

Article

A Study of Specific Open Innovation Issues from Perspectives of Open Source and Resources—The Series Cases of Tesla

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Abstract: It is difficult for enterprises to adapt to the rapidly developing market demand and increasingly intense competition by relying only on internal resources to carry out innovation activities. We identify three new issues for the Cross-Functional Consortium Families (CFCFs, CF²s) open innovation model based on a cooperating network: participation of large-scale high-tech enterprises (LHEs), impact from open source, and motivation of keeping resource independence. By studying the series cases of Tesla, Inc. (Austin, TX, USA) cooperating with small and medium enterprises (SMEs) through an open source CF² model, we examined and discussed these three issues and gave new connotations to both open innovation and the CF² model from perspectives of open source and resources. This paper also provides strategic reference for other LHEs to mitigate the dependency on key resources and generate new key resources accepted by the environment.

Keywords: open innovation; cross-functional consortium family; open source; resource dependence; electric vehicles (pure electric vehicles); small and medium enterprises (SMEs); case study



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1. Introduction

The concept of open innovation was first proposed by American scholar Henry Chesbrough in 2003 [1]. It is an innovative model of dynamic multi-angle cooperation with multiple partners at all stages of the innovation chain. Chesbrough believes that valuable ideas can come from inside or outside an organization, and enterprises should consciously use these knowledge inputs and outputs to promote internal innovation and expand the external use market of innovation results, respectively, and at the same time, continue to maintain these internal and external sources of the enterprise [2–4]. A brief illustration graph (see Figure 1) is attached to describe the forming of open innovation.

Open innovation can be divided into input innovation and output innovation, product innovation and process innovation, and technology-driven innovation and market-led innovation [5]. At the specific practical level, enterprises usually adopt one or more of the following modes in open innovation practices, such as acquire and development (A&D), joint research and development (R&D), joint venture, and platform integration [6]. It should be noted that the core of open innovation lies in cooperation. Neither using external marketing agencies in the commercialization stage nor entrusting a simple R&D task to a professional enterprise means open innovation [1,4]. If the marketing agency is included in the scope of open innovation, then only when the agency actively participates in cooperation and makes a great contribution to the innovation process through market development, market inspection, or customer demand analysis, will open innovation happen [7].

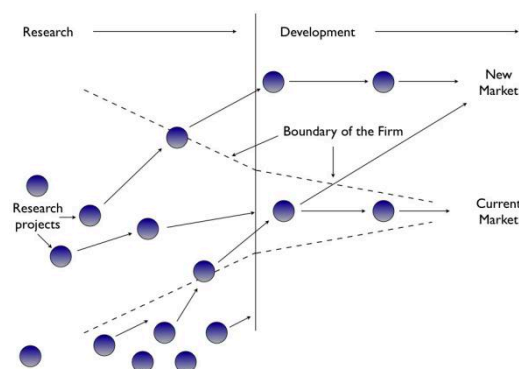


Figure 1. Illustration of open innovation [1].

Accordingly, the cooperation issues under the open innovation framework have been studied at multiple levels and angles, ranging from large-scale enterprises to small and medium enterprises (SMEs), and even many regarding innovative organizations, such as research teams in universities and research institutes [1,4–6]. The basis of such cooperation is to have common interests and consensus, which can be confirmed in some studies regarding strategic alliances, especially the topic of “Exploration vs. Exploitation” [7–10]. It is also generally acknowledged that the exploitation from large-scale high-tech enterprises (LHEs) to SMEs will limit the free opportunities and choice of SMEs in the process of innovation and, therefore, innovative SMEs are more willing to cooperate with other SMEs or institutions (such as universities and private research institutions) to explore potential business value together [5,11]. This conclusion could also be confirmed by Yang’s research on the participation of SMEs in strategic alliances [10]. Is it possible that a better cooperative mode between LHEs and SMEs can leave more free opportunities and choice to SMEs? This is a concern of this article.

We noticed that a series of the open innovation cooperative model called Cross-Functional Consortium Families (CFCFs, CF²s) could possibly describe the cooperative relationship between LHEs and SMEs as above, even though it is an intermediated network model originally described among SMEs [5]. The reason why we made such an assumption is that this model is a kind of mediation model and LHEs may replace the intermediary role set in the original CF² model, such as government departments. Whether it is regarding information, technology, or funding, both government departments and LHEs have commercial resources for innovation that SMEs cannot reach, and these may be needed when creating high-tech large innovations. However, the current research on CF²s focuses more on how to help SMEs obtain value and commercial success than expand more theoretical and practical value and in-depth knowledge of this model. Based on the original CF² model, it is obviously too simple and not convincing to directly replace the intermediary from government departments to LHEs. Therefore, we try to develop a variation of the original CF² model that can better fit the situation we designed.

In this paper, we seek to advance the debate on these issues in several important ways and our study indeed makes several contributions. First, we explain why and how cooperation may happen between LHEs and SMEs under the framework of open innovation and choose a proper cooperative network model for them. Then, our study adds an important missing piece in the research about network models of open innovation. To be specific, we talk about how LHEs participate in the CF² cooperative network as intermediaries, which affirms our previous contribution and broadens the application range of the CF² cooperative model as well. Moreover, the motivation of LHEs participating in the CF² cooperative model to realize open innovation is illustrated and discussed as well. Furthermore, our study contributes to the growing literature of open innovation and resources. Despite rising research interest in the resource-based open innovation issues [6–14], few studies realize the survival and development issues of the enterprise through such perspective, especially studying them in the context of LHEs struggling for

key resources monopolized by giant state enterprises. We think that this level of game can better reflect the value and significance of open innovation. Finally, we provide a strategic reference for other LHEs to mitigate their dependency on key resources and generate new key resources accepted by the environment through open innovation.

2. Problem Definition and Statement

The CF²s, an open innovation cooperation organization composed of business-related SMEs, was first proposed and practiced by KICMS (Korean Integrated Contract Manufacturing Service). The mission of CF²s in Korea is to solve the problem of Korean SMEs participating in innovation. With the help of the intermediaries (such as KICMS), the traditional cooperation model based on reliance on large enterprises or outsourcing from SMEs can develop towards a more open structure [5]. Four types of CF²s are illustrated in the article, which are the R&D-focused CF²s, manufacturing-focused CF²s, marketing-focused CF²s, and new business-focused CF²s. With the help of intermediaries such as KICMS, SMEs can develop into a more open structure through CF²s based on the traditional cooperation model of dependence on large enterprises or outsourcing of SMEs [5]. In the example of the commercialization of WGH antenna technology in South Korea, the KICMS established a R&D-based CF² for enterprise M and provided consulting services in cooperation to help M to manage the whole product production process. Specifically, this CF² helped M to cooperate with enterprises with advantages in antennas, low-cost research and development (R&D) materials, logistics and transportation, and market sales. Finally, it took less than a year to bring WGH antenna technology to the market and successfully signed sales contracts with customers [5].

However, in the in-depth study of CF²s, especially in the process of value acquisition of cooperative network models and innovative results, some new problems have been continuously emerging. The following article will provide a detailed discussion on these issues.

2.1. Participation of LHEs

The existing literature does not fully discuss the success and failure of CF² cooperation and the potential factors of such. Only few cases of cooperation failure due to insufficient funds are discussed in the literature [5]. In addition to funding issues, we ought to be aware of some originality problems of SMEs, such as lacking long-term accumulation of cooperating resources (funds, technology, markets, etc.), the ability to integrate upstream resources, the ability to build and promote downstream markets, and the ability to implement cooperating plans [15]. Moreover, it is difficult for them to accurately grasp market demand and consumption orientation as well.

Let us consider a CF² cooperative model that only consists of SMEs. For some high-tech big innovations that rely on intensive and massive enterprise resources, such as the green energy charging station mentioned below, their commercialized process may be delayed and even increase the risk of its failure to match the innovation results with the market and eventually lead to failure of cooperation [16].

On the other hand, in the process of innovation, SMEs mainly face the shortage of human resources and the mismatch of innovation achievements with the market, while LHEs mainly face the problems of monopolistic market structure and high innovation costs [5]. LHEs can use the advantages of SMEs to break the monopolization of market structure and obtain innovation achievement in a reasonable way. Meanwhile, SMEs can also make use of the resources of large enterprises to solve problems such as the mismatch of innovation results with the market and shortage of human resources. Since it is reasonable and necessary for large enterprises to participate in CF² cooperation, under the framework of CF² cooperation, can SMEs cooperate with LHEs while preserving the free opportunities and choice space? Moreover, if such LHEs can participate in or even lead the construction of CF²s, does this practice have a deeper meaning?

