MOBILITY STRATEGY FOR DECARBONIZATION - THE FUTURE OF GREEN VEHICLES AS SEEN FROM ANALYSIS OF PATENTS -

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SUMMARY

- As technological innovation and the adoption of green vehicles continues, EV sales volumes have reached record highs in China while remaining low in Europe, demonstrating that trends differ between regions, and thus requiring companies to review their strategies.
- Among those green vehicles, electric vehicles and hybrid vehicles lead in terms of the number of patents. By player, the presence of major automakers such as Toyota Motor Corporation stands out while battery manufacturers, emerging manufacturers, and the like are also attracting attention.
- While individual companies may focus on different areas, patent analysis is important to support strategic decisions in green vehicles, where improving range is a common issue.

1. MOBILITY STRATEGY FOR A DECARBONIZED SOCIETY AS SEEN IN PATENTS

1-1. THE IMPORTANCE OF PATENT ANALYSIS IN THE CHANGING ENVIRONMENT OF GREEN VEHICLES

While countries and companies are actively working to innovate and promote the adoption of environmentally friendly green vehicles, trends vary by countries and regions, as seen in reporting[1] that while the number of electric vehicles (EVs) sold in Europe last summer was at a record low, the number sold in China hit a record high. In the United States, Donald Trump's inauguration as president in January 2025 is expected to lead to policy changes, including a review of measures to support electric vehicles and renewable energy. For automobile-related companies, patent analysis that highlights the competitiveness of individual companies is becoming increasingly important as measures and strategic reviews are called for that flexibly respond to the infrastructure, regulations, and consumer needs of each region.

In this report, we classify green vehicles into four categories: electric vehicles (EV), hybrid vehicles, fuel cell vehicles (FCV), and hydrogen engine vehicles, and then identify[2] patents that are highly relevant to each category. Based on this analysis, we then consider which companies will be ahead of the times and play a central role and what strategies will be needed in the future.

[1] Source: https://jp.reuters.com/economy/industry/IYPCUTNWABKWHKPOTBXBESR42Y-2024-09-12/ (accessed November 11, 2024)
Search using LexisNexis PatentSight, with reference to the Green Transformation Technologies Inventory (Japan Patent Office). (Valid patents, including those pending, as of November 2024)

1-2. TECHNOLOGY TRENDS AND CORPORATE STRATEGY AS REVEALED BY PATENT ANALYSIS

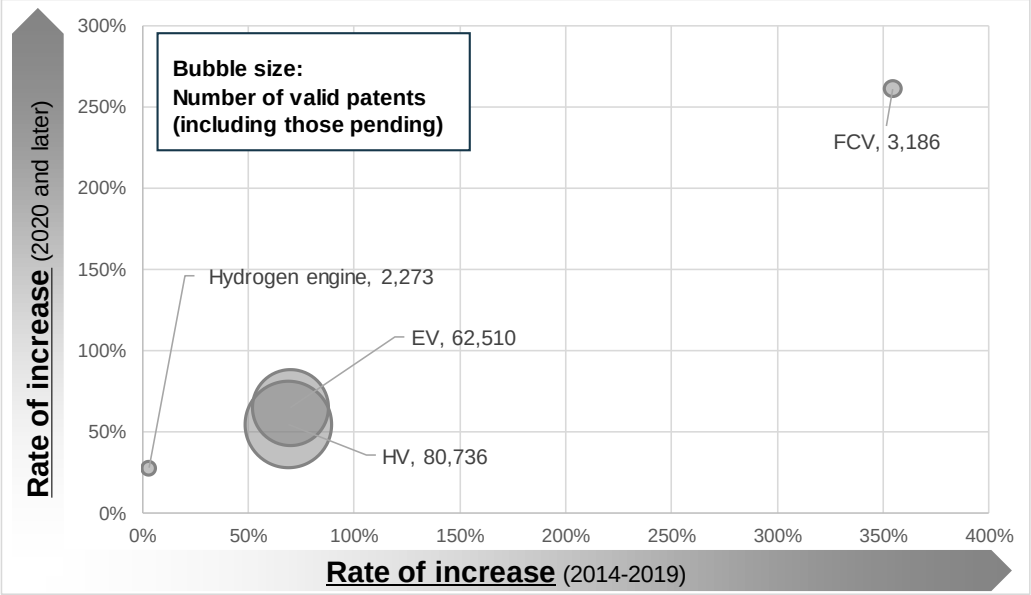
Patent information is an important source of information in the field of science and technology, and its purpose is to promote technological progress through the sharing of knowledge. Although patents are expensive to apply for and to maintain after obtaining rights, holders can obtain exclusive license and economic benefits. Therefore, by focusing on specific themes in analysis of patent information, which can be said to be information on cutting-edge technologies that are close to being put into practical use, it is possible to deduce the technological areas that companies are focusing on and their future aims.

2. TRENDS AND COMPETITION IN GREEN VEHICLES AS SEEN IN PATENT ANALYSIS

2-1. PATENT TRENDS IN GREEN VEHICLES

Figure 1 shows a comparison of the number of patents and the rate of increase for four types of green vehicles (EV, hybrid, FCV, hydrogen engine), with the size of the bubbles representing the number of patents and the horizontal and vertical axes representing the rate of increase during each period. In the EV and hybrid fields, where there are many patents, there has been significant technological innovation and investment, and in FCV where an increase trend is seen, we see that there has been active development in recent years.

