Research Article

Green Innovation Regarding Electromobility in Germany and China: Who and How to Get Involved?

Qu Zhao[1, 2]

[1]Department of Social Sciences, Humboldt-Universität zu Berlin, Universitätsstr. 3b, Berlin, 10117, GERMANY.
[2]Department 2, German Centre for Higher Education Research and Science Studies (DZHW), Schützenstr. 6a, Berlin, 10117, GERMANY.

ABSTRACT

Over the last two decades, Electromobility (e-mobility) has gained significant popularity as a favourable approach to circumvent problems related to both resources and pollution whilst meeting mobility demands. Germany and China as the major exporter and volume producer in the automotive industry have respectively set themselves the goal of becoming the lead market for e-mobility by 2020. It calls for the implementation of national strategies and a great attention from scholars. E-mobility refers a whole host of components from drive technologies to charging infrastructure. The extensive coverage results in a focus on statistical analysis based on patents. However, the existing research seldom proceeds from the issue of green innovation, in particular from the applicant perspective. In addition to the overview of e-mobility and green innovation, the present study draws on recent methodological advances and refines indicators to measure innovation in e-mobility-related technologies. It bases analyses on a unique and integrated patent dataset reconstructed upon Espacenet under Cooperative Patent Classification (CPC). Applicants are classified manually and compared with corresponding classifications, inventors and jurisdictions, aiming at comparing the development, collaboration and diffusion of technologies between countries. The co-ownership and legal status are further discussed for tracing correlations and intellectual property management. German applicants, notably the business giants occupy an irreplaceable position in international cooperation and market penetration. Applicants in China are scattered but have laid a solid foundation of scientific research. Taking technology transfer and novelty into account, both countries still have more spaces on the issue of e-mobility to move up.

Keywords: Electromobility, Green innovation, Patent analysis, Applicant, China, Germany.

Correspondence
Qu Zhao
[1]Department of Social Sciences, Humboldt-Universität zu Berlin, Universitätsstr. 3b, Berlin, 10117, GERMANY.
[2]Department 2, German Centre for Higher Education Research and Science Studies (DZHW), Schützenstr. 6a, Berlin, 10117, GERMANY.
E-mail: zhaoqu@dzhw.eu

Received: 02-02-2018
Revised: 11-03-2018
Accepted: 07-05-2018
DOI: 10.5530/jscires.7.1.1

INTRODUCTION

To effectively address climate change, plenty of research has reasoned that a transition away from fossil fuels to renewable energy sources is required.[1] This has motivated in the last decade, the sustainable redesign of mobility with e-mobility getting increasing attention.[2] Advanced technologies within this field range from the ones for improving efficiency of conventional internal combustion engine (ICE) to subcategories for supporting the interoperability of electric vehicles (EV) and thus ultimately realize the sustainable transport as a way of green innovation. This consists of new or modified processes, practices, systems and products which benefit the environment.[3] Instead of the proverbial concept of EV,[4] e-mobility takes a systematic standpoint that integrates numerous components and thus transcending the boundaries of traditional industrial sectors.[5] Correspondingly, it only works as a complete system with vehicles on sale and good charging infrastructure, as well as a legal framework and proper incentives. The systemic aspects of e-mobility thus reach far beyond mere technical aspects and a transition to electric propulsion must be understood as a process of socio-technical transformation.[6]

E-mobility provides a key to protect the climate, environment and resources, as well as promotes technological innovations and enables new business models. (NEP, 2012). It has received significant political attention and is becoming hugely important internationally, in developed and developing countries alike.[7] The typical case associated with this development would be Germany and China, alongside the United States and Japan, being the top four automobile manufacturers worldwide[8] and both set themselves ambitious targets to develop e-mobility by 2020.[9-10] Besides, plentiful bilateral projects on issues of EV standardization, batteries recycling and e-mobility promotion have been conducted since 2009 and Germany has dedicated to developing and providing technical input for political dialogues to promote cooperation between two countries.[11] However, the respective market performance is different.[12] Germany, as a forerunner in e-mobility[13] has been regarded as the most competitive and innovative[14-15] but indicated by Kagermann[16] it is still failing to catch the imagination of electric vehicles (1 million EVs on the road) and falls behind China. The slow take-up of e-mobility in Germany contrasts with its extraordinary growth in China, where the government has key goals for the electrification of much traffic.[17]

Does this difference is also traceable in their technological innovation on e-mobility? To identify trends in relevant technologies, innovation research on e-mobility has captured a growing interest and topics vary widely,[18-19] including the international comparison of EV technological development and battery technologies with patent data,[20-21] an agent based model for assessing system integrating technologies,[22] the signification and optimal design of energy management converters[23] and a solution for optimal placement of charging stations in a smart city.[24] However, insights into comparing e-mobility innovation between China and Germany with a broader classification of environmental technologies are not profound. Furthermore, this field is not merely experiencing technological change but associated with a shift to a broader network.[25-26,3] It consists of established members of the automotive industry, start-up companies, governments, energy providers with an active role in the process by investing in charging infrastructure, and new participants such as battery producers and IT providers. However, the question of who is involved and how to get involved in e-mobility technological innovation in two countries remains unclear.

