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Who holds the power? Lessons from hybrid car innovation for clean technologies

The Opportunity

Companies wanting to create a profitable market position in the competitive clean technology landscape must understand their competitors' patents and how these will impact their business.

By **Mike Lloyd** and **Justin Blows**

Clean & Sustainable Technologies Group

Griffith Hack's Clean & Sustainable Technologies Group provides intellectual property services to organisations that develop technologies with a reduced environmental impact. We have been immersed in these technologies for many years. We are excited by the challenges and opportunities that now present to innovators in Australia and worldwide.

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Lessons from hybrid car innovation

Toyota has become synonymous with hybrid cars: three out of four hybrid cars sold in the US are made by Toyota. This is no accident. Toyota set out in 1994 to develop hybrid cars and to protect their development with patent filings. Toyota has now sold more than two million hybrid cars.

Research by Griffith Hack on patents filed in the hybrid car area showed that Toyota has filed more than 4000 patent filings, or 43% of hybrid car patent families filed by car companies, with more than 1000 patents claimed for the 2009 Prius alone.

Toyota's aggressive product development and patent filing strategy has forced its competitors to react in different ways:

- Some companies have licensed hybrid car technology from Toyota.
- Other companies have attempted to develop hybrid car technology in different directions not patented by Toyota.
- Some patent holders have sued Toyota for patent infringement, with mixed success.
- Other innovative companies have developed technologies demanded by some consumers and not offered by market leaders.

There are valuable lessons here for all innovation managers on how to use patents to support innovation strategies.

This is also an excellent case study of how the patent system assisted in bringing forward investment in a clean and sustainable technology. Toyota invested in hybrid car innovation when global oil prices were relatively low, possibly because they saw an opportunity to create a valuable patent position when petrol prices increased.

Hybrid cars provide a great case study of how a visionary patent strategy can positively impact commercial success

A growing market

Hybrid cars provide a great example of consumers showing a willingness to purchase environmentally friendly products when given a choice. While the hybrid-only Toyota Prius is perhaps the best known hybrid car, Toyota, along with Honda, Ford, Nissan, General Motors (GM), Audi and BMW have all offered hybrid cars since 1997. Toyota has since gone on to sell more than two million hybrid cars. Sales are still increasing, with hybrid car sales expected to grow by 20% to 2012¹, and to comprise 80% of US vehicle sales by 2020².

The 2009 Toyota Prius hybrid car recently displaced Honda's Insight hybrid car as the biggest selling car in Japan. Hybrid engine technology has even infiltrated Formula One, with some teams trialing a hybrid technology option in the 2009 season.

This success has been largely in the absence of major supporting regulations and comparatively few economic incentives³. Hybrid cars consume less petrol than conventional cars, and can attract lower local

government charges as well as tax incentives, but tend to be more expensive than equivalent conventional cars.

Technology trends

Hybrid cars are also a stepping stone towards plug-in cars, which recharge their batteries from mains electricity and may or may not include a conventional engine. Plug in cars may even be programmed to recharge their batteries when electricity is cheap, and then resupply some of this energy back to the electrical grid. This may help to smooth out erratic supply from renewable sources such as solar and wind.

Hybrid cars provide a great case study of how a visionary patent strategy can positively impact commercial success. Hybrid car patents are relatively easy to identify, allowing patent trends to be easily identified and related back to commercial drivers. The lessons revealed from hybrid car patent analysis can be applied to other areas of clean technology as well as to conventional technology.



"The hybrid car industry is a great example of clean technology innovation in action. Toyota's initiative and aggressive patent filing strategy have both led to worldwide sales dominance and forced competitors to respond in a variety of ways. There are lessons here for all innovative companies, including the need to adjust your IP strategy depending on your existing IP position within your sector." – *Mike Lloyd*

Mike Lloyd, IP Management Consultant: phone (03) 9243 8315 or email mike.lloyd@griffithhack.com.au

The Method

In-depth research

Griffith Hack patent searchers searched international patent databases for patents that had the words 'hybrid' and 'car' within two words of each other in either the title or the abstract, and where patents were filed in 1980 or later. Altogether around 58,000 individual patents were found, which were combined into 19,500 patent families.

