organic dye, while South Korea is in the second position on carbon electrodes and ZnO, followed by China. On the other technologies, China and South Korea show close positions, but significantly lower than Japan. The analysis may help countries to identify their technical strengths and weakness, and further understand their technology development structures.

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We also graph the top assignees of the component technologies in Figure 9. Blue nodes represent assignees; yellow nodes represent technologies. Lines link assignees and technologies if they coincide in patents. Thickness of lines represents occurrences - thicker lines represent a higher count of occurrences. Based on technology – assignee analysis, we can further understand assignees’ emphases and distinguish the most active organizations in those component technologies. In Figure 9, most of the organizations are Japanese companies (but recall footnote 2); however, we find three Chinese organizations: CAS Changchun Applied Chemical Institution (CASX), Chinese Academic Science Physics Institution (CHSC), and IRICO Group CO LTD (IRIC)—CASX has a strong linkage with organic dye and gel electrolyte; CHSC shows its contribution to research on the carbon counter-electrode; IRIC manufactures soft wiper blades for automobiles and focuses on the platinum counter-electrode and TiO2. Actually they are the top 3 patent assignees in China on DSSCs.

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2 This is apt to reflect both actual Japanese strengths in DSSCs development and their relative inclination to patent in Japan where the number of patents tends to be far higher than in other patent authorities. Japan both “grants” patent applications without examination (unless the patent is challenged) and tends toward component patenting (whereas other authorities bundle related component advances into single patents).
Technology – Assignee analysis can also provide a way to explore potential collaboration opportunities. Organizations with similar or complementary technologies (and application interests) are better candidates for collaboration. So we try to find potential collaboration opportunities by profiling similar development emphases and interests. Figure 10 shows the top assignees who emphasize sensitizer research. We can clearly see that organizations have different choices if they develop sensitizer technologies. However, some organizations research both, such as Fuji Photo Film CO LTD (FUJF), CAS Changchun Applied Chemical Institution (CASX), and Ecole Polytechnique Fédérale de Lausanne (EPFL). We also conducted a co-assignee analysis for those organizations to determine if any collaboration already exists between them. We find that CAS Changchun Applied Chemical Institution and Ecole Polytechnique Fédérale de Lausanne collaborate on developing pure organic dye and organic ruthenium dye. Aishin Seiki Kabushiki Kaisha and Toyota Chuo Kenkyusho KK collaborate on metal complex dyes. Actually, the DSSC research team at EPFL is led by Michael Grätzel, who won the 2010 Millennium Technology Prize for the invention of the DSSCs. If the Chinese Academy of Sciences can collaborate with EPFL, that may imply that it is the technical leader of DSSCs’ sensitizer research in China and has the potential to participate effectively in global competition.

--- Figure 10 about here ---

Actually, by analyzing China’s collaboration, we find that national or international collaborations are rare.3 The top 10 assignees in China, CAS Changchun Applied Chemical Institution, Wuhan University, and Peking University have collaborated with others. And Qinghua University and East China Normal University have collaborated with small local companies. Furthermore, the two most interesting international collaborations are the following: Sony Corporation and EPFL both collaborate with Chinese Academy of Sciences (CAS) (different affiliates within CAS) on dye research. They represent two major types of collaboration in China: collaboration between an academic institution and a company can push DSSCs commercialization, while collaboration among academic institutions may advance DSSCs technology. Since, in China, most of the research occurs in academic institutions, encouraging these collaborations is important for advancing technology development and commercialization.

--- Figure 11 about here ---

### 3.3 Market Analysis

Dye-sensitized solar cells, as a NEST, are just starting their commercialization. By now, the total market amounts to some 1MW. Experts predict it to grow to 6.2MW in 2011, to 25.3MW

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3 We note that co-assignation is much rarer than co-authoring publications.
in 2012, and to 261.6MW by 2015 (DSSC Technology Trend and Market Forecast [2008~2015]). We can believe that DSSCs’ photovoltaic market is going to expand as the technology further develops. The immense potential market drives the need for market forecasting.

Family patent analysis is used to understand the layout of countries’ potential markets. In columns of Table 2, we can see how many patents have been applied for by country (or region in the case of Europe): Japan, China, United States, South Korea, Europe, Australia, and India are represented. China’s assignees applied for most of the DSSCs patents in their home country. Although China applied for patents in the United States, Japan, South Korea, Europe, and Australia, the records are much lower than for applications from Japan and South Korea. It may imply that China’s future market is mainly located in the home country. In addition, family patents also can be an indicator of patent value because filings patents abroad is associated with higher costs for the applicant (in terms of patent office fees, patent attorney bills, and translation costs), which means that applicants would only extend protection to foreign countries if the time, effort, and cost associated with it seems worthwhile. From family patent size applied abroad, we gain a sense that Japan, South Korea, and Europe have relatively highly valued patents, possibly closer to commercialization. China’s international market potential seems largely undeveloped to date.