Patent data contains a valuable source of information for plotting the evolution of technologies over time.[20] To form a better understanding of this emerging and defining field, more information on contributors extracted from an extended patent comparison is necessary and intuitive. Taking account of the deficiencies inherent in patent research,[27] an applicant perspective can, to some extent, cover the shortage of obscure descriptions provided in patent text and the concern of how universities perform in knowledge utilization.[28-29] Data of applicants and inventors provides a better explanation of differences stated in patents because of its close connections to the knowledge flow, market shares and policies. The present study draws on recent methodological advances that allows a more specific assessment of innovation across different groups of applicants and covering a greater variety of the relevant technologies. Besides, CPC is adopted to recombine scattered e-mobility technologies from the perspective of environmental sustainability, thus solving the problems caused by ambiguous concepts and classifications. The paper approaches comparisons of general trend, leading actors, diffusion and management of technologies by integrating the multilevel analysis drawn from refined technological field and insights into patent documents, as with the information extracted from legal status and cooperation reaching far beyond statistics.

METHODS AND DATA

Patent as a rich indicator of technological development is much more available, quantitative and commensurable compared to R and D expenditure, industry and commodity classifications or scientific publications.[30] For novel technologies covered by e-mobility, not yet sold in substantial units, little to no data is attainable, the only metric – particularly for the private sector – is patent data.[31] Recently, Stein *et al*.[21] have compared well-established measuring methods based on Euclidian distances with min-complement distance, indicating that the latter is more reasonable to measure technological distance in e-mobility collaborations. However, this specific discussion on selected innovation collaborations is limited by the small simple size and the underlying approximation of technological distances based on patent data. Golembiewski *et al*.[21] apply patent families to analyze battery technologies and found shifts in value creation activities by the increase in collaboration. Even this explorative approach extends the current knowledge base on e-mobility industry and value chain structures, the general drawback of using patents cannot be ignored, especially for the integrity and interpretation of relevant technological information. For recognizing the pattern of e-mobility innovation and exploring differences among groups of applicants in China and Germany, the present study compares e-mobility patents sourced from firms, universities and individuals from six aspects -- general trend, global innovation, key technologies, co-patents, since linkage and legal status. Besides, CPC is employed in this study instead of the conventional criteria – International Patent Classification (IPC), which allows the technologies with approximately 250,000 distinct entries to be resolved in a more refined manner.[32]

Research setting

The paper first measures the development of e-mobility technologies through a cross-country comparison, which is performed multi-dimensionally with annual patent filings, leading applicants, international collaborations, core technologies and their layouts. Then it proceeds to apply patentometrics to explore correlations among applicants and possible science linkages for further visualization of co-applicants and keywords by *Gephi* and *Vantage Point*. Patent kind codes are finally reviewed to gain additional insights into the legal status, particularly the publication level and type of patent document. Indicators involved in each phase above are listed as follows:

Table 1: Indicators involved in each phase.

Analysis level	Analysis Phase	Indicators
Status of technological innovation	General trend and source of inventive activity	Annual patent fillings – based on the priority date Proportion of applicants – based on groups listed in Figure 1 Average number of patents per applicant– based on 1 and 2
Pattern of technological innovation	Global innovation and talent flow	Distribution of co-inventors (with/without domestic inventors– based on inventor country of residence Distribution of inventors from China and Germany in non-native organizations
	Main technological field and market coverage	Top 10 CPC classifications of each group Top 5 publishing offices - based on patent number
	Co-ownership of patents and pivotal actors	Top 10 applicants from China and Germany Cross-organizational cooperation of applicants
Chain of technological innovation	Science linkages captured from patent citations	Non-patent literature (citation -applicant) Usage of patent – based on patent abstract Keywords of scientific papers
	Legal status of relevant patents	Document status– based on patent kind codes