A patent family is defined as a group of patents for the same invention and sharing the same initial filing date. This can arise where the same or similar patents are filed in two or more countries, or where different aspects of a common invention are protected by related patents.

Patent Network Analytics

Patent data was analysed for trends that illustrate patent strategy. In addition, patent quality or 'dominance' was assessed by network analysts Optimice using a method that combined all known hybrid car patents by building a network of their citations ('Network Patent Analytics'), and then finding the patents at the centre of this network⁴. This method was used to assess both individual patents and also patent portfolios; a more dominant patent portfolio had more patents in the centre of the patent network.



What is a hybrid car?

Hybrid cars can be defined as a vehicle that includes both a petrol or diesel engine (hereafter '**engine**') and a secondary form of propulsion. The secondary form of propulsion is most often an electric motor powered by a battery or the engine, but may include other secondary power devices such as compressed gases or a flywheel.

Hybrid cars offer better fuel consumption than equivalent conventional cars because 1) the energy normally lost as heat during braking can be captured and reused to assist the engine and 2) there is scope to plug hybrid cars into power points at night and recharge the battery from mains electricity, which is cheaper and has less environmental impact than energy from fossil fuels. The major disadvantage with hybrid cars is they require complex systems to integrate the engine and the secondary propulsion system. This complexity has formed the basis of many hybrid car patent applications.

The Results

Leading the way

Toyota leads the world in hybrid car patent families (Figure 1). Toyota holds 43% of the known hybrid car patent families, or more than 4000 patent families, compared to just 8% of patent families held by US car companies. Other Japanese car companies, including Nissan and Honda, have filed an additional 35% of the known hybrid car patents filed by car companies.

Toyota achieved its leading position in around 1995 (Figure 2). Toyota had filed almost no hybrid car patents in the beginning of the 1990s, and European car companies (mainly Volkswagen/Audi) were leading the patent race. However, Toyota ramped up patent filing in 1992, and quickly built a strong lead, which only other Japanese car companies attempted to keep up with in the 1990s. US car companies also started filing more patents in the mid-1990s, but much more slowly than the Japanese companies.

Hybrid cars offer better fuel consumption than equivalent conventional cars

Figure 1: Toyota, Nissan and Honda lead the rest of the world in hybrid car patent families