Table 2 about here

Since patents applied for abroad are usually more highly valued, we look into further information on this. China started to apply for patents abroad in 2006. Table 3 lists China’s top assignees abroad and their patent topics. We find many companies in Taiwan (included with China in these analyses). And, except for Tripo Technology Corporation, all the other organizations have applied for patents on dye research. It seems that China has an especially strong capability in dye research as compared to other component technologies. And it is worth paying attention to IND Technology Research Institution since it developed the Building Integrated Photovoltaic (BIPV), which is an important potential application for China to supply power for the needs of remote countryside locations.

Table 3 about here

4. Discussion
In R&D analysis, we investigate DSSC technical component developments based on keyword extraction. This analysis helps to recognize the key component technologies in DSSCs and their development directions. Among the four components, TiO2, organic dye, gel electrolyte and platinum counter-electrode predict to be the most promising technology according to global trend analyses. And China also shows a similar development pattern on those technologies. Comparing to other countries, China has demonstrated a relatively high level of attention directed to developing platinum counter-electrodes, and, secondly, to organic dye and gel electrolytes, following Japan.
Seeking progress on those technologies might be the most promising pathway to advance DSSCs for China. Assignees-technologies analysis is used to look into activity by organizations on these technologies and helps to identify the three leading Chinese patenting organizations—CAS Changchun Applied Chemical Institution, Chinese Academic of Sciences Physics Institution, and IRICO Group Co. Ltd. CAS Changchun Applied Chemical Institution shows special research strengths in the specialization on organic dyes and collaborates with the Ecole Polytechnique Fédérale de Lausanne. Meanwhile, China’s patents abroad focus mostly on dye. It implies a notable opportunity for China—continuously seeking and producing new, practical, and efficient dyes to reduce cost and improve the stability of DSSCs. It seems to offer a promising way to make China’s DSSC technology globally competitive. Patterns suggest that China’s near-future market will be focused mainly in the home country. China still has a long way to go for significant commercialization of DSSCs globally as it holds relatively few foreign patents. Also, China’s patenting is not heavily initiated by companies. It is important to encourage more companies to become involved in DSSCs. China might also consider ways to promote collaboration between companies and academic institutions.

This research implements a special in-depth analysis on DSSCs’ component technologies rather than more “macro” analyses. The keywords selection and classification is challenging but benefits from inputs by knowledgeable colleagues. It is important to carefully identify technology morphology with experts according to the purpose of that analysis.

References


**FIGURES:**

![Diagram of Technology Opportunities Analysis](image)  

**Figure 1 Technology opportunities analysis model**
Figure 2. Trend analysis of semiconductor materials

Figure 3. Trend analysis of sensitizers
Figure 4. Trend analysis of Electrolytes

Figure 5. Counter-electrode
Figure 6. Technology portfolio map

Figure 7. DSSCs analysis for China
Figure 8. Countries’ patent ratio on important DSSCs component technologies
Figure 9. Top Assignee–technology map
Figure 10. Assignees-technology map on dye research
Figure 11. Co-Assigenee map in China

TABLES:

Table 1 Example keywords

<table>
<thead>
<tr>
<th>Component</th>
<th>Keywords</th>
</tr>
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<tbody>
<tr>
<td>photoanode</td>
<td>TiO2, ZnO, SnO2, ZrO2, Al2O3, WO3, NiO, Nb2O5, SrTiO3,…</td>
</tr>
<tr>
<td>Sensitizer</td>
<td>ruthenium dye, organic dye, porphyrin based dye, metal complex dye…</td>
</tr>
<tr>
<td>Electrolyte</td>
<td>liquid electrolyte, electrolyte liquid, gel electrolyte, solid electrolyte, quasi-solid electrolyte…</td>
</tr>
<tr>
<td>Counter-electrode</td>
<td>platinum counter-electrode, carbon counter-electrode, alloy foil…</td>
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</table>

Table 2. Numbers of patent applications by country (region)
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<th>Patent Topics</th>
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<td>IND TECHNOLOGY RES INST (ITRI)</td>
<td>Gel electrolyte, Ruthenium dye, Fabricating method solar cell integrated in building</td>
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<td>2</td>
<td>6</td>
<td>EVERLIGHT USA INC (EVER-N) LED</td>
<td>Ruthenium dyes</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>ACAD SINICA (SNIC)</td>
<td>Ruthenium Dyes, Organic Dyes</td>
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<td>4</td>
<td>3</td>
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