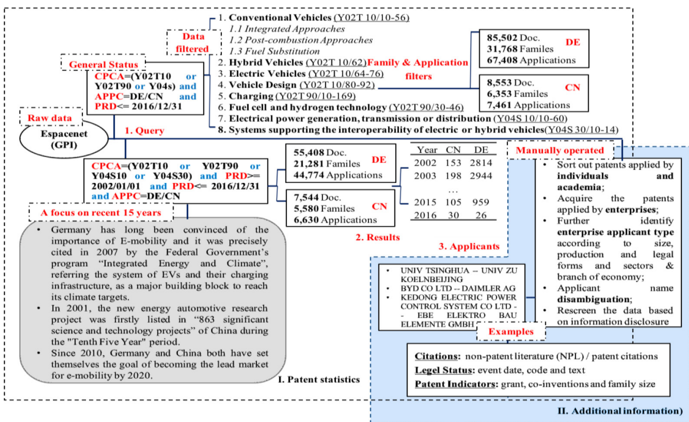


Figure 1: Construction of patent dataset regarding e-mobility technologies.[1]

1 Relevant CPC scheme and CPC definitions are drawn from: https://www.cooperativepatentclassification.org/cpc/scheme/Y/scheme-Y02T.pdf https://www.cooperativepatentclassification.org/cpc/scheme/Y/scheme-Y04S.pdf

Data

E-mobility technology can be applied to all forms of transportation including rail, shipping and heavy-duty trucks.[33] However, this research has a specific focus on road transport technologies (Figure 1), requiring a specific infrastructure that includes EV charging stations, connected within a network grid infrastructure based on electric energy and which supplies the energy for recharging.[34] Filtered by families, 55,408 (DE) and 7,544 (CN) documents from 2002 to 2016 are gathered by query "CPCA=(Y02T10 or Y02T90 or Y04S10 or Y04S30) and APPC =DE/CN and PRD>= 2002/01/01 and PRD<= 2016/12/31". Applicants are regrouped manually together with legal and business information. To highlight some potential science linkages, nearly 120 keywords and 23 "use" items are retrieved from *Web of ScienceTM Core Collection* and *Derwent Innovations IndexSM.*

RESULTS AND DISCUSSION

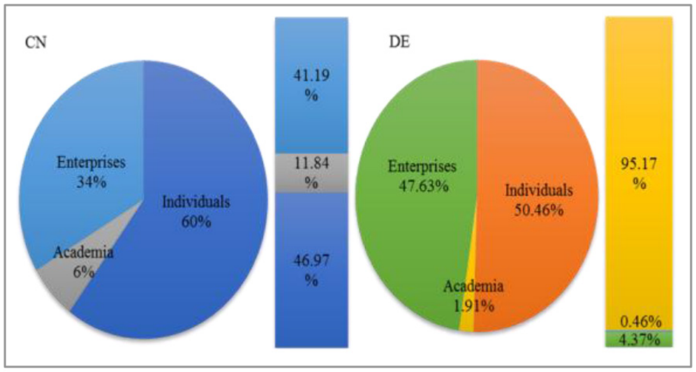
General trend and source of inventive activity

On basis of name disambiguation, 1,413 and 3,250 applicants from Germany and China are classified and compared by their holdings, indicating that enterprises and individuals have numerical superiority on patent fillings (Figure 2, Table 2). However, German enterprises dominate both proportion and capacity, whereas Chinese patents are scattered at individuals and local enterprises in Shanghai, Shenzhen and Beijing. None of the per-capita application exceeds four in three, verifying the degree of dispersion still further. However, individual applicants cannot be proved only by patent documents that they have no relations with firms or universities. To figure out whether there exists an undisclosed link between them, such as the employment relationship, profiles of applicants should be further explored.

Although the patents of selected technologies between two countries have a vast difference in the aggregate, their trends of application have changed similarly over time (Figure 3). Either has made dramatic breakthroughs since 2007. In comparison with groups, the proportion of patents held by German applicants fluctuates on a small scale, and the dominant position of enterprise in innovation is extremely stable. By contrast, the three types of Chinese applicants act diversely in inventive activities.

Table 2: Average number of patents per applicant.

Average	CN	DE
Individuals	1.51	1.54
Academia	3.58	4.30
Enterprises	2.38	35.60



Average	CN	DE
Individuals	1.51	1.54
Academia	3.58	4.30
Enterprises	2.38	35.60

Figure 2: Proportion of applicants and number of patents.

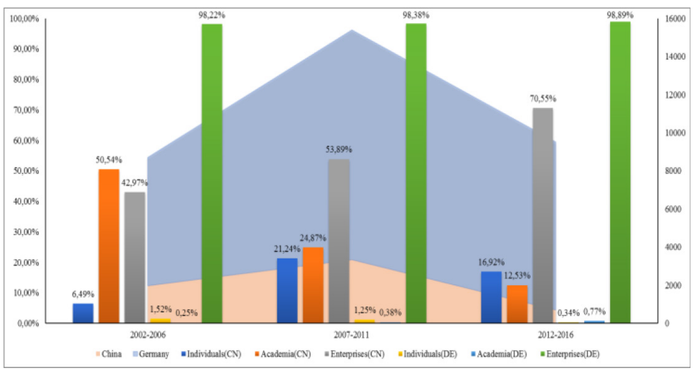


Figure 3: Inventive activity in countries and applicant groups (5-year interval).