It should be noted that our discussion on the possibility of cooperation between LHEs and SMEs in the form of CF²s should be based on the basic framework of open innovation as well. SMEs cannot just use the resources of LHEs to achieve “technical exploitation” and market expansion during the commercialization stage, nor do they simply hand over certain R&D or production tasks to LHEs. LHEs need to deeply participate in open innovation cooperation and make important contributions in one or even more sectors [1,3].

2.2. Potential Impact of Open Source on CF²s

In the beginning, the word “open source” originated in software development and refers to a special form of software development. Now, “open source” has broadly referred to a set of concepts, including open-source projects, products, or spontaneously advocating and welcoming open changes, cooperative participation, openness, transparency, and the principles of community-oriented development, etc. [14]. If enterprises develop their own products through open-source practicing and commercializing, internally or externally, they can also be considered to have used open innovation methods because the business model allows them to derive value from them. The business model based on open-source projects has become more and more mature. Moreover, if some of the projects and products of an enterprise have determined commercial value and expectation, the open-source model can be implemented to accelerate the improvement of its influence, empower cooperative partners, so as to enhance the ability to realize commercialization. Of course, the choice of the open-source model also needs to be linked to the core business strategy of the enterprise to ensure the continuity of investment [17].

Through the establishment of an open-source innovation platform, LHEs gather creative and innovative resources from all over the world, bring together suppliers and demanders of knowledge innovation, and continue to produce innovative products. It can help enterprises solve the “Where” and “Why” in innovation, help innovators solve the marketization and commercialization of innovation results, and help innovators find like-minded people and innovate together [18]. Under the framework of open innovation, the concept of open source can be combined with CF²s to realize “freedom in cooperation, and cooperation in freedom.” Regardless of whether the members participating in cooperative innovation are LHEs or SMEs, they can choose under the premise of cooperation and finally obtain value through a reasonable model.

2.3. Motivation of Keeping Resources Independence

In the process of open innovation, SMEs are most likely to use the resources of external partners to focus on maintaining high levels of internal capabilities in certain specific technical fields [11,19]. In the case of the WGH antenna provided by KICMS in Lee’s research, the researchers just seemed to demonstrate the success of the CF² cooperation model based on how M’s sales had increased, how costs had been reduced, and how quickly enterprise M could conduct the final sales contract with customers [5]. This research on the CF² focused more on how to help SMEs obtain value and commercial success. We also noticed that innovating antennas did not require high-intensity innovative resources, such a case was not conducive to continuing to explore the theoretical value of the CF² model.

Among all the members in the CF²s, no matter if SMEs, LHEs associated with SMEs, or research institutions, they are actually not able to provide all the resources needed for their own survival and development by themselves. Everyone is living and developing by exchanging resources with others from the environment [20]. Therefore, rather than commercial success and value creation, our discussion of the theoretical value of CF²s should be more on the survival and development of the organization and achieved sustainable development through producing valuable innovations continuously. Since the original purpose of CF²s was to reduce the outsourcing needs of SMEs in the innovation process and their dependence on large enterprises, we can also conduct an in-depth analysis of CF²s from affecting the relationship of dependence and demand on some key resources.

Specifically, we are concerned with how to use the CF² model to reduce dependence on key resources on a wider occasion, and the beneficiaries were not limited to SMEs.

3. Literature Review

Henry Chesbrough initially coined the term “open innovation” in 2003 to describe the dynamic communication between the enterprise and the outside world and the development and utilization of a large amount of external knowledge. At this point of view, enterprises also continuously strengthen the maintenance of their external knowledge and regard its relationship with the external organization as an extension of the organization’s internal knowledge [1,3,4]. Therefore, in the process of open innovation, enterprises usually need to focus on the establishment and maintenance of relationships with other external organizations. The resource-based theory predicts the potential of partners to provide additional resources and provides a powerful reference for the establishment of a cooperative network [21]. So, for enterprises, especially many SMEs, what kind of partners should they choose? What kind of model is needed to build and maintain a cooperative network?

Open innovation has brought more extensive cooperation and more knowledge sharing and knowledge transfer to enterprises [1,3]. Due to the close cooperation and liquidity of technologies and patents, it is easy for an enterprise to face the risk of losing intellectual property rights and unfair competition of intellectual property rights [3,6]. This puts forward higher requirements for the protection of intellectual property rights of enterprises and the protection to which can neither be insufficient nor excessive [22].

Commonly, SMEs do not have the advantages of in-company resources such as obtaining information and capital like many LHEs, and so undertake specialized and intelligent processes to find partners, competitors, and customers from the outside [11]. They need to find a way to achieve their goals within limited resources, form the production scale, effectively promote the products, and provide customer-satisfied service support [5]. Technology intermediaries can meet these needs of SMEs as a non-governmental organization that provides necessary information, resources, and services for the integration of technology and economy, and serves SMEs [23]. The responsibility of the technology intermediary is to be responsible for the production, transfer, and transformation and application of technical knowledge, making it easier for decentralized scientific and technological innovation achievements to penetrate into the enterprise through the boundaries [24]. To realize open innovation, SMEs need to find suitable partners and obtain sufficient innovation resources, so technology intermediaries will play an important role in this process.

Among all the technology intermediaries that can help SMEs realize open innovation, the CF² model is a notable model. This model was initially proposed and practiced by KMCIS and mainly based on the establishment of a dynamic cooperative relationship between SMEs so as to achieve complementary advantages [5]. However, it cannot be ignored that LHEs also have the need to integrate ideas from SMEs and participate in innovation together. Similarly, SMEs can also use the resources of LHEs to better achieve innovation, or participate in the innovation process, and finally realize innovation and obtain value through innovation outcomes at a reasonable cost. To LHEs, such achievement also affects their dependence on certain key resources from the environment and is related to the motivation to seek open innovation as well [15,25].

Under the framework of resource dependence theory, organizations cannot generate some kinds of necessary resources by themselves. These resources are also known as a “Key Resource” [25]. The resource dependence relationship between an organization to another one consists of three such items: importance of resources to the survival, discretion in the allocation and use of resources, and availability of an alternative resource. Generally speaking, they are “importance, autonomy, substitutability” [25]. Since the organization’s power source is based on the control of key resources, which cannot be produced by the organization itself, the organization needs to interact with the external environment and obtain key resources to maintain the survival of the organization and expand the power of the organization, so as to finally realize the development and success of the organization [8].

At this time, the organization needs a rational and effective structural form to effectively grasp the input and output resources in the environment [15]. The organizations that exchange resources with organizations are other organizations in the environment. Therefore, the relationship between the organization and the environment can be equivalent to the relationship between the organization and the organization with different resources in the environment, and the dependence on resources between organizations is the object of resource dependence theory discussion [2].

4. Hypothesis and Research Method

4.1. Hypothesis and Description

Hypothesis 1 (H1). *The concept of open source can be introduced into the CF² model and deeply change its cooperative mode among the participators of the CF² model.*

Supplemental Description of Hypothesis 1 (H1). LHEs that adopt the concept of open source introduced into a CF² model and play an intermediary role in it, which can produce market-competitive large innovations at a reasonable cost, break the market structure monopoly and expand new markets. The prerequisites of this hypothesis are related to the value acquisition sector, which is that the marketization and commercialization of innovation outcomes require the support and cooperation of relatively intensive enterprise resources (funds, technology, markets, etc.).

Hypothesis 2 (H2). *The main purpose of a large-scale high-tech enterprise building a CF² with SMEs and other innovative units through an open source based CF² model can be mitigating the dependence to some key resource providers and generating new key resources admitted by the environment.*

Supplemental Description of Hypothesis 2 (H2). The theoretical value of forming a CF² and conducting open innovation is to obtain innovation achievements that help reduce dependence on key resources and increase organizational power in a reasonable and efficient organizational form, the final goal of which is to improve the survival and development conditions.

4.2. Research Methods

4.2.1. Research Design

The research design is a series cases of the same enterprise, Tesla, in which these cases are treated as a series of independent experiments that confirm or disconfirm emerging conceptual insights and finally test the hypotheses mentioned in the previous subchapter [26,27]. In this article, we mainly referred to Kathleen M. Eisenhardt's case study research method to develop and proof arguments and theories, and there are some changes in details. As to information and data regarding this research, they were mainly gathered from the Tesla official website and relevant official reports, literature research, third party media reports, information and data from Tesla's collaborators, and some other real-time observations and retrospective data.