Figure 1: Number and Rate of Increase of Green Vehicle Patents



Rate of increase (2014-2019): Comparison of number of valid patents (including those pending) as of the end of 2019 and 2014

Rate of increase (2020 and later): Comparison of number of valid patents (including those pending) as of November 2024 and the end of 2019

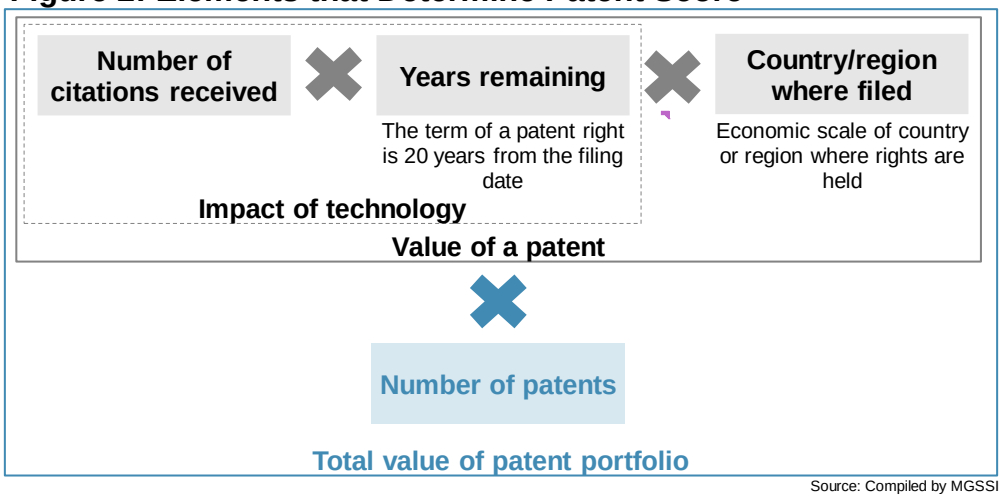
Source: Compiled by MGSSI based on data from LexisNexis PatentSight

2-2. GREEN VEHICLE LEADERS SEEN FROM PATENT SCORES

When identifying companies and research institutions that are worth paying attention to from technological trends that are revealed by the number of patents and the rate of increase in patents, it is also important to conduct analysis that focuses not only on the quantity of patents but also on the quality of patents. As shown in the example in Figure 2, it is now possible to evaluate the patent score for each player using a method that evaluates the quality of each patent based on factors such as the number of citations received, the length of

time remaining on patent rights, and the economic scale of the country in which the application was filed, and then calculates the value of the patent portfolio.

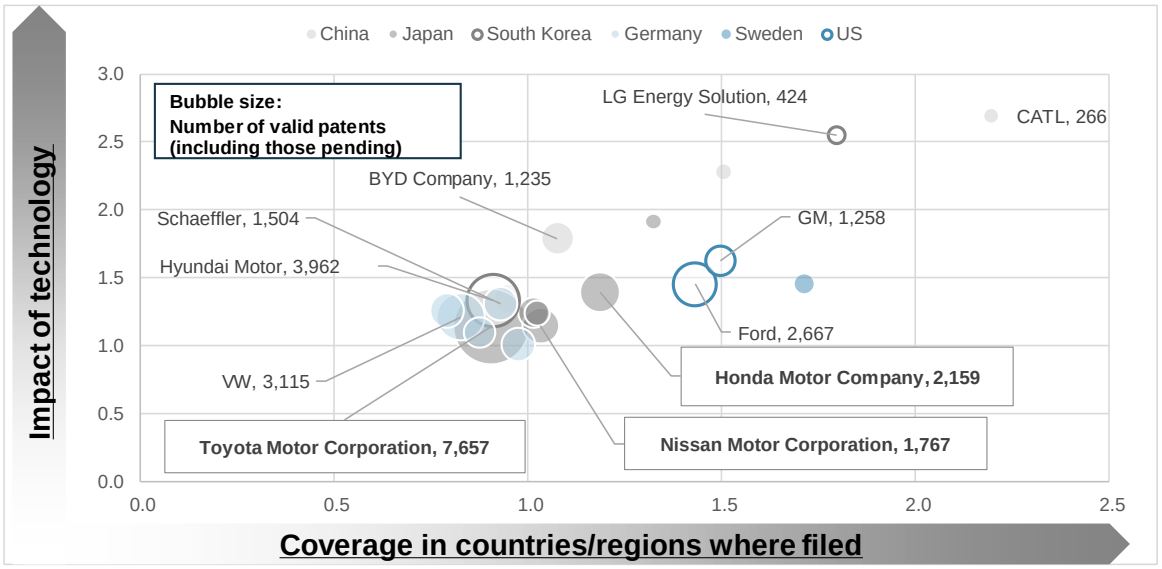
Figure 2: Elements that Determine Patent Score



Source: Compiled by MGSSI

Figure 3 is a graph comparing the top players in green vehicles using such patent scores. The bubble size indicates the number of patents, the horizontal axis indicates the score for the country/region coverage, and the vertical axis indicates the size of the technological impact score. Toyota Motor Corporation (Japan) edges out Hyundai Motor Company (South Korea), which is second place in both number of patents and patent score, indicating the company's strong commitment to investment and innovation in environmental technologies. The next most prominent are major automakers such as VW Group (Germany), Ford (US), and Honda Motor Company (Japan), while battery manufacturers CATL (China) and LG Energy Solution (LGES, Korea), have a large size technological impact and country/region coverage despite the number of patents they hold being small. This indicates that they are becoming increasingly influential even amongst the top players.