Global innovation and talent flow

Co-inventive activity is constructed as a count of priority patent applications with inventors from at least two different countries, including inventions made purely by foreigners and the rest containing German/Chinese participant (Figure 4). There are approximately 2500 patents co-invented by an international team in Germany and the two categories (with/without domestic inventors) of collaboration part evenly. Those co-inventors span the globe and are mainly from the US, most European countries (e.g. Austria and France), and some Asian countries like China and Korea. Despite the limited number of patents, the strength of co-inventive activity in China remains considerable. American inventors also have exerted significant influences on promoting Chinese e-mobility development due to a high involvement. Moreover, a growing number of talents from Taiwan, Germany and Japan have expanded the diversity of inventors.

Taking inventors from China and Germany in non-native organizations into account, 16.79% of patents involving German inventors are authorized by American firms

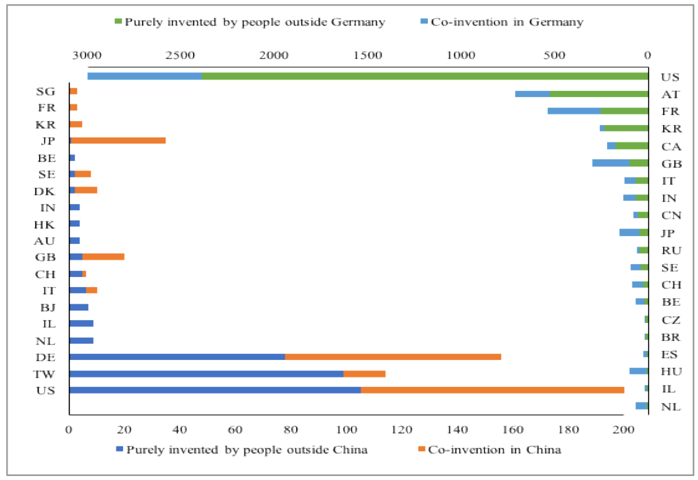


Figure 4: Distribution of co-inventors in Germany and China.

(e.g. *FORD GLOBAL TECH LLC* and *GM GLOBAL TECH OPERATIONS INC*) and applicants from other European countries (e.g. *AVL LIST GMBH and GE JENBACHER*), while 440 patent families (7.61 percent) invented by Chinese researchers are distributed evenly in enterprises from the US and Germany. By contrast to the global innovation managed by German or Chinese applicants, this phenomenon is regarded as an outflow of talents, which refers to local inventors who are involved in inventions of foreign entities.

Main technological field and market coverage

As stated in Table 3, there are partial overlaps between the technologies of two countries, especially the fields of batteries (e.g. Y0210T/7005) and charging systems (e.g. Y02T10/7072 and Y02T90/14). Technologies for the improvement of ICE (e.g. Y02T10/14-148) are highlighted by both sides as well. The general technological focus of two courtiers differs slightly compared to the difference in number, issues concerning energy storage and management are continuously discussed. EVs as e-mobility's central idea in principle should now have a bright future, however to address the problems of high costs and short range, evolved battery technologies, charging technologies and comprehensive charging infrastructures are especially needed. In addition, there is still considerable concern that the conventional powertrains need to be more fuel efficient and less-polluting. In terms of the rest, German applicants have immersed themselves in the scope of exhaust treatment, while Chinese patent technologies are inclined to use of alternative fuels. Technologies involved in individual patents are extremely distinct and only coincide with those relating to non-reciprocating piston engines (e.g. Y02T10/17). Individuals in China prefer technologies of temperature control and conversion of power, whereas individual patents in Germany concentrate on EV charging technologies. For patents filled by enterprises and academia, the technological fields differ slightly, but with divergent rankings. In addition

Table 3: Main Technological field compared among countries and groups (top 10)[1].