We chose Tesla, Inc. (also known as Tesla) as the research object, which is the main role of the series cases. It is necessary to give a brief introduction to this enterprise. In 2003, a group of engineers who wanted to prove that electric vehicles are better, faster, and have more driving pleasure than fuel vehicles founded Tesla in the United States. Today, Tesla not only manufactures pure electric vehicles but also produces clean energy collection and storage products that can be expanded infinitely. Tesla believes that the sooner the world can eliminate dependence on fossil fuels and move towards zero emissions, the prospects for mankind will be better (from <https://www.tesla.com> accessed on 17 November 2021).

We need to explain why and how Tesla meets our research needs. Firstly, Tesla is one of the most valuable LHEs in the world and focuses relentlessly on innovation and

relies on all kinds of technological and commercial cooperation to help achieve goals of technological and commercial success and further reducing carbon emissions as well [28]. Second, Tesla has built a “shared, fast-evolving open-source technology platform” for technology innovation and commercialization, providing a good example for open innovation cooperation between LHEs and SMEs in line with the main idea of this article [29]. Finally, but most importantly, in recent years, Tesla has fallen into tough and endless negotiation with State Grid in China regarding charging station construction and charging interface divergences. There are many signs that Tesla is looking to solutions for these problems through this platform.

4.2.2. Data and Information Collection

We mainly collected information and data through interviews, observations, and some secondary sources. The primary sources were interviews as well as some secondary sources, such as all kinds of Tesla official reports, United States patents database, and authoritative and famous third-party media reports.

We conducted some remote and on-site interviews to support our research. As to interviewees, we tried our best to spread the interviewees across the entire industry chain, so we chose a lithium battery technology researcher from Peking University (PKU); a policymaker of State Grid Corporation of China (State Grid); a senior vice president of a famous listed lithium battery manufacturing enterprise in China; a senior partner of a well-known private equity investment institution in China who led several rounds of investment in electric vehicles and the smart manufacturing industry; a Tesla staff member in Beijing, China; and the CEO of an SME in the industrial vision area. All the descriptions of these interviewees were summarized in Table 1. We believed that these interviews could help us understand Tesla’s open innovation strategies more objectively and efficiently.

Table 1. Information of interviewees.

Interviewee’s Pseudonym	Prometheus	Selene	Glauke	Zeus	Themis	Boreas
Domain	Scientific research	Power industry	Battery industry	Private equity	Automobile industry	Industrial vision
Position	Postdoctoral Researcher	Director	Senior Vice President	Senior Partner	Manager	CEO
Employer information	Peking University	State Grid Corporation in China	Gotion High-tech Co., Ltd.	Zhejiang Silicon Paradise Asset Management Group	Tesla, Inc.	Boyan Intelligence Technology Co., Ltd.
Employer characteristic	University and Research Institute	State-owned Company	LHE	Investment Institute	LHE	SME
Location	Beijing, China	Beijing, China	Hefei, Anhui, China	Hangzhou, Zhejiang, China	Beijing, China	Hefei, Anhui, China
Age	27	63	51	39	26	42
Seniority (working years)	1 (exclusive of graduate period)	40	26	14	4	17
Interview format	Phone call	Phone call	On-site	On-site	Phone call	On-site
Number of interviews	2	1	1	1	1	1

5. Case Study on Tesla

5.1. Case 1: Tesla’s Open-Source Strategy

5.1.1. Case Background

On 12 June 2014, the CEO of Tesla Motors, Inc. (henceforth “Tesla”, now “Tesla, Inc.”) announced that “All our patents are belong to you” on the official website [29]. As the 2018 Tesla impact report described, this strategy was considered as a mission of Tesla:

We recognize that we cannot achieve our mission alone, so we decided to open source Tesla patents, making them accessible to anyone who wants to design and build electric vehicles [30].

Tesla has been dedicated to building a “shared and fast-evolving open source technology platform” through open-source movement [30]. The cooperative model also provides free and efficient cooperation between Tesla and SMEs and lays a good foundation to innovation. As Tesla’s impact report revealed, Tesla is willing to work with others in the industry to drive greater transparency, opportunity, and equity in its supply chain and reduce carbon emissions at every level [28]. This model can be mainly divided into the following steps:

A. A. A. Patent Open-Source Strategy

Under the patent open-source model, enterprises do not need to deliberately protect intellectual property rights but can transfer intellectual property rights to other enterprises or even competitors in the form of outsourcing or licensing operations, so that intellectual property rights can generate greater benefit [18,31]. Tesla uses its own open-source patents to create a “shared, fast-evolving open source technology platform” that absorbs innovative resources from all over the world and avoids falling into the centralization and monopoly of scientific and technological information, thereby reducing the obstacles between Tesla and SMEs [29,32].

It is also worth mentioning that the patent open-source strategy is benefiting everyone, including cooperating partners, competitors, and neutrals, which is another important contribution of this strategy. For those enterprises that have not joined Tesla’s open innovation platform, Tesla’s patent open-source strategy still has its positive value to them. The patent describes Tesla’s specific solutions for each technical point with few implementation details and feasible value, so these opened patents are not instructive at all [32]. Other enterprises do not need to deliberately bypass Tesla’s patents while innovating, which is a real contribution to the industry and market [12,29].

A. B. B. Technical Standard Promotion

In the past ten years, Tesla has been raising its technical thresholds and barriers, technically forming a greater advantage to its global competitors and providing technical support for its open-source strategy [33]. In addition, Tesla exports its technical standards through its open-source strategy, making its own technical standards more universal. On this basis, Tesla’s leadership in the construction of infrastructure, such as charging facilities and the unification of charging standards, are obviously not a problem [29,32].

A. C. C. Infrastructure Layout and Construction

Charging facilities are an important part of Tesla’s open-source strategy and infrastructure construction. Tesla has already deployed nearly 2000 super charging stations and nearly 20,000 fast charging piles around the world [28]. For enterprises interested in cooperating with Tesla, if they want to use Tesla’s open-source technology patents and ready-made fast charging piles, they must also accept the matching technical standards, especially the technical standards for charging [29,32]. Binding the innovation outcomes to the hardware ensures the close relationship between Tesla and the partners.

5.1.2. Patent Data Statistics

Since Tesla announced and implemented its patent open-source strategy in 2014, considering the delay effect of the strategy, we focused on data collection of Tesla’s patents in two periods: from starting up to 2015 and from 2016 to the present. For the first part, we referenced the data from Moritz’s work in 2015, while we mainly relied on the official database of the US Patent and Trademark Office (USPTO) to search for the patent data for Tesla for the second part [29]. We then developed corresponding conclusions by comparing and analyzing the patent data of these two time periods.

We should also explain publicly how we have collected the patent data of Tesla from 2016 to the present. Since Tesla changed its official name from “Tesla Motors, Inc.” to “Tesla, Inc.” in Feb 2017, and had a Canadian branch named “Tesla Motors Canada”, we had to find suitable searching and statistical strategies for it. Here are the specific steps: We counted all the patents where the applicant was “Tesla, Inc.” and “Tesla Motors Canada”, also inclusive of all the patents in 2016 that the applicant was “Tesla Motors, Inc.”.

Regarding the patents categorizing method, we referenced Moritz’s work, who had categorized all the patents into these columns: battery, charging, motor, user interface, cooling and coolant, audio, and “not categorized” [29]. Comparing to his, we deleted the “audio” column and added “driving” and “energy storage” columns in our categorizing work. We believed that such a statistical method could minimize errors and bring relatively accurate results and better fit the cases mentioned before as well.

Here, we demonstrate the column graphs and pie charts of these two periods as figures below. For better comparison, we remastered Moritz’s work.

5.1.3. Analysis and Conclusion

With no theoretical preferences, we began with an in-depth analysis of each case through the lens of our research question [27]: How does the open-source strategy impact the CF² cooperating model?

Firstly, we noticed that these charts and graphs (see Figure 2a,b and Figure 3a,b) reflected Tesla’s electric vehicles technologies layout to some extent. Before implementing the patent open-source strategy in 2014, Tesla’s main R&D focus was on the battery, as Figure 2a,b shows. Since 2015, Tesla started to focus on some new areas: solar energy, auto driving, and energy storage. Correspondingly, the percentage of battery patents decreased during this time. At this point, combining the information of CF² cooperating partners of Tesla in the following cases, it seems that Tesla’s R&D focus shifted to photovoltaics and energy storage; of course, the battery technologies were still necessary to Tesla.