Figure 3: Top Players Overall in Green Vehicles



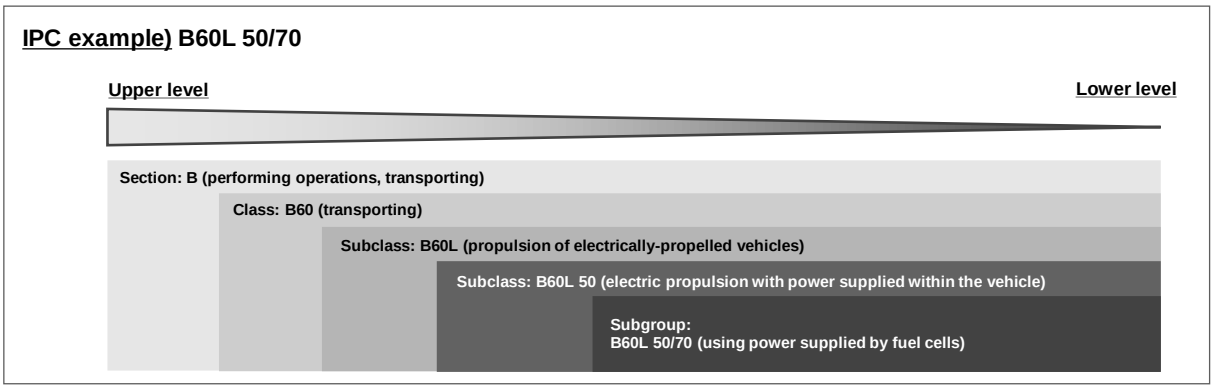
Source: Compiled by MGSSI based on data from LexisNexis PatentSight

3. PATENT TRENDS IN GREEN VEHICLES PER TYPE

All patents are assigned a technology classification code, and the International Patent Classification (IPC), which is widely used internationally, subdivides technology from higher to lower classifications, as shown in the

example in Figure 4. In this section, we would like to identify the state of technological development and the efforts of individual companies and research institutes to address technological issues by analyzing the four types of green vehicles per technology using IPC and per player using patent scores.

Figure 4: International Patent Classification (IPC) Examples



Source: Compiled by MGSSI

3-1. EV, HYBRID

Figures 5 and 6 show the results of the analysis of EV and hybrid patents per IPC, respectively, with the bubble size representing the number of patents and the horizontal and vertical axes representing the rate of increase during each period. For EV, many patents are for motors (B60K 1) and power supply (B60L 50), which are functionally essential, and there has been a recent surge in patents for battery monitoring (B60L 58) and for charging methods and controlling (B60L 53). For hybrid, patents for battery monitoring have surged in recent years among the many patents for power delivery and for control (B60W), which is important for improving vehicle safety and efficiency. Battery monitoring technology leading to optimized battery life and performance continues to be a major challenge shared by both areas, as it has a significant impact on driving range and safety.

Figure 5: Number and Rate of Increase of Patents per IPC (EV)