Total_CN	Total_DE	Ent_CN	Ent_DE	Ind_CN	Ind_DE	Aca_CN	Aca_DE
Y02T10/7005	Y02T10/7005	Y02T10/7005	Y02T10/7005	Y02T10/90	Y02T10/7005	Y02T10/7005	Y02T10/7005
Y02T10/32	Y02T10/24	Y02T90/14	Y02T10/24	H01M10/625	Y02T90/14	Y02T10/125	Y02T10/26
Y02T10/7083	Y02T10/144	Y02T10/705	Y02T10/144	H01M10/615	Y02T90/121	Y02T10/32	Y02T90/14
Y02T10/641	F01N3/2066	H01M10/625	Y02T10/47	H01M10/6571	Y02T10/7072	Y02T10/144	F01N3/2033
Y02T10/121	Y02T90/14	B60W10/08	B60K6/48	Y02E60/12	Y02T90/128	Y02T90/16	F01N3/025
Y02T10/7241	F01N2610/02	H01M10/615	Y02T10/6221	F05B2240/941	Y04S30/14	Y02T10/7241	F01N3/2006
Y02T90/14	Y02T10/47	B60L2240/545	B60W10/08	H02M3/158	Y02T90/169	Y02T10/121	Y02T10/7072
Y02T90/16	B60K6/48	Y02T10/7072	F01N3/2066	H01M10/657	Y02T90/163	Y04S10/522	F01N2240/02
Y02T10/126	Y02T10/6221	Y02T90/121	F01N2610/02	Y02T10/7055	Y04S10/126	Y02T10/7077	Y02T10/7011
Y02T10/17	B60W10/08	Y02T90/16	B60W10/06	Y02T10/144	Y02E60/721	Y04S10/545	Y02T90/32
Y02T10/7072	Y02T10/7072	Y02T90/128	Y02T90/14	H02J7/0014	Y02T10/146	Y02T10/7022	Y02T90/121
Y02T10/146	B60W10/06	Y02E60/12	Y02T10/6286	Y02T10/17	Y02T10/36	Y02T10/641	Y02T10/7022
Y02T10/144	Y02T10/146	Y02T10/7241	Y02T10/7072	H02J7/0093	B60L11/184	Y02E40/76	Y02T10/56
Y02T10/125	Y02T90/121	H01M10/6571	Y02T10/44	H02J7/0091	Y02T10/32	Y02T90/14	H01M2250/20
Y02T10/705	Y02T10/705	B60L3/0046	Y02T10/705	H02J7/0075	B60L11/1816	Y02T10/166	F01N3/0222
Y02T10/16	Y02T10/6286	Y02T90/163	Y02T10/7077	H02J7/0054	Y02T10/7077	Y02T10/16	Y02T10/82
Y02T90/121	Y02T10/7077	B60L11/1861	Y02T10/146	H01M10/6572	Y02T10/17	G06Q50/06	Y02T10/645
Y02T10/7275	Y02T10/20	Y02T10/7011	Y02T10/645	H01M10/651	F02D19/081	Y02T10/7275	Y02T10/6217
Y02T90/128	Y02T10/7011	B60L2240/547	B60L2240/423	H01L2924/0002	Y02T90/127	Y02T10/7072	Y02T10/144
Y02T10/7011	Y02T10/645	H02J7/0054	Y02T10/7011	H01L23/345	Y02T90/124	Y02T10/146	F01N3/2889

1 More information on relevant CPC definitions can be found from: https://www.cooperativepatentclassification.org/cpcSchemeAndDefinitions/.html.

to the overlapped parts, enterprises focus on specific technologies of electric equipment and exhaust treatment. Another issue found in academia patents is the system that supports electrical power generation, transmission or distribution.

As a measure of technology diffusion, an indicator constructed as a count of inventions that have sought patent protection in a given jurisdiction. In general, China and Germany are alike in adopting protection strategies of technologies. World Intellectual Property Organization (WIPO) and IP5 (EPO, JPO, KIPO, SIPO and USPTO) are the main convergences of patent applications except as domestic markets. Specifically, applicants show minor differences in technology diffusion correspond to different categories, for instance, German patents from academia are more likely to make applications in European countries other than Asia regions and Chinese enterprises have more patents in Canada than South Korea. The size and scope of business, patent costs, and personal willingness are all potential factors resulting in this difference.

Co-ownership of patents and pivotal actors

The top 10 German applicants (Table 4) are all large German-owned enterprises with a global presence, covering products of automobiles, security and control systems, batteries and other key spare parts, whose patents account for 62% of the total. China's representative applicants contain a relatively complex composition, including foreign venture capital firms, State Grid Cooperation of China, automobile manufacturers and universities, only occupying 13.41 percent of all applications. Manufacturers are subdivided into private and state-owned enterprises.

Unlike scientific collaboration, co-application of patents not only indicates the technical cooperation of crucial actors, but the sharing of patent-related costs, risks and benefits, giving rise to a relatively complex network of applicants. 32 and 144 applicants (individuals are excluded) from China and Germany has cooperated more than two times in 65 and 1,576 patents respectively, which is specifically depicted as Figure 5.