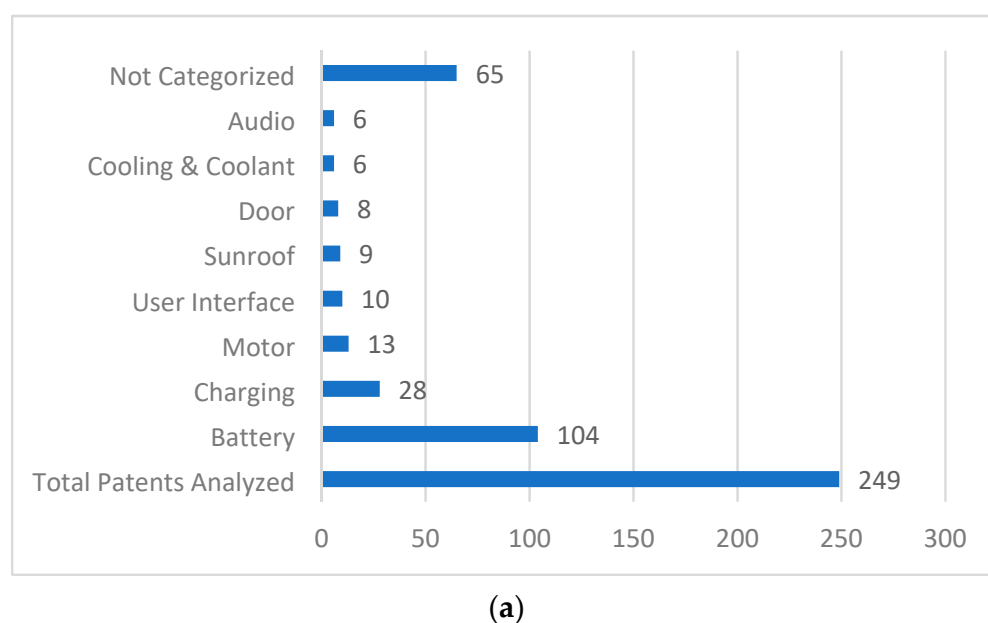


Figure 2. Cont.

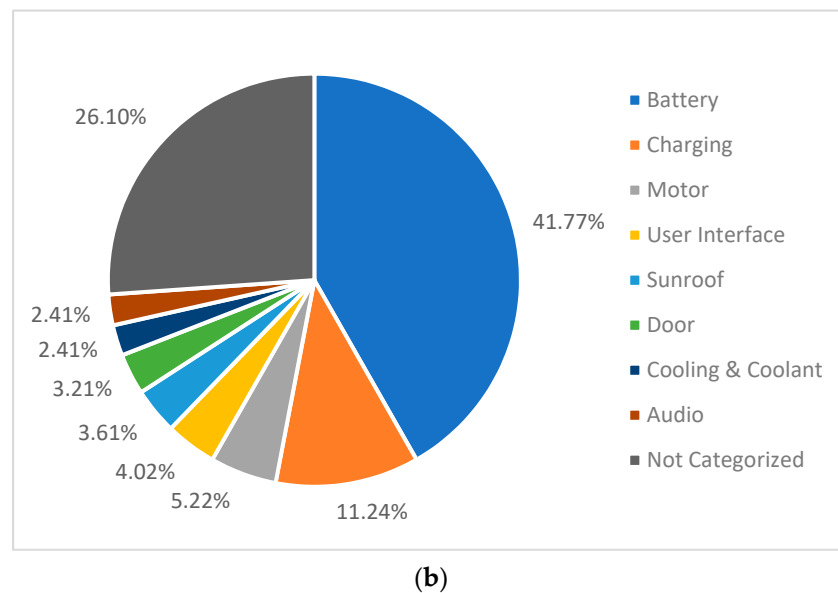


Figure 2. (a) Column graph of Tesla patents by category up to 2015 (remastered from [29]). (b) Pie chart of Tesla patents by category up to 2015 (remastered from [29]).

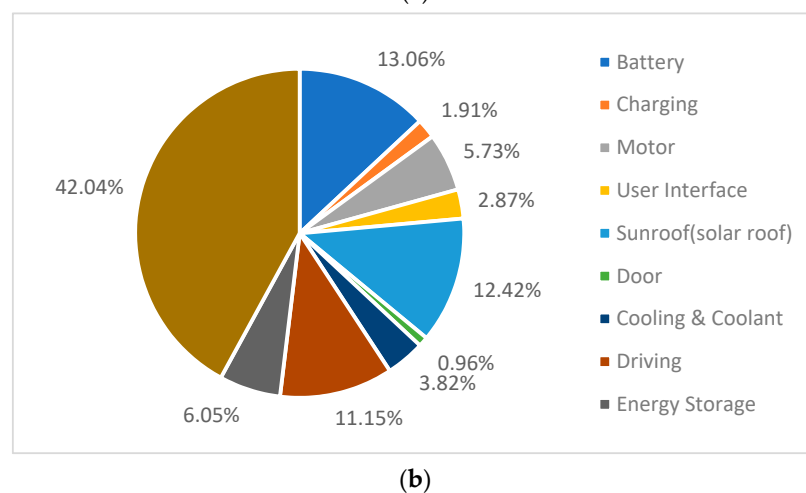
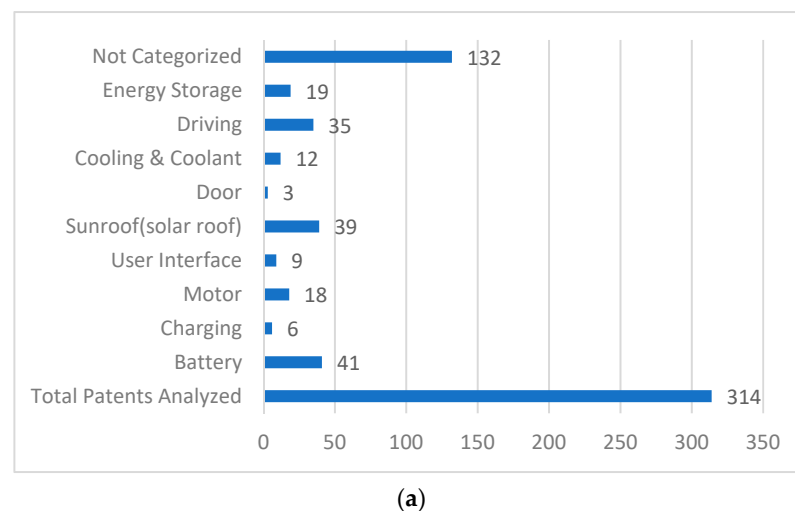


Figure 3. (a) Column graph of Tesla patents by category since 2016 (source: USPTO <https://appft.uspto.gov/netahtml/PTO/index.html> accessed on 20 November 2021). (b) Pie chart of Tesla patents by category since 2016 (source: USPTO <https://appft.uspto.gov/netahtml/PTO/index.html> accessed on 20 November 2021).

However, developing the above argument only by patent statistics data is obviously a bit hasty. To better explain the argument mentioned above, we performed key words frequency statistics on Tesla's impact reports from 2018 to 2020 to support and supply our argument. Here, we present the statistics results in Table 2 and Figure 4a–c.

Table 2. Key words frequency statistics of Tesla's 2018–2020 impact reports.

Frequency of the Key Words	Years		
	2018	2019	2020
Batt—(Battery, Batteries)	53	68	117
Renewable	13	20	19
Sustain—(Sustainable, Sustainability, Sustainably, Sustained)	44	36	62
Emission	36	96	180
Carbon	6	29	35
Solar	49	45	92
Wind	4	1	3
Ecosystem	3	5	8
Environment	26	30	60
Stor—(Store, Storage, Stored)	26	23	28
Pollut—(Pollution, Polluting, Pollutant, Polluter)	3	13	19
Total number of key words	263	366	623

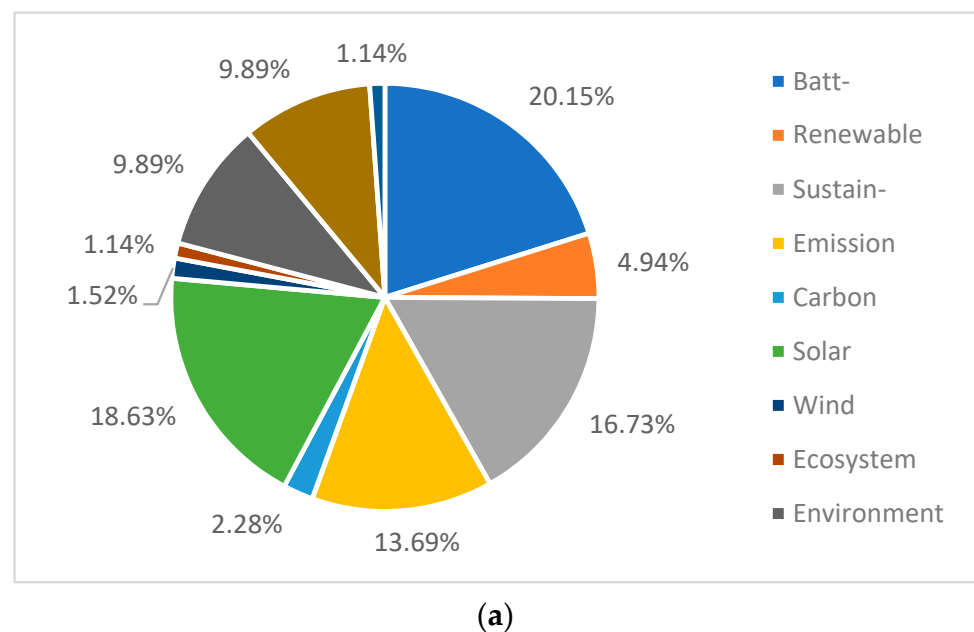


Figure 4. Cont.