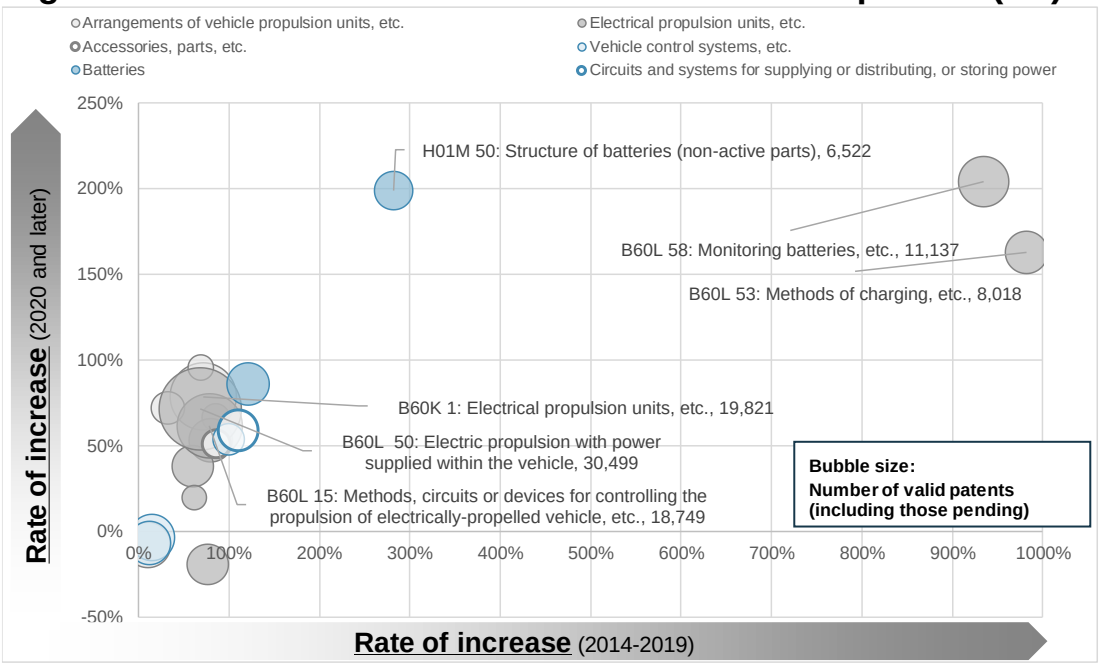


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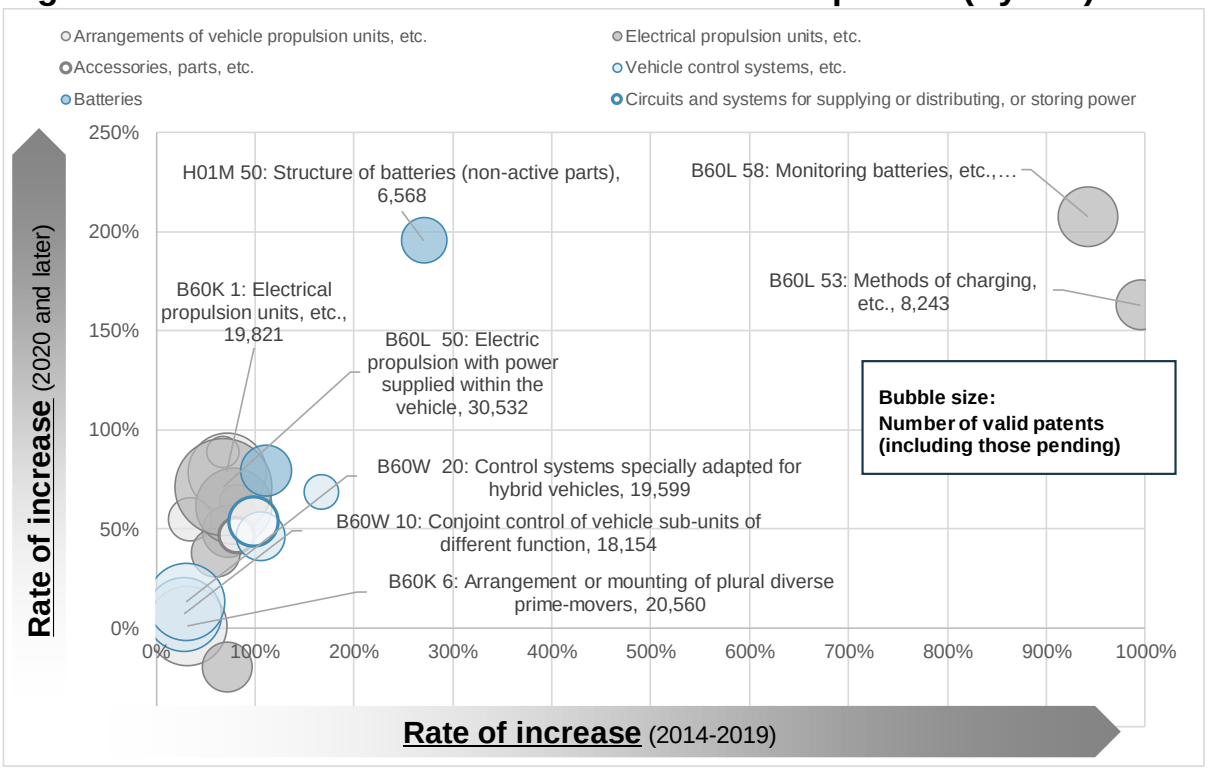
Figure 6: Number and Rate of Increase of Patents per IPC (Hybrid)