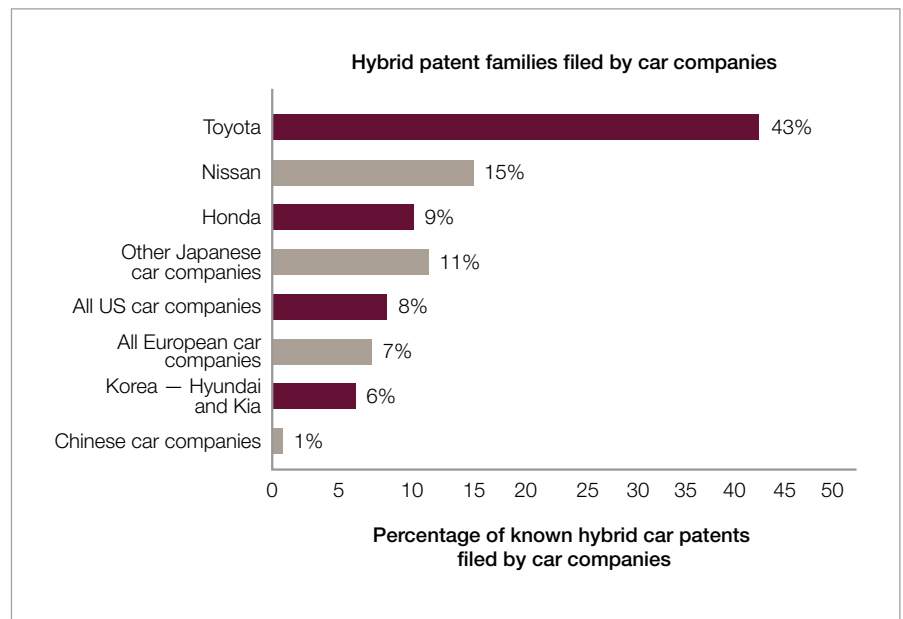
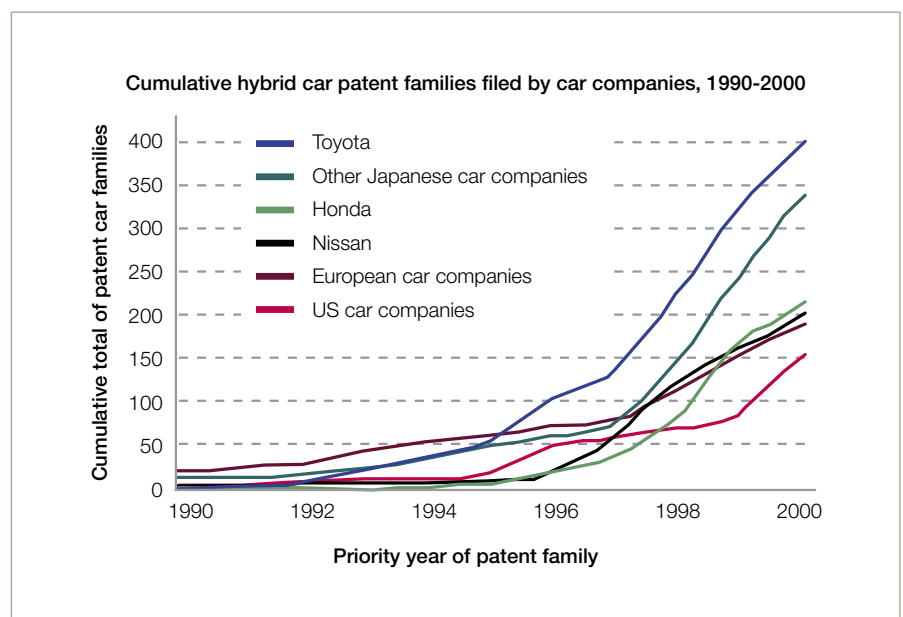


Figure 2: Toyota moves ahead of its competition in the number of hybrid car patents in about 1995, building from a very low base