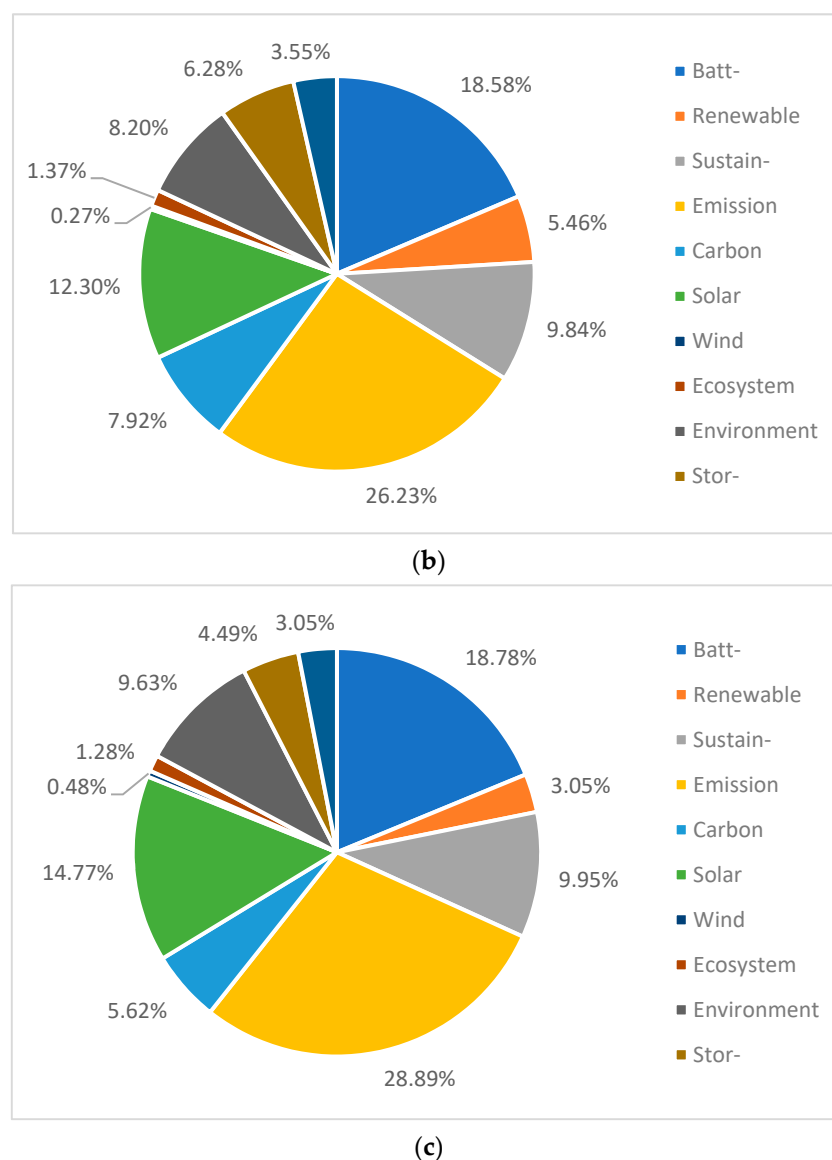


Figure 4. (a). The pie chart of key words frequency statistics of Tesla's 2018 impact report. (b). The pie chart of key words frequency statistics of Tesla's 2019 impact report. (c). The pie chart of key words frequency statistics of Tesla's 2020 impact report [28,30,34].

As can be seen, although the total number of key words was increasing, Tesla's 2018–2020 strategic focus was always on the following four perspectives: batteries, photo-voltaics, sustainability, and emissions issues (mainly CO₂ and other greenhouse gas emissions). It is worth mentioning that the percentage of the key word “emission” increased from 13.69% to 28.89%. Combining the statistics results of both patents categorization and key words frequency from impact reports, as well as the innovation information in Table 3, all these key words can logically point to the imagination, planning, and construction of Tesla's Green Energy Fast Charging Station: Ladepark Kreuz Hilden (LKH) in the next case. As the benchmark of Tesla's charging stations, the missions of LKH were to generate and consume green energy and reduce carbon emissions and develop an energy storage system which consisted of batteries and capacitors, which was used to store unstable clean energy and transferred it into stable charging power. Prometheus, working at Peking University, had some comments on green energy and its generation:

Table 3. Description of technologies and innovations regarding Tesla’s green energy charging station.

No.	Date	Related Enterprise and Organization	Innovation Item	Description	Relationship with Tesla
1	October 2020	Tesla, Inc. and its partners	Ladepark Kreuz Hilden Green Energy Charging Station (LKH)	Located in Dusseldorf, Germany. A total 28 charging piles, 20 Tesla V3 Superchargers, and 8 Fastned chargers capable of speeds of up to 300 kW. Powered by solar and wind energy, as it is equipped with a large solar roof.	-
2	October 2016	Tesla, Inc.	Solar Roof	A building-integrated photovoltaic (BIPV) product that functions as both a roofing material and a photovoltaic solar panel system.	-
3	April 2015	Tesla, Inc.	Powerwall and Powerpack	Powerwall: lithium-ion battery packs that can store electrical energy from renewable energy generation. Powerpack: based on Powerwall, higher capacity that could be scaled indefinitely to GWh capacities.	-
4	September 2012 now	Tesla, Inc.	Supercharger V1-V3	Supercharger V1 and V2: up to 150 kW charging power (through over the air update). Supercharger V3: up to 250 kW charging power. Assisted by Tesla’s liquid-cooling cables and super charging stations.	-
5	August 2010 now	Chademo Association	CHAdEMO (CHArge de Move)	CHAdEMO 1.0: up to 62.5 kW by 500 V, 125 A direct current via a special electrical connector. Revised CHAdEMO 2.0: up to 400 kW by 1000 V, 400 A direct current.	A Japanese technological association. Standards compatible with Tesla.
6	May 2012 now	SAE (Society of Automotive Engineers) and ACEA (Association des Constructeurs Européens d’Automobiles)	CCS (Combined Charging System)	Accepted by many European and Japanese electric vehicle manufacturers. Varying speeds ranging from 43 kW up to 450 kW.	Associations and electric vehicle manufacturers alliances, compatible with Tesla.
7	September 2020	Jeff Dahn’s Team	Representative Electrolyte Technology Innovation (during cooperation)	Louli, A.J., Eldesoky, A., Weber, R., Genovese, M., and Dahn, J.R. (2020). Diagnosing and correcting anode-free cell failure via electrolyte and morphological analysis. <i>Nature Energy</i> , 5(9), 1–10.	Research team, sponsored by Tesla via “NSERC/Tesla Canada Industrial Research” project since 2016.
8	August 2019	Jeff Dahn’s Team	Representative Expanding Battery Life Research Progress (during cooperation)	Weber, R., Genovese, M., Louli, A.J. et al. (2019). Long cycle life and dendrite-free lithium morphology in anode-free lithium pouch cells enabled by a dual-salt liquid electrolyte. <i>Nature Energy</i> 4, 683–689.	Research team, sponsored by Tesla via “NSERC/Tesla Canada Industrial Research” project since 2016.
9	May 2020	CATL Co., Ltd. (Contemporary Amperex Technology Co., Ltd.)	Battery Innovation: Cobalt-free Electrode Materials	CATL’s cobalt-free LFP/LFMP batteries. Cost per kWh (cell): ~60 USD. Cost per kWh (battery): ~80 USD. Pros: High power density, safe, high cycle life, low cost. Cons: Gravimetric and volumetric energy densities, are not as high as in NCM and NCA chemistries.	LHE, Tesla’s upstream supplier, may be invested by Tesla in the future.