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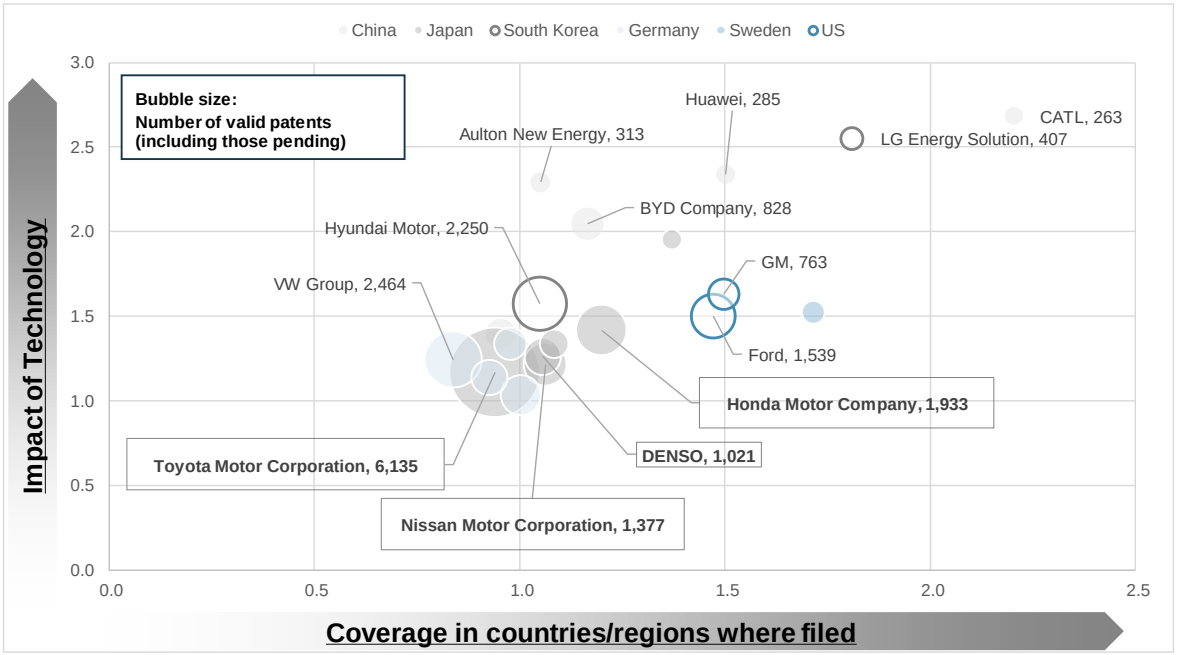
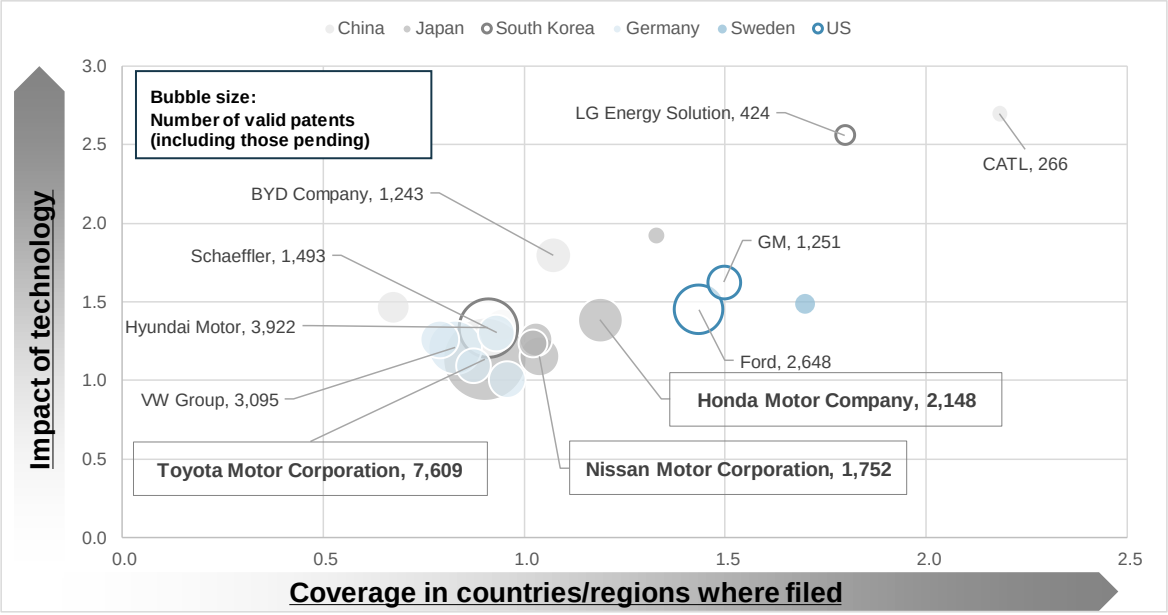
By player, as shown in Figures 7 and 8, Toyota Motor Corporation has a strong presence, coming in top in both the number of patents and the patent score in both areas. For EV, Chinese companies such as BYD Company (China) and Aulton New Energy Automotive Technology (China), which provides battery replacement services, as well as Huawei, which operates a variety of businesses centered on telecommunications and smartphones, hold high-scoring patents and are outstanding.

Figure 7: Patent Score per Top Player (EV)



Source: Compiled by MGSSI based on data from LexisNexis PatentSight

Figure 8: Patent Score per Top Player (Hybrid)



Source: Compiled by MGSSI based on data from LexisNexis PatentSight

Also, for both the areas of EV and hybrid, battery patent disputes are intensifying as battery-related companies such as CATL and LGES increase their presence. As restrictions on Chinese batteries become stricter in the US, CATL, which holds more than 20,000 patents, is working to secure patent licensing revenue. Ford has announced plans[3] to build a lithium-ion iron phosphate battery plant in February 2023 after receiving technology, including licenses, from CATL, and several media outlets in the US and China have reported that Tesla and GM have similar plans to receive technology from CATL and build plants[4]. Meanwhile, LGES has recognized that there have been numerous infringements of its patents in batteries for EVs and consumer devices, and it has indicated that it will aggressively crack down on patent infringement and work to protect its patent rights[5], and that competitors, including CATL, and end-product manufacturers using those batteries, may also be targets of crackdowns.