Non-Japanese suppliers have been slower to increase patent filings

Figure 3: Toyota has continued to increase its lead over other patent applicants since 1995

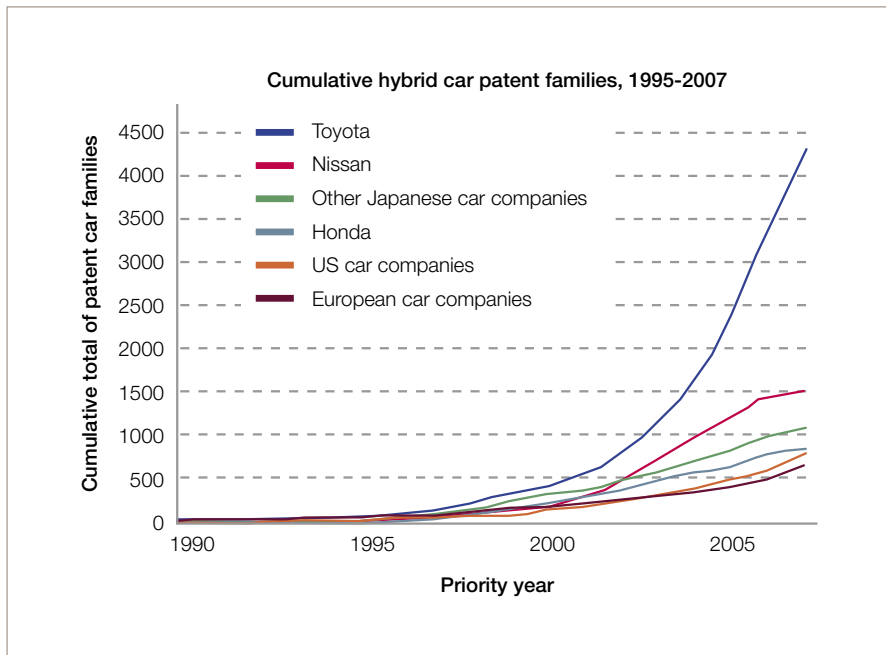
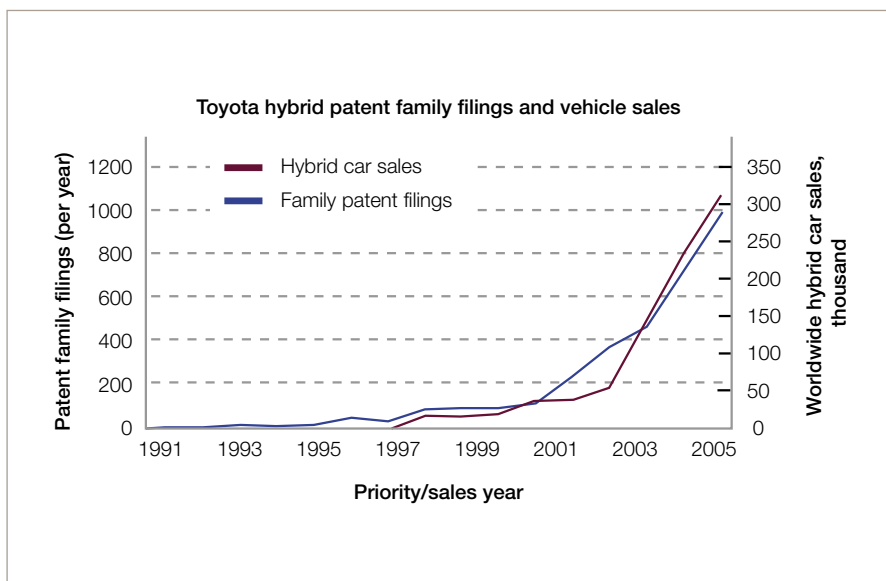