Table 4: Top 10 applicants from China and Germany.

Rec.	Applicant (CN)	Rec.	Applicant (DE)
272	BYD Co Ltd	6026	Bosch Gmbh Robert
135	Chery Automobile Co Ltd	3055	Daimler AG
75	Univ Tsinghua	1623	Bayerische Motoren Werke AG
68	State Grid Corp China	1359	Volkswagen AG
62	Univ Shanghai Jiaotong	1162	Siemens AG
48	GOGORO Inc	998	ZF Friedrichshafen AG
39	Univ Tianjin	898	Audi Ag
38	Dongfeng Motor Co Ltd	807	Continental Automotive Gmbh
36	Shanghai Zhongyou Entpr Group	524	Porsche AG
35	China First Automobile Works	431	Behr Gmbh and Co Kg

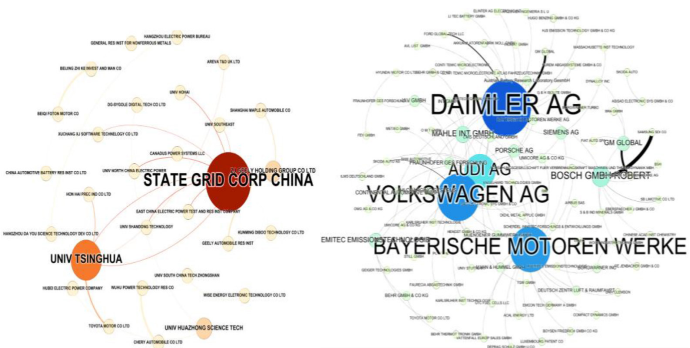


Figure 5: Cross-organizational cooperation of applicants in China and Germany.

German applicants, especially the magnates as per *Daimiler, BMW* and *Volkswagen*, have played a crucial role in this network, participating in more than 90 percent of co-applications. Except for close partnerships with firms, *Audi* and *Siemens* have also built a few solid connects with universities and research institutes (e.g. *Univ Stuttgart and Chinese Acad Inst Chemistry*). Multinational corporations, such as *Samsung* and *GM*, are active actors as well because of their joint business in Germany. Those interrelated applicants work in an intricate network and potentially expand the possibilities of technical cooperation, patent assignment or dispute risks. Applicants from China constitute a pretty simple but different network in contrast to the former. State-owned enterprise and universities are key nodes that have frequently co-occurred with each side and certain foreign companies (e.g. *Toyota Motor Corporation* and *Canadus Power Systems*). Compared to leading applicants listed in Table 4, for instance, *BYD* and *Bosch* have not presented a similar superiority in each network of cooperation. Whereas, this phenomenon cannot be over-interpreted since this dynamic network is changing because stakeholders and intercompany transactions in the field of e-mobility are on the rise.[26,25,3]

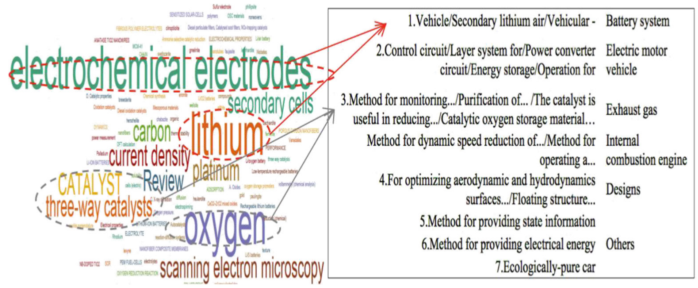


Figure 6: Connections of scientific terms and patent uses.

Science linkages captured from patent citations

Non-patent literatures (NPL) represent explicit connections between scientific research and technological innovations and thus can be used as indices to analyse the features of science–technology linkages. (Tijssen, Buter and Van, 2000). However, applicants might be reluctant to disclose information that invalidates or greatly complicates their efforts to secure a patent. In this paper, we take a glance at NPL citations stated by applicants, which are necessary and unavoidable in laying a knowledge base, and merely collect 52 citations from 23 German patents appearing after 2010. Large enterprises, such as *BMW* and *Siemens,* are main sources of revealing such references and those innovations are performed merely by German teams. Citations consist of 7 conference papers, 23 journal articles and 22 books, which were published since the 1980s and concentrated on a span from 2002 to 2006. For tracing the innovation trajectory in connection with scientific research, the main uses extracted form patent abstracts are correlated to keywords in their citations (Figure 6). Applicants volunteer to disclose relevant art that are mainly applied on patent technologies concerning battery system, electric motor vehicle and exhaust gas.