3-2. FCV, HYDROGEN ENGINE

Figures 9 and 10 show the results of an analysis of patents related to FCVs and hydrogen engines, respectively, per IPC. For FCVs, the greatest number of patents is related to the power supply within the vehicle (B60L 50), such as for optimizing the battery and energy conversion system, and these have been increasing in recent years. In addition, those for battery monitoring (B60L 58) and charging methods and control (B60L 53) have also been increasing in recent years, indicating that the importance of the battery as a supplementary application for improving the driving range is increasing. For hydrogen engines, while the majority of patents are related to engine control (F02D 19) and fuel supply (F02M 21), patents related to improving engine output and efficiency, such as those for pre-combustion chambers (F02B 19), have been increasing in recent years.

[3] Source: https://media.ford.com/content/fordmedia/fna/us/en/news/2023/02/13/ford-taps-michigan-for-new-lfp-battery-plant--new-battery-chemis.html) (accessed November 15, 2024)
[4] Source: https://www.bloomberg.co.jp/news/articles/2024-03-25/SAW7EHT0G1KW00 (accessed November 15, 2024) https://news.qq.com/rain/a/20240328A0AG5800 (accessed November 15, 2024)
[5] Source: https://news.lgensol.com/company-news/press-releases/2636/ (accessed November 15, 2024)

Figure 9: Number and Rate of Increase of Patents per IPC (FCV)

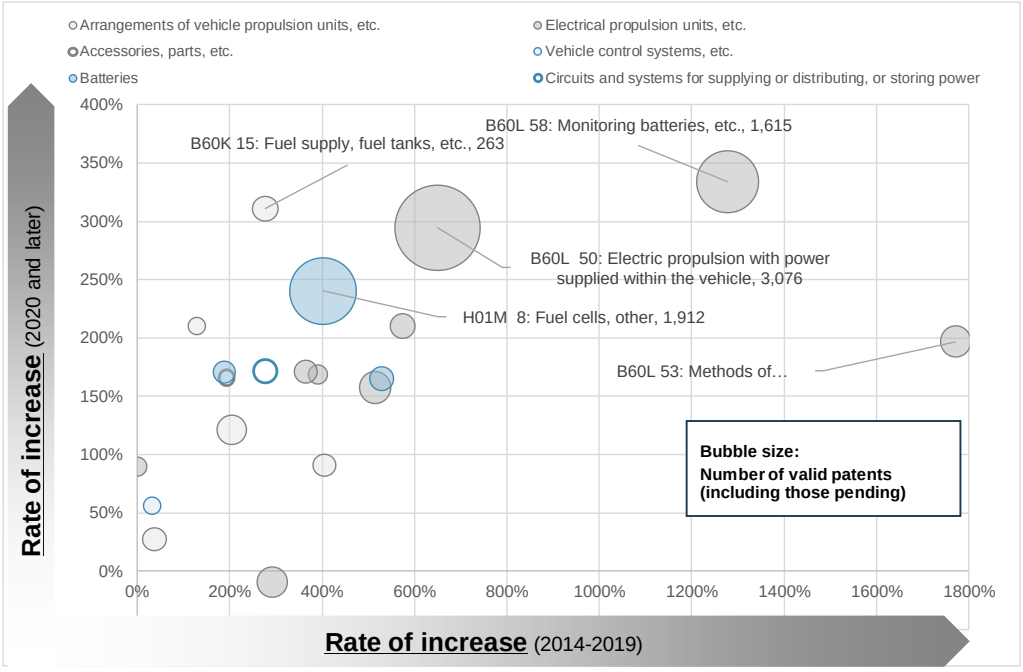


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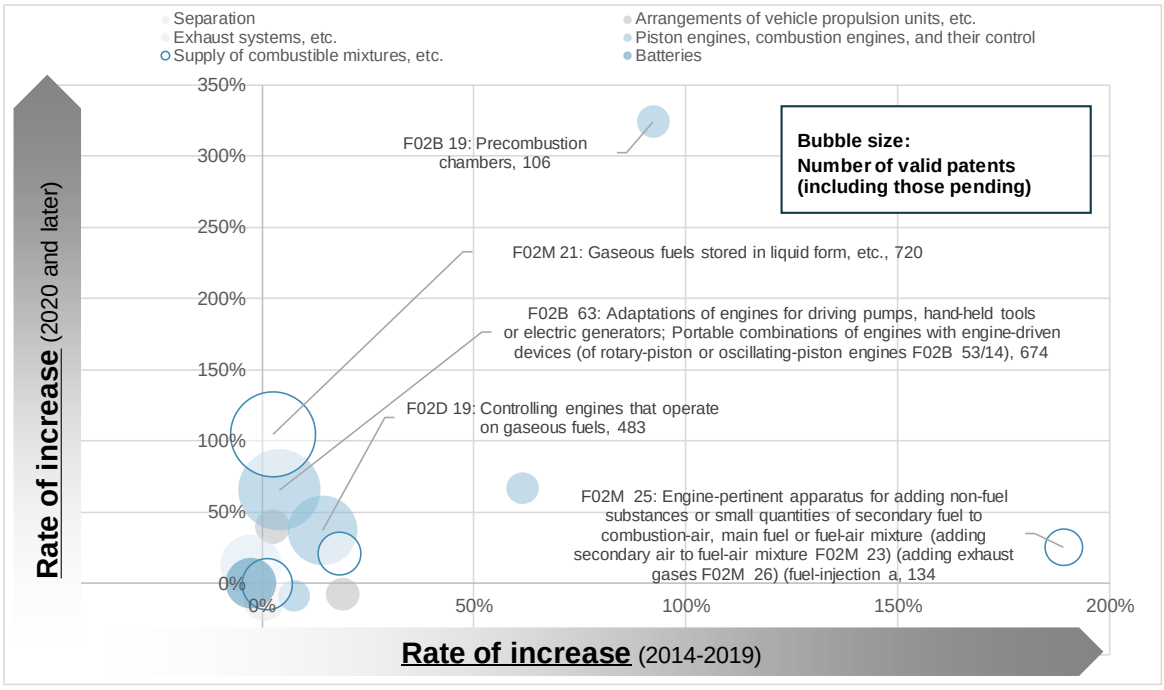
Figure 10: Number and Rate of Increase of Patents per IPC (Hydrogen Engine)