Figure 4: Toyota hybrid car patent filings precede hybrid car sales, but then ramp up along with hybrid car sales. Sales data: Toyota website⁵



Toyota retains a commanding lead in patent filings to this day (Figure 3).

The analysis showed an apparent correlation between the number of hybrid cars sold by Toyota and the number of patents filed (Figure 4). This suggests that commercial success of the Toyota hybrids is encouraging Toyota to file more patents.

This has helped Toyota to dominate hybrid sales in the US, the largest car market in the world (Figure 5).

The dominance of Toyota and other Japanese car companies in hybrid car patents is also mirrored by suppliers to these companies (Figure 6). Japanese suppliers also ramped up patent filings in the mid-1990s and have continued to increase their patent filings, although they have not filed as many patents as Japanese car companies. In contrast, non-Japanese suppliers, while filing fewer patents than Japanese suppliers, filed more patents than non-Japanese car companies. Hybrid car innovation may be more driven by suppliers than car companies outside of Japan, while the converse applies within Japan.

Toyota retains a commanding lead in patent filings

Figure 5: Toyota and sub-brand Lexus account for three quarters of the 660,000 hybrid cars sold in the US in 2007-8. Source: Hybridcars.com

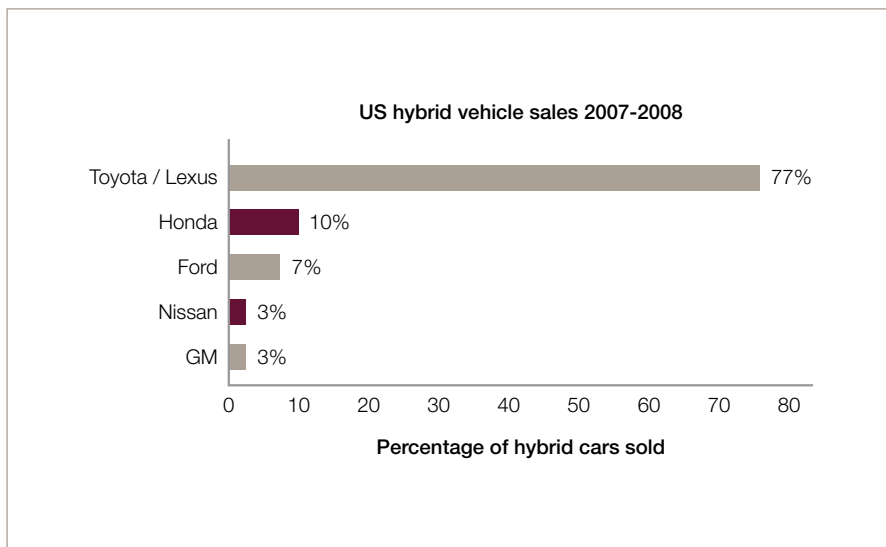
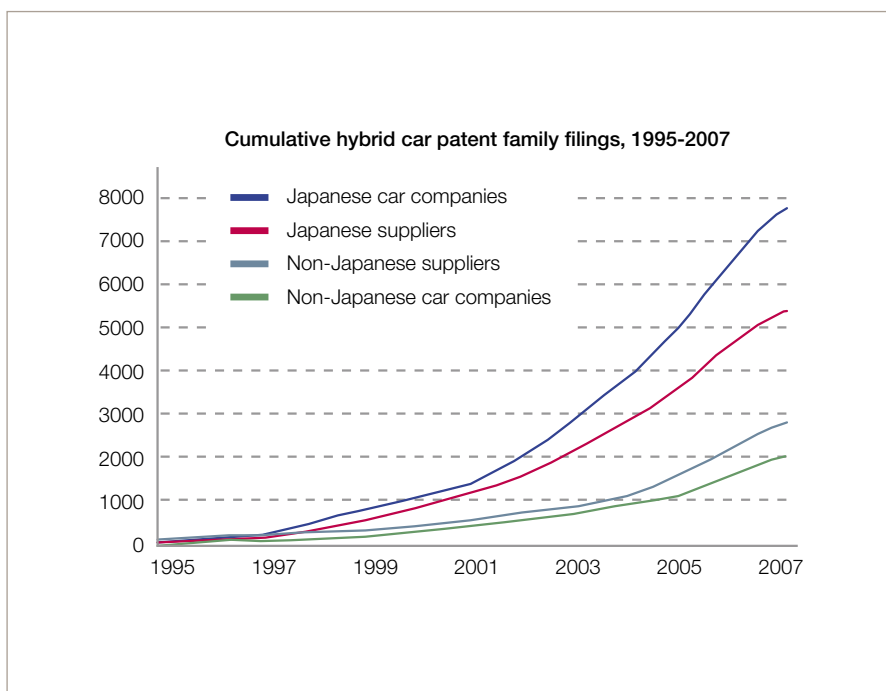


Figure 6: Japanese suppliers supported Japanese car companies in filing hybrid car patents from 1995 onwards



“Growing concerns about energy security, climate change and pollution are motivating governments everywhere to introduce strong measures that favour innovation in clean technologies such as hybrid cars, renewable energy and the smart grid. This report demonstrates that industry players, such as Toyota in the case of hybrid cars, are massively investing in IP to ensure that they will be competitive as the world moves into a new age of clean technology. Businesses that embrace sustainability innovate and flourish, provided they protect their IP carefully and thoughtfully.” – *Justin Blows*.

Dr Justin Blows, Associate:
 phone (02) 9925 5900
 or email justin.blows@griffithhack.com.au