Legal status of relevant patents

Informed by patent kind codes at the end of publication numbers, 2,048 German patents and 2,340 Chinese patents are granted. The granted ratio of German patents is much lower in view of the aggregate and enterprises still stand out, holding 1,491terms. In China, individuals and enterprise almost split 95% of all granted patents. Utility model is the main type of those documents in both countries, which has less stringent patentability requirements. Accordingly, they cause a shorter average time lag (China: 1.1 years, Germany: 1.8 years) than other forms between priority date and the grant date. Also noticeable is the assignment information revealed by five German patents – individual assignors have transferred their rights, titles, and interests in granted patents to *Robert Bosch GmbH.* Furthermore, part of applications is entering the national phase in various countries other than China and Germany, signaling their intention to pursue patent grants in these areas.

CONCLUSION

Based on comparative analysis of 51,404 e-mobility patents from a green innovation perspective, the present findings indicate that Germany occupies an irreplaceable position in such inventive activities. Extensive international cooperation of inventors and the multi-region diffusion of technologies indirectly identify the relative high quality of these German patents. Two countries have certain technological fields in common, however, China has more patent grants and expresses much concern over emerging technologies of EVs, hybrid vehicles and electric power systems. German patents emphasize the development of conventional vehicles, particularly technologies for the improvement of ICE and exhaust system. Leading German enterprises, as the main actors of innovation, have an absolute advantage in counts and co-applications over other types of participants. Science linkages and their influence on innovation performance are not explicitly captured due to the scarcity of NPL citations, but the origin of main uses decelerated in patent abstracts is traceable. Whereas, if we look far and wide of the whole chain of technological innovation, German firms are more prominent from science-technology interactions to patent trading flows. Conversely, applicants in China are scattered across individuals, universities, local firms and the state-owned enterprises. Even those universities have laid a solid foundation of scientific research, the practical application of their patents is still uncertain owing to few connections to markets. It could be a sign of renewal in e-mobility-related technologies if Chinese enterprises integrate those patents and promote further co-inventions. In addition to the financial incentives focusing on productions and consumers, platforms for gathering information and improving networking among key stakeholders in e-mobility sector can be generalized.

Patents cannot be used to develop a comprehensive measure of innovation because not all innovations are patentable and as well not all patentable inventions are patented. Thus, the major limitation of this study is that characteristics of e-mobility technologies cannot be fully identified by our findings since they are only drawn from patents in eight technological fields and two countries. Nevertheless, issues intercepted from those documents are not to be neglected.

ACKNOWLEDGEMENT

The authors would like to thank for financial supports provided by the China Scholarship Council (No.201506060153), the National Science Foundation of China (No.71673036) and the Consulting Project of Chinese Academy of Engineering (2016-XZ-03-05).