Table 3. Cont.

No.	Date	Related Enterprise and Organization	Innovation Item	Description	Relationship with Tesla
10	September 2019	CATL Co., Ltd. (Contemporary Amperex Technology Co., Ltd.)	Battery Manufacturing and Assemble Innovation	CATL CTP (Cell-To-Pack) highly integrated power battery development platform: battery cells directly integrated into the battery pack. Volume utilization rate increased by 15–20%; quantity of battery pack components reduced by 40%; production efficiency increased by 50%; energy density of traditional battery packs averages 180 Wh/kg, while the energy density of CTP battery packs can reach more than 200 Wh/kg.	LHE, Tesla's upstream supplier, may be invested by Tesla in the future.
11	August 2014	Maxwell Technologies	DuraBlue® Technology	DuraBlue® technology solved the technical characteristics of anti-shock, anti-vibration, and anti-overcharge. The anti-shock and anti-vibration levels are increased by 3 times and 4 times, respectively, and were more suitable for the application of electric vehicles and hybrid buses.	SME, acquired by Tesla in February 2019.
12	March 2014	Maxwell Technologies	Dry Electrode Process	Working by fibrilizing bits of PTFE (Teflon) mixed with particles of active electrode material, resulting in a self-supporting film of anode or cathode material. The cell energy density can be improved to more than 300 Wh/kg and even 500 Wh/kg in the future. After 1500 cycles of charging and discharging, the battery still retains 90% of its capacity.	SME, acquired by Tesla in February 2019.
13	April 2019	Hibar Systems Ltd.	High-speed lithium-ion battery manufacturing systems based on advanced Automated Vacuum Filling Systems	Alleviate the problem of Tesla's insufficient battery manufacturing capacity and reduce the costs.	SME, acquired by Tesla in October 2019.
14	May 2017	Tesvolt GmbH	TS System	Can be recycled 6000 times on a 100% discharge basis and 4500 times at a normal temperature of 23 °C. Will solve the pain point of the instability of the photovoltaic energy storage system.	SME, Tesla's upstream supplier.
15	May 2014	SolarCity Corporation	Distributed Power Generation System	The fixed cost of distributed power generation and the absence of grid transmission fees have made the cost of rooftop photovoltaic power lower than traditional grid retail electricity prices.	SME, acquired by Tesla in November 2016.
16	August 2015	Silevo, Inc.	Triex™	Integrating a high-performance N-type crystalline silicon substrate, thin-film passivation layer, and tunneling oxide layer into a solar cell module reduces manufacturing costs while improving conversion efficiency to 24% as maximum.	SME, acquired by SolarCity Corporation (acquired by Tesla) in June 2014.

Table 3. Cont.

No.	Date	Related Enterprise and Organization	Innovation Item	Description	Relationship with Tesla
17	January 2019	Vestas Wind System A/S	EnVentus™	Built on Vestas 2 MW, 4 MW, and 9 MW platforms, the Vesta EnVentus™ platform can more efficiently meet customer customization needs through advanced modular design.	SME, corporation with Tesla since 2017.
18	-	Fastned B.V.	-	A Dutch enterprise that owns and operates a network of over 100 EV charging stations in the Netherlands, Germany, the United Kingdom, Belgium, and Switzerland.	SME, corporation with Tesla since 2020.
19	-	Seed & Greet Bakery	-	Provide dining service for customers waiting for electric vehicles charging as a value-added service.	SME, corporation with Tesla since 2020.

The off-grid charging was very hard to realize. First, the efficiency of photovoltaics and wind turbines was limited. Then, the power output of them is not stable at all The first task (for Tesla) is to find a solution to store the electricity generated from photovoltaics and wind turbines, and then build private photovoltaics and wind turbines farms.

More broadly, our findings offered a holistic (i.e., relatively complete and integrated) view that the patent open-source strategy from the LHE has a guiding significance for the innovation direction of SMEs participating in the open innovation platform led by the same LHE. The LHE formulated open patent strategies and attracted SMEs to join the open innovation platform for innovation by both a technical guide through open-source patents and funds incentive (strategic investment, merger or acquisition, and research funds sponsoring). Under the guidance of a patent open source and supporting other necessary resources from the LHE, SMEs could fully focus on their own internal ability to provide more possibilities to the CF² corporation organization. Of course, the cooperation of funds for a patent open source is also very important. We will go on, discussing this part in the following cases.

5.2. Case Study on Tesla's Green Energy Fast Charging Station: Ladepark Kreuz Hilden

5.2.1. Case Background

Tesla's green energy fast charging station LKH (as Figure 5 showed) is Tesla's benchmarking project combining charging technology, battery technology, and green energy generation technology. It was built in 2020 and mainly served Tesla's customers (also a small number of Nissan, BMW, and Hyundai customers). Based on Table 3, its charging interface standards came from Tesla and other technological alliances (Supercharger, CCS, and CHAdeMO). Battery technology mainly came from lithium battery expert Jeff Dahn's team (electrolyte and battery life), Contemporary Amperex Technology Co., Ltd. (Yichun, China) (CATL, battery assembly and cobalt-free electrode materials), MAXWELL (super capacitor and dry electrode technology), and Hibar (battery manufacturing process and battery cell production). German enterprise Tesvolt supplied capacitors for the charging station. Photovoltaic panels came from Solar City and Silevo in the USA and the wind power fans were mainly from Vestas in Denmark. Fastned and Seed & Greet in the Netherlands were responsible for the main market operations and management services in Europe. Except for CATL, most of the enterprises involved in the case are SMEs which were all fully or partially funded and held or acquired by Tesla.



Figure 5. Tesla's green energy fast charging station, Ladepark Kreuz Hilden (source: <https://www.electrive.net/2020/10/08/schnellladepark-seed-greet-am-kreuz-hilden-eroeffnet/> accessed on 21 November 2021).

5.2.2. Analysis and Conclusion

Based on the observation of the case, LHEs, through acquisitions and holdings, ensure the source of funds for SMEs participating in innovation to achieve the innovation process and, firstly, solve the most common problem of the shortage of funds in the failure of innovation of SMEs. Accordingly, the open-source innovation platform emphasizes the concepts of independence and community operation, and guides and assists SMEs in linking global innovation resources through the platform. This points out the direction of cooperative innovation for SMEs and indirectly solves the shortage of human resources faced by SMEs in the innovation process, so that they can fully focus on their own internal ability to provide more possibilities for opportunities and choice space in the innovation process.

SMEs are also facing the problem of VUCA during innovating, which stands for volatility, uncertainty, complexity, and ambiguity [35]. The current world is changing at a different speed from the past. The relatively fragmented innovations of SMEs need to face unavoidable and unpredictable challenges. Furthermore, the mismatch between innovations and the market cannot be ignored. If SMEs' innovations can be integrated into a part of the supply chain of LHEs and converged into the market to accept large-scale innovations with strong competitiveness, the risk of mismatch between the innovations of SMEs and the market may be reduced.

On the other hand, the marketization and commercialization of some large-scale innovations require intensive cooperating resources as support, which is difficult for SMEs to provide. Tesla not only plays the role of an intermediary in the CF² but also uses its own strong enterprise resources to support innovation activities and innovation outcomes, mainly from the three dimensions of funding, technology, and market. Therefore, we can reach the following conclusions that LHEs that adopt specific open-source strategies can form market-focused CF²s to cooperate with SMEs, and finally they will export market-competitive innovations to the market, break the monopoly of the original market path, and even open up new markets.

Finally, we should also discuss the free opportunities and choices for SMEs through the innovating of the LHE [36]. Based on our observation and archive data of this case, Tesla's intellectual property management was very simple and direct. Except for opening their own patents, Tesla would directly acquire its partners or other SMEs for their technologies or patents necessary to Tesla, because Tesla seemed not short of money, market, and commercial opportunities anyway. Moreover, from the SME manager's view, mergers and acquisitions by LHEs could also bring more opportunities to them at the strategic and organizational levels [16].

5.2.3. Discussion on Limitations

Limited by many factors, such as technology, even if the innovations are marketized and commercialized, it cannot help innovators to completely eliminate the dependence on some key resources [12]. In this case, electric power generated by photovoltaic and wind power is unstable and limited, and the demand of electricity for charging electric

vehicles can only be met on the premise of power supply from the grid; so-called “off-grid charging” cannot be really achieved. This can be evidenced by Tesla’s need for a professional operating enterprise to coordinate the relationship between the charging station and the local power grid.