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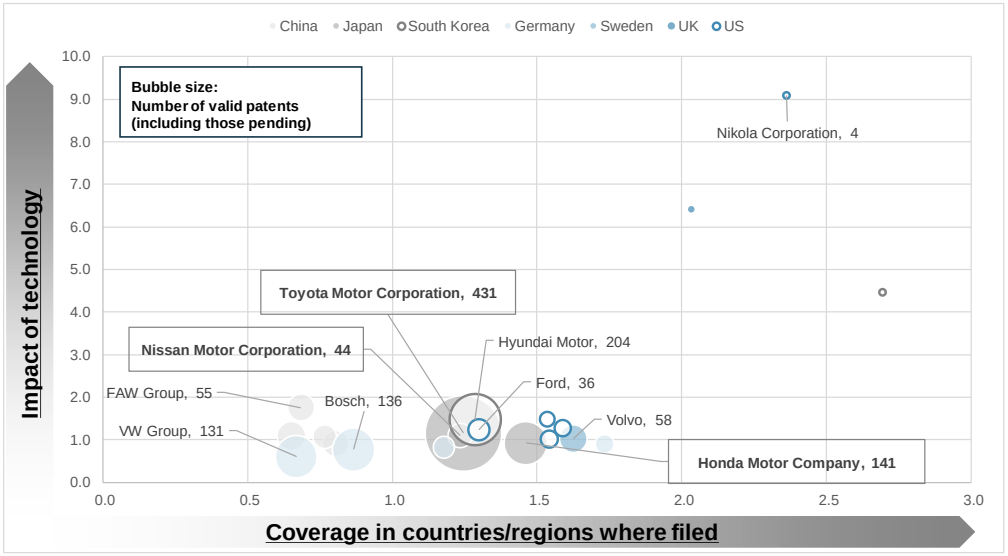
By player, as shown in Figures 11 and 12, Toyota Motor Corporation is at the top in terms of both the number of patents and patent scores, demonstrating a strong presence in both areas, while South Korean companies such as Hyundai Motor Company are also pursuing patent activities in FCVs. In addition, although the number of patents it holds is small, Nikola Corporation (US), a manufacturer of EV and FCV large trucks, has a large

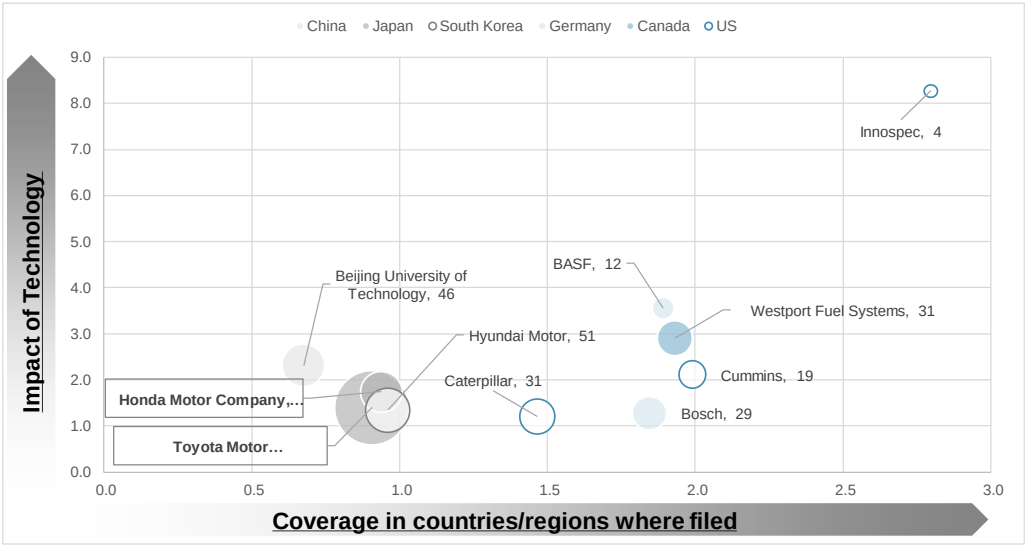
presence among the top players. It has been revealed that Nikola has developed and manufactured fuel cell power modules under technology license from Bosch (Germany), another company that appears in the top ranks,[6] and in October 2024, it announced that its FCV trucks, which have a maximum cruising range of 500 miles (approx. 805 km), had been introduced by major logistics company DHL (Germany) and others.[7] Nikola Corporation has had some difficult times, including when its founder and first CEO was investigated[8] for allegedly providing false information to investors in 2020, but since then it has achieved an improvement in its patent position while also achieving technological and cost advantages and accelerating market development through technology licensing from other companies. For hydrogen engines, in addition to major automobile manufacturers such as Toyota Motor Corporation, companies from industries including energy and chemicals, such as Westport Fuel Systems (Canada), also have a significant presence.