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

1. Dahlin J, Nelles M, Herbes C. Biogas digestate management: Evaluating the attitudes and perceptions of German gardeners towards digestate-based soil amendments. Resources, Conservation and Recycling. 2017;118:27-38.
2. Schwedes O, Kettner S, Tiedtke B. E-mobility in Germany: White hope for a sustainable development or Fig leaf for particular interests? Environmental Science and Policy. 2013;30:72-80.
3. Schiederig T, Tietze F, Herstatt C. What is Green Innovation? A quantitative literature review (No. 63). Working Papers/Technologie-und Innovationsmanagement, Technische Universität Hamburg-Harburg. 2011.
4. Kempton W, Letendre SE. Electric vehicles as a new power source for electric utilities. Transportation Research Part D: Transport and Environment. 1997; 2(3):157-75.
5. Bundesregierung. Nationaler Entwicklungsplan Elektromobilität der Bundesregierung", Berlin, August. 2009.
6. Grauers A, Sarasini S. Karlström M. Why electromobility and what it is? In Sandén, B. (Ed.), Systems Perspectives on Electromobility (page number 10-21). Chalmers University of Technology, Göteborg. 2013.
7. Tagscherer U, Frietsch R. E-mobility in China: Chance or daydream? (No. 40). Fraunhofer ISI Discussion Papers Innovation Systems and Policy Analysis. 2014.
8. World Motor Vehicle Production. 2016. Retrieved August 10, 2017, from OICA: http://www.oica.net/category/production-statistics/2016-statistics/
9. Bundesregierung. Regierungsprogramm Elektromobilität", Berlin: BMWi, BMVBS, BMW, BMBF. 2011.
10. Chinese State Council. Energy-saving and new energy vehicles industry development planning (2012-2020). 2012. Retrieved from http://www.gov.cn/zwgk/2012-07/09/content_2179032.htm
11. Projects and programmes on environment and climate change. 2017. Retrieved August 21, 2017, from GIZ: https://www.giz.de/en/worldwide/377.html
12. Substancial Growth in all Regions. 2017. Retrieved August 30, 2017, from EV volumes: http://www.ev-volumes.com/country/total-world-plug-in-vehicle-volumes/
13. Leal Filho, Walter, *et al.* Fostering Sustainable Mobility in Europe: The Contributions of the Project "E-Mobility North Sea Region". In: E-Mobility in Europe. Springer International Publishing. 2015:3-25.
14. Germany - The World's Automotive Hub of Innovation, Germany Trade and Invest, Ernst and Young European Automotive Survey 2013, retrieved. 2017.
15. MacDougall W. Electromobility in Germany: Vision 2020 and Beyond. Germany Trade and Invest. 2013.
16. Kagermann H. Why E-Mobility is Failing in Germany. 2017. Retrieved July 5, 2017, from an interview with Handelsblatt Global: https://global.handelsblatt.com/companies-markets/why-e-mobility-is-failing-in-germany-790818
17. Truman C. Electric Vehicles in China. 2015.
18. Vergragt PJ, Brown HS. Sustainable mobility: From technological innovation to societal learning. Journal of Cleaner Production. 2007;15(11):1104-15.
19. Dijk M, Orsato RJ, Kemp R. The emergence of an electric mobility trajectory. Energy Policy. 2013;52:135-45.
20. Pilkington A, Dyerson R, Tissier O. The electric vehicle: Patent data as indicators of technological development. World Patent Information. 2002;24(1):5-12.
21. Golembiewski B, Vom Stein N, Sick N, Wiemhöfer HD. Identifying trends in battery technologies with regard to electric mobility: Evidence from patenting activities along and across the battery value chain. Journal of Cleaner Production. 2015;87:800-10.
22. Galus MD, Waraich RA, Noembrini F, Steurs K, Georges G, Boulouchos K, *et al.* Integrating power systems, transport systems and vehicle technology for electric mobility impact assessment and efficient control. IEEE Transactions on Smart Grid. 2012;3(2):934-49.
23. Lai JS, Nelson DJ. Energy management power converters in hybrid electric and fuel cell vehicles. Proceedings of the IEEE. 2007;95(4):766-77.
24. Hess A, Malandrino F, Reinhardt MB, Casetti C, Hummel KA, Barceló-Ordinas JM. Optimal deployment of charging stations for electric vehicular networks. In Proceedings of the first workshop on Urban networking (page number 1-6). ACM. 2012.
25. Capgemini. Managing the Change to e-Mobility. 2012. Retrieved from: http://www.capgemini.com/resource-file-access/resource/pdf/Managing_the_Change_to_e-Mobility___Capgemini_Automotive_Study_2012.pdf.
26. Bakker S. The competitive environment of electric vehicles: An analysis of prototype and production models. Environmental Innovation and Societal Transitions. 2012;2:49-65.
27. Qu Z, Zhang S, Zhang C. Patent research in the field of library and information science: Less useful or difficult to explore?. Scientometrics. 2017;111(1):205-17.
28. Ma J, Porter AL. Analyzing patent topical information to identify technology

pathways and potential opportunities. Scientometrics. 2015;102(1):811-27.

29. Huang MH, Yang HW, Chen DZ. Industry-academia collaboration in fuel cells: A perspective from paper and patent analysis. Scientometrics. 2015;105(2):1301-18.
30. Hascic I, Migotto M. Measuring environmental innovation using patent data. OECD Environment Working Papers. 2015;(89).
31. Daim TU, Rueda G, Martin H, Gerdsri P. Forecasting emerging technologies: Use of bibliometrics and patent analysis. Technological Forecasting and Social Change. 2006;73(8):981-1012.
32. Ross P, Fucito P, Coggins W. USPTO and EPO Announce Launch of Cooperative Patent Classification System. Washington: USPTO Press. 2013.
33. Deason K. Governmental Programs on E-Mobility. Ulm, Germany. 2010. Retrieved from: http://www.iphe.net/docs/Events/uect/final_docs/Ulm_Workshop_Report_FINAL.pdf.
34. Trip JJ, Lima J, Bakker S. Electric mobility policies in the North Sea Region countries. 2012. Retrieved from:http://www.northsearegion.eu/files/repository/20130716113551_3.3__Emobility_policies_in_the_NSR_countries.pdf.pdf.
35. Elektromobilität NP. Progress report of the German National Platform for electric mobility (third report). Berlin: National Platform Elektromobilität. The state council of the people's republic of china (2015). 2012.
36. MacDougall DJ. Electric Vehicle Waves of History: Lessons Learned about Market Deployment of Electric Vehicles. In Electric Vehicles-The Benefits and Barriers. InTech. 2011.