Intellectual property and other related issues in open innovation were not perfectly solved during the case study above. Mainstream academics worried intellectual property issues were an obstacle hindering the application of open innovation [1,4,31]. For many SMEs participating in open innovation, the integrity of their intellectual property management system was limited, and the internal and external complexity was relatively high. Moreover, the technology applications were usually in high liquidity and with no significant border, which would lead to many risks and threats in the development of enterprises [21].

In the case of LKH, most of the SMEs were acquired by Tesla. Direct mergers or acquisitions may be the easiest way to solve intellectual property issues but only apply to conditions of both abundant funds and proper investment time. The timing of mergers and acquisitions usually depends on the events that take place in the acquired company. Besides, from the acquiree’s view, acquisitions from LHEs may succeed when target SMEs meet strategic problems or their TMT (top management team) have special personal situations [16,36]. These were also verified in the interview with Boreas. Boreas, an entrepreneur in the field of industrial vision, let us observe the potential relationship between the acquirer and the acquiree from the perspective of SMEs (usually the acquiree part):

The biggest problem of us in the early stage is arrogance in our technologies and products. We were so confident of them that we ignored the true needs and the volume of the market Honesty speaking, we have missed lots of opportunities then Now we are seeking for possibility to be the supplier of two listed LHEs, helping them upgrade industrial vision chips in their products such as color sorters and high-speed cameras In fact we are not so keen to IPO (Initial Public Offerings), acquired by any one of these two LHEs is also acceptable to us Everyone will get plenty of money instantly and have a good position as well (in the new enterprise) From my personal view, I have family to feed, and am paying off the house loan for the apartment in Shanghai.

Boreas’s situation meets the two conditions of the acquisitions that may happen, which are meeting strategic problems (missing the golden development stage for many reasons) and personal reasons of the TMT (money and position incentives) [16,36]. However, the premise of all these is that his enterprise has to be a supplier of at least one of the LHEs he mentioned. According to our inference, acquisitions can not only solve intellectual property issues during open innovation but also meet the wishes of SMEs TMTs under certain circumstances. Moreover, Boreas’s case also revealed the willingness of SMEs to join in the supply chain of LHEs by integrating SMEs innovations into LHEs large innovations in order to cancel the risk of mismatch to the market [5]. This should also be attributed to the free choices and opportunities of SMEs in the open innovation process. Therefore, we hold the following argument that acquisitions are usually a necessary part of open innovation, which cannot be simply regarded as “a violation toward free opportunities and choices of SMEs during open innovation”.

Furthermore, the timeliness of such acquisitions and mergers also needs to be considered or the open innovation process may be unfortunately delayed. If in the process of open innovation, LHEs needs to use the technology and patents of SMEs by acquiring them, then the acquisitions process needs to be as short as possible. At this point, Zeus, a senior partner of a private equity investment institute, provided us a brief illustration as to how institutes make investment decision:

We have to follow a rigorous, complex and time-consuming process (in equity investment) . . . We need 3 months or even longer to fully understand the target enterprise, sign a confidentiality agreement with them, conduct due diligence

which is very necessary to both, and hold at least 3 rounds of internal meetings inclusive of project establishment, internal verification, and committee vote Due diligence mainly consisting of business investigation, financial investigation and legal investigation happens after the project establishment meeting and before the internal verification meeting (The process of) Acquisitions and mergers will be more complicated (It) needs the participation of investment banks, law firms and accounting firm.

5.3. Case Study on the Resource Dependence Issues of Tesla

5.3.1. Case Background

The main divergence between Tesla and State Grid in China was, at first, about charging interface standards. Tesla held Supercharger charging interface technology, and compatible CCS and CHAdeMO charging interfaces as well, while the charging standard in China was GB/T 20234-2015. Table 4 briefly compares the technical specifications of these four electric-vehicle charging standards.

Table 4. A brief comparison of technical specifications of four electric vehicles.

No.	Standard Name	Formulate Date	Related Enterprise and Organization	Brief Introduction to Technical Specifications
1	Supercharger	September 2012 now	Tesla, Inc. and its partners	Supercharger V1: up to 120 kW charging power. Supercharger V2: up to 150 kW charging power. Supercharger V3: up to 250 kW charging power. Assisted by Tesla's liquid-cooling cables and super charging stations. Forthcoming 350 kW charging power chargers.
2	CHAdeMO (CHArge de Move)	August 2010 now	Chademo Association	CHAdeMO 1.0: up to 62.5 kW by 500 V, 125 A direct current via a special electrical connector. Revised CHAdeMO 2.0: up to 400 kW by 1000 V, 400 A direct current.
3	CCS (Combined Charging System)	May 2012 now	SAE (Society of Automotive Engineers) and ACEA (Association des Constructeurs Européens d'Automobiles)	Varying speeds, ranging from 50 kW up to 350 kW.
4	GB/T 20234 series	GB/T 20234-2006 (1 December 2006–1 March 2012) GB/T 20234-2011 (1 March 2012–1 January 2016) GB/T 20234-2015 (1 January 2016–)	Standardization Administration of China, China Electricity Council, and other related organizations and enterprises	AC rated voltage, not exceeding 690 V, frequency 50 Hz, and rated current not exceeding 250 A; DC rated voltage not exceeding 1000 V, and rated current not exceeding 400 A; Standardized plug and socket: should allow GB 2099.1. GB/T 20234-2006 and GB/T 20234-2011 revoked, only GB/T 20234-2015 available.

In February 2014, Tesla hoped to cooperate with State Grid in building charging stations and formulating charging standards (forthcoming GB/T 20234-2015) but was unfortunately rejected. Later, Tesla CEO Elon Musk declared that super charging stations can exist independently to provide sustainable charging service without China's grid support.

From past to future, State Grid has always been dominating the public charging service in China and strictly following the GB/T 20234 series standards, while Tesla had almost no chance to cut in. So, in 2016, as a kind of compromise, Tesla announced that their vehicles sold in China would uniformly adapt to China's GB/T 20234 series charging standards. Adapting to Chinese standards brought significant charging efficiency loss to

Tesla's Chinese customers. Even so, as Themis, working for Tesla, explained, Tesla "still had solutions at this circumstance":

Actually we provided several solutions for our customers in China As you may see, many commercial zones in Beijing have installed our Superchargers. We call it "Destination Charging" . . . to minimize the impact of the loss of charging efficiency Many customers also purchased home charging facilities with Powerwall or Powerpack to enjoy the original charging experience and we gave them some giveaway, like free charging cables as maximum as 40 m. So it is not really a big problem to us and our customers.

In 2020, Tesla had successfully built LKH, a green energy fast charging station in Germany as its benchmarking project on green energy generation and use. Tesla also implemented the plan for electric vehicles to absorb green energy in order to reduce dependence on power grids with great possibility.

5.3.2. Analysis

In recent years, with the advancement of technology and the improvement of the industrial chain, the costs of photovoltaics, wind power, and energy storage have been gradually decreasing. These provide basic technical conditions for the massive emergence of green energy. The technological upgrade and breakthrough provide necessary conditions for Tesla to obtain innovative results at a reasonable price. Green energy (photovoltaic, wind, etc.) power generation is not stable, so high-performance energy storage systems will become an essential element of the future energy system. Enterprises can form a new platform for related technologies, acquire and use these technologies at a reasonable cost, and even export related technical standards to the outside world.

In this case, the influence of the public and the consensus of the industry cannot be ignored. While the public is increasingly dissatisfied about "new energy vehicles are still powered by coal", the consensus that they should be powered by green energy is correspondingly stronger. Furthermore, Tesla also criticized this phenomenon in their 2020 impact report and mentioned its willingness to cooperate with the Chinese local government (such as the government of Sichuan Province) for promoting their green energy technologies and reducing greenhouse gas emissions, mainly through replacing internal combustion engine (ICE) vehicles with electric ones.

In China, much of the grid is powered by coal. That said, even in this scenario, charging a Tesla Model 3 from the grid is still less emissions intensive than running an ICE vehicle. Just like in Europe, we have assumed a vehicle lifetime of 150,000 miles. We are expecting the grid mix in China to improve dramatically over time as China remains a dominant deployer and manufacturer of renewable energy. Sichuan Province (with a population of 81 million) is a great example of this. In this province, given the high percentage of renewable energy penetration, charging an EV (Electric Vehicles) from the grid is less polluting than charging an EV in most global countries or states [28].