Figure 11: Patent Score per Top Player (FCV)



Source: Compiled by MGSSI based on data from LexisNexis PatentSight

Figure 12: Patent Score per Top Player (Hydrogen Engine)



Source: Compiled by MGSSI based on data from LexisNexis PatentSight

[6] Source: https://www.prnewswire.com/news-releases/nikola-announces-strategic-agreements-with-bosch-for-fuel-cell-manufacturing-301368083.html (accessed November 25, 2024)
[7] Source: https://www.nikolamotor.com/dhl-supply-chain-and-diageo-north-america-power-up-sustainability-partnership-with-deployment-of-hydrogen-fuel-cell-trucks (accessed November 25, 2024)
[8] Source: https://www.bloomberg.co.jp/news/articles/2020-09-21/QGZVRIT0G1KX01 (accessed November 25, 2024)

4. SUMMARY

Green vehicles are advancing due to the active efforts of individual countries and companies, and the results of patent analysis (Figure 13) revealed that, from a technological perspective, the common issue is considered to be improving the efficiency of batteries and engines, which are important for improving driving range. The results of analysis per player also revealed that Toyota Motor Corporation is leading by a wide margin over other companies in all types, even though many companies have their own strategies with their own focus areas. Toyota continues to be actively engaged in the search for optimal solutions for green vehicles, as evidenced by the unveiling[9] of a prototype hybrid vehicle powered by a hydrogen engine and an electric motor with the aim of improving cruising range in November 2024.

In green vehicles, where patent analysis reveals that improving cruising range is a common issue, many companies are focusing on different areas, and companies like Toyota Motor Corporation that can provide comprehensive solutions are the exception. In the future, as it is assumed that manufacturing industries will form blocks due to global fragmentation and regulations and consumer needs for green vehicles will differ by individual country, partnerships with companies that can flexibly respond to the situation in the individual regions will become even more important, and measures that take into account the associated risk of intellectual property disputes will also be necessary. We hope that the use of patent information analysis, which is an important tool for identifying technological trends and the competitive landscape, will spread in strategic decision-making of companies working toward the realization of a decarbonized society.

Figure 13: Summary of Top Players in Green Vehicles and Technologies to Watch Seen from Analysis of Patents

Patent score Technology to watch	EV	Hybrid	FCV	Hydrogen engine
1	Toyota Motor Corporation (Japan)	Toyota Motor Corporation (Japan)	Toyota Motor Corporation (Japan)	Toyota Motor Corporation (Japan)
2	Hyundai Motor Company (South Korea)	Hyundai Motor Company (South Korea)	Hyundai Motor Company (South Korea)	Westport Fuel Systems (Canada)
3	Honda Motor Company (Japan)	Ford (US)	Honda Motor Company (Japan)	Innospec (US)
4	Ford (US)	Honda Motor Company (Japan)	Bosch (Germany)	Hyundai Motor Company (South Korea)
5	VW Group (Germany)	VW Group (Germany)	Volvo (Sweden)	Honda Motor Company (Japan)
6	BYD Company (China)	GM (US)	Nissan Motor Corporation (Japan)	Cummins (US)
7	Nissan Motor Corporation (Japan)	BYD Company (China)	FAW Group (China)	Beijing Univ. of Technology (China)
8	**LG Energy Solution (South Korea)**	Nissan Motor Corporation (Japan)	**Nikola Corporation (US)**	BASF (Germany)
9	GM (US)	**LG Energy Solution (South Korea)**	VW Group (Germany)	Bosch (Germany)
10	DENSO (Japan)	Schaeffler (Germany)	Ford (US)	**Caterpillar (US)**
Technology to watch (# of patents)	Motor, Power supply	Motor, Power supply, Vehicle control systems	Power supply, Fuel cell	Engine control, Fuel supply
Technology to watch (rate of increase)	Battery monitoring, Charging means and control	Battery monitoring, Charging means and control	Battery monitoring	Pre-combustion chamber

Automobile manufacturing (black), Truck manufacturing (**black bold**), Auto parts (blue), Batteries (**blue bold**), Others (green)
Source: Compiled by MGSSI based on data from LexisNexis PatentSight

[9] Source: https://www.nikkei.com/article/DGXZQOFD172QZ0X11C24A1000000/ (accessed November 21, 2024)