Figure 7: Most Japanese patents were only filed in Japan

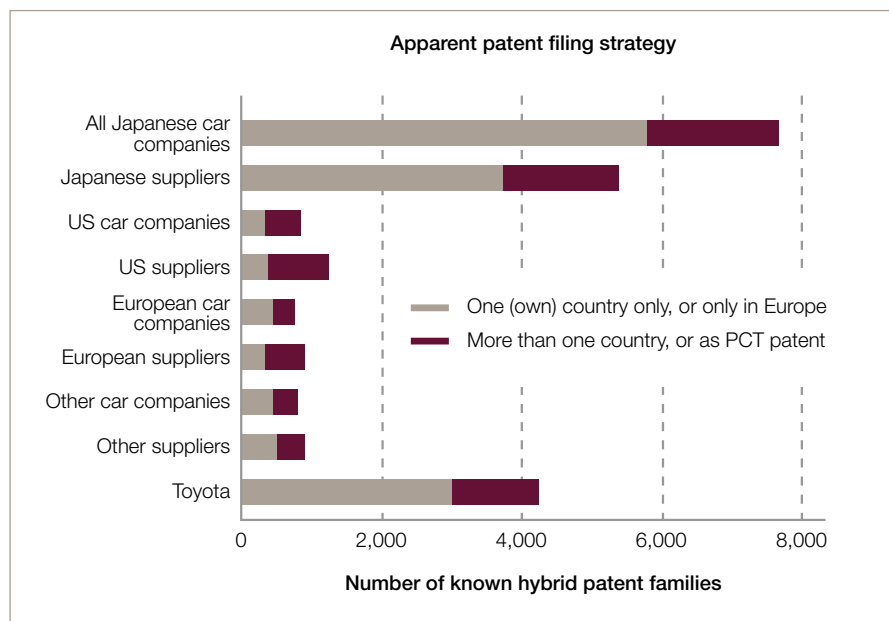
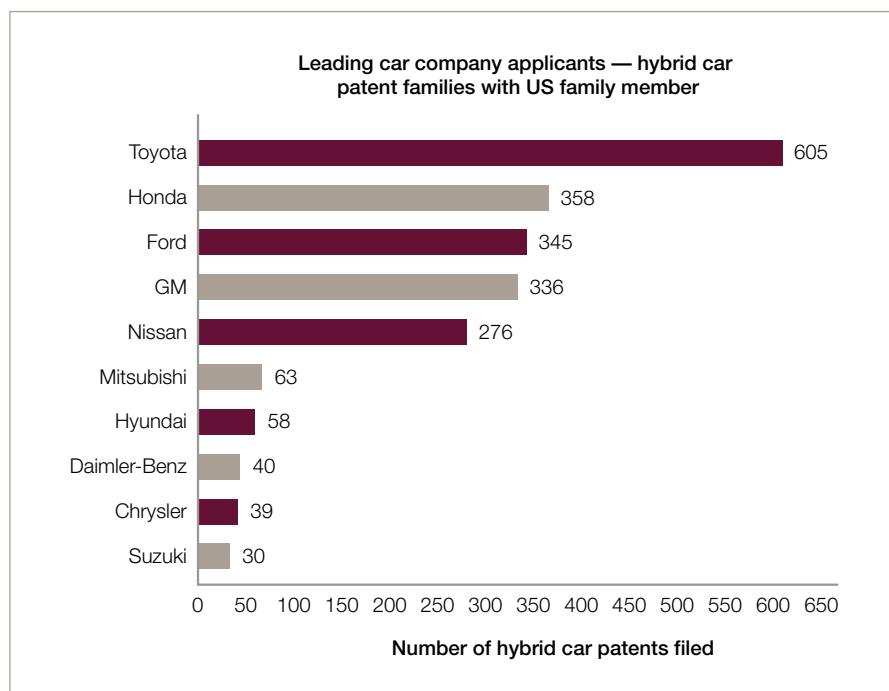


Figure 8: Toyota has filed the most hybrid car patent families with a US family member



While Japanese companies filed many hybrid car patents, the majority of these patent families were only filed in Japan, although enough Japanese patents were filed outside of Japan to make them the most common international patents as well (Figure 7). In contrast, the majority of patent families filed by non-Japanese companies were filed in more than one country.

Of the patents filed internationally, the majority of Japanese and non-European patents were filed in the US, but less than half of these patents were filed in Europe. In contrast, European applicants only tended to file their patents in Europe, with less than 50% of their international patents in either the US or Japan.

The net effect of these different patent filing strategies is that Toyota dominated hybrid car patents in the US as it does elsewhere, but the relative lead was not as strong. Also, Ford and GM follow closely behind the second strongest filer Honda (Figure 8).

Network Patent Analytics has confirmed that Toyota had the most dominant patent portfolio (Table 1). Honda and Nissan were next, with Ford patents having greater dominance than those from GM.

Surprisingly, four of the ten most dominant patents, including the top two, were filed by the

Toyota had virtually no hybrid car patents until the early 1990s

relatively unknown American hybrid car drivetrain developer Paice Corporation (see Table 2, page 10). The leading patent filed by Toyota was in sixth position, and the leading patent filed by Ford was in equal eighth place. Paice's dominant patents allowed it to have the ninth most dominant patent portfolio despite having comparatively few patents.