Tesla's impact reports showed how significant electric vehicles (such as Tesla Model 3) and green energy technology could be in helping reduce carbon emissions from both country and local perspectives [28,30]. First of all, the large number of ICE vehicles provided sufficient replacement market space for electric vehicles, the owners of which were the electric vehicle enterprises' important potential customers. Then, such replacements would have significant effect on environmental protection and mitigating carbon emissions, and even help enterprises to seek possibilities for the corporation with the government on related business [30].

We hereby developed an argument that, under both the influence of large innovations acquired from the CF² open innovation cooperative model and driving macro policies, resources that the company once mastered can be upgraded to new key resources recognized by the environment. It will be even better if such new key resources are increment

resources that can be continuously replenished by current resources (such as electric vehicle customers shifting from ICE vehicle customers), which no doubt further increased its importance and value as well as enterprises' organizational power in the environment.

We also interviewed Selene to indirectly support this argument from the perspective of national strategies, but he refused to discuss whether State Grid and Tesla may cooperate in the future or not.

We are responding “Peaking Carbon Dioxide emissions” and “Carbon Neutral” policies actively Obviously burning coal is unsustainable, for many reasons Electric vehicles will replace fossil energy vehicles and help green energy development, and we are also stepping up the construction of related infrastructure The knockout of fossil energy vehicles is a widely accepted and irreversible trend in China, and even in the world.

Note: “Peaking Carbon Dioxide emissions” means China’s carbon emissions in social and economic activities will strive to reach a peak before 2030 and no longer increase as well, while “Carbon Neutral” means the total emissions and absorption of carbon dioxide and other greenhouse gases will be zero by 2060 (Sources: http://www.xinhuanet.com/english/2020-12/18/c_139601263.htm accessed on 22 November 2021)

5.3.3. Conclusion

Subject to factors such as technology and market, the innovative achievements that are committed to solving the problem of key resource dependence, even if they are supported by sufficient cooperating resources, make it difficult to completely eliminate some key resources. Even so, when it is difficult to completely eliminate the dependence on current key resources, the motivation of LHEs to practice open innovation may also be to obtain or consolidate new key resources and improve their ability to compete with other key resource providers.

The new key resources need to be related to the key resources the enterprise is lacking, to some extent. In this case, Tesla’s green energy charging station is still unable to easily eliminate its dependence on the power grid even though it is supported by some advanced technologies. Under these circumstances, Tesla and SMEs have made efforts in the fields of photovoltaic and wind turbine manufacturing, energy conversion, and energy storage, and successfully built green energy charging stations with commercial value at a reasonable cost. Furthermore, they have partially reduced the dependence on the grid by building self-owned wind turbines and photovoltaic electricity systems.

Open innovation can not only help enterprises reduce their dependence on original key resources but can even help them with acquiring new key resources, so we should be aware that new key resources may emerge during the game, which will become a new focus for everyone. Under the multiple driving forces of policy, industry, and technology, the new key resources can bring new organizational power to the enterprise and may eventually affect the power distribution pattern among all the related organizations in the environment.

Tesla’s case provided a feasible solution for finding, identifying, and implementing new key resources, especially incremental and refillable resources formulated by applying the innovations created by the CF² model open innovation process, finally adding target enterprises’ organizational power and game space to other organizations in the environment. This process will not happen in a vacuum but needs to be driven by external conditions, such as favorable macro policies. Specifically, using only solar and wind energy may never meet the demand for charging electric vehicles, so Tesla sensitively grabbed the favorable macro policies of “Peaking Carbon Dioxide emissions” and “Carbon Neutral” policies in China, and continuously add new key resources for itself with the support of innovations and the developing market [30].

Generally speaking, through leading an open innovation with SMEs, Tesla has mastered at least three new key resources needed and recognized by the total environment: the ability to build green energy charging stations, energy storage technologies reducing

the instability of green energy, and the large amount of customer resources for consuming green energy. For Tesla, mastering these new key resources can not only reduce dependence on the previous key resource—grid electricity—and, to a certain extent, ensure its survival and future development, but also meet the consensus of the industry and the needs of social development.

6. Conclusions, Limitations, and Future Prospects

This article delivered a further study of the CF² cooperative model from the perspectives of both resources and open source, exploring the possibility of establishing a new and efficient CF² by LHEs as intermediaries, tested by the series cases of Tesla. The issues regarding free choice opportunities of SMEs during cooperation and intellectual property were also discussed while explaining the cases.

In the process mentioned above, LHEs adopt specific open-source strategies to form a CF² cooperative network with SMEs. The original purposes of SMEs and other innovation institutions participating in the CF² by joining the open-source innovation platform for cooperative innovation were the right to free opportunities and choices and to obtain market-competitive innovation results with LHEs. With the help of these LHEs and open-source platforms built by them, fragmented innovation results created by SMEs will be integrated into large-scale innovations with market competitiveness. We also noticed that there would be some issues during CF² open innovation cooperation, such as intellectual property, and mergers and acquisitions were effective and simple ways to solve it while still needing the following conditions: funds, proper investment time, and timeliness. Accordingly, we reached a conclusion that acquisitions from large companies cannot be considered a violation toward free opportunities and choices of SMEs, as discussed in the previous chapters.

Meanwhile, the practice of open innovation led by LHEs in this form is of extraordinary significance, that is, to obtain innovative results that help reduce dependence on key resources and obtain alternative resources in a reasonable and effective organizational form and, ultimately, affect the internal environment, the pattern of power distribution, and improve their own survival and development status. This conclusion enhances the theoretical value of CF²s and gives new connotations to open innovation.

The innovation in the research method of this article is that when discussing the resource dependence of LHEs and the environment, the analysis of the organizational network of resource dependence theory is placed in the CF² open innovation model for discussion. Thus, only the relationship between the target organization and the single key resource supplier and power distribution pattern based on key resources need to be considered, thereby improving the accuracy of this research and decreasing its complexity as well.

Through a series of theoretical derivation and case analysis, it is concluded that the purpose of LHEs to form CF²s for open innovation is to obtain reasonable and effective organizational forms that help reduce dependence on key resources and obtain alternative resources. The results of innovation affect the power distribution pattern within the environment and help LHEs with better survival and development.

However, from the case perspective, the study of this article has certain limitations. One is that the obstacles to the construction of charging stations are not only from the power supply of the grid but also from factors such as administrative approval and land planning, which means organizations that provide key resources such as administration and land have been partly ignored in this case. Accordingly, as the senior vice president of a lithium battery company, Glauke had a better understanding of the electric vehicle charging business, and he admitted that the current charging station construction was not easy:

Actually, building a charging station for electric vehicles in China is not easy Except administrative approval from government, there are still so many things you need to consider, such as electricity, land space and rent, environmental

protection and environmental impact assessment, relationship with power grid, all kinds of security issues If operators want to earn more beyond providing charging service, some value-added operating services are also essential, just like many gas stations cooperate with convenience chain stores.

The second limitation is that State Grid will also take alternative measures such as signing some targeted consumption green energy agreements with car enterprises and implementing the V2G (Vehicle to Grid) “peak load shifting” project to support a refined grid management strategy. These strategies pose an actual threat to Tesla’s key resources (electric vehicle customers) generated by their large innovations, thereby affecting the distribution of organizational power in the environment and, correspondingly, weakening Tesla’s organizational power. We have interviewed Selene on these issues, and his reply preliminarily confirmed them:

The two-way interaction between electric vehicles and the power grid is called V2G. It can use the energy storage characteristics of electric vehicles’ own batteries to enhance the flexibility and efficiency of the power grid, and reduce all kinds of electricity costs through peak-to-valley shifting Of course, to achieve V2G, a two-way intelligent charging station or charging pile with V2G function is required At present, we have completed the development of the V2G application platform and low-power V2G DC charging piles. It has also jointly carried out the research and development of V2G functional customized vehicles with related car companies We will explore a new market-oriented operation model with reasonable cost and efficient business.

Finally, many of the SMEs participating in Tesla’s CF² cooperating network were initially or finally acquired by Tesla. We were aware that LHEs integrating internal or external innovations may face higher coordination costs and risks than if all activities were internalized [17]. Due to the particularities of this case, in addition to the three conditions we discussed before, Tesla’s strategy of patent open source and acquisitions is also based on the rapidly growing market for electric vehicles, which means this strategy is not that suitable for other companies and industries and may not be suitable for Tesla in the future if market or policy changed.

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[Figure 2] Tesla patents by category Ref. [29].

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