The ascent of Toyota

Hybrid sports cars and patents are not new. The first known hybrid car was designed by Dr Ferdinand Porsche in 1898 as a means of extending the performance of a pure electric car⁶, and before Dr Porsche went on to design the iconic Volkswagen Beetle and Porsche range of sports car. The first known US hybrid car patent was filed in 1905 by the Belgian engineer Henri Pieper. Audi started developing prototype hybrid cars from 1989, with an unsuccessful attempt to commercialise these vehicles in 1997.

The single event that has done more than any other to commercialise hybrid technology was Toyota investing in this area. Toyota had virtually no hybrid car patents until the early 1990s, but a corporate decision was made to develop this technology in 1994⁷. The first Toyota Prius was sold in Japan in 1997, followed by the US and Europe in 2000.

Figures 2 and 3 show that the decision by Toyota to invest in hybrid car development was mirrored by a decision to invest aggressively in patent protection. Toyota's aggressive patent filing strategy has made life difficult for other companies, and likely forced them into either designing around the Toyota patents and/or taking a license from Toyota. Ford and Nissan have elected to do the latter, with Toyota thought to be open to licensing its hybrid

technology to offset its high development cost and to help set "the standard for the hybrid power train"⁸.

Toyota has been open about its patent strategy, claiming in a recent presentation⁹: "The first-generation Prius held more than 300 patents on its hybrid technology. The second-generation Prius claimed 370 patents. Since then, the Prius nameplate has had more than 2000 patent applications filed across the world,

Table 1: Most dominant hybrid car patent owners according to network analysis

<u>Rank</u>	<u>Patent owner</u>	<u>Relative dominance index*</u>	<u>Number of patents in data set</u>
1	Toyota	100	3635
2	Honda	71	1435
3	Nissan	62	1644
4	Ford	60	809
5	General Motors	23	428
6	Peugeot-Citroen	22	255
7	Hitachi	21	393
8	Volkswagen	20	127
9	Paice Corporation	18	28
10	Renault	16	209

Table 2: Most dominant hybrid car patents according to network analysis

<u>Rank</u>	<u>Patent number</u>	<u>Priority year</u>	<u>Summary</u>	<u>Owner</u>
1	US 6,209,672	1998	Hybrid car with two electric motors, one connected to engine and one connected to car wheels	Paice Corporation
2	US 5,343,970	1992	Transmission that combines power from electric motor and engine	Paice Corporation
3	US 5,806,617	1995	Control system for combining electric and motor power in transmission	Equos Research
4	US 6,338,391	1999	Electric motor coupled to turbocharged motor, and control system	Paice Corporation
5	US 4,351,405	1978	Engine driving one set of wheels, and electric motor partially powered by regenerative braking driving the other set of wheels	Hybricon Incorporated
6	US 5,428,274	1991	Control system for electric motor powered by internal combustion motor or battery	Toyota
7	US 6,554,088	2001	Hybrid only runs engine when high torque needed	Paice Corporation
8 =	US 5,264,764	1992	Controller for requesting an engine driven generator to top up the vehicle battery	Ford
8 =	US 6,470,983	1999	Controls battery level on hybrid drive according to navigation plans of drive	Hitachi
9	US 6,943,460	2002	Control system for a hybrid car including cylinder deactivation program	Honda

with the third-generation Prius filing 1000 on its own¹⁰.”

In fact, the patent advantage enjoyed by Toyota may be greater than its numerical advantage suggests. The patent system allows early patent applicants in a new technology area to gain an important ‘first mover advantage’. The first company to file a patent or patents in a particular area has an opportunity to secure a broad monopoly and use this monopoly for commercial advantage.

Secondly, early patent applicants have an opportunity to file further patents for related inventions, where the use of these related inventions may infringe on the earlier patents, but still represent a patentable improvement over the earlier patents.

Owning a large number of patents also lowers the risk that a court may find one or more of the owner’s patents invalid. A determined competitor may find the evidence needed to invalidate a major patent, but the probability of invalidating or even avoiding some 4000 patent families, such as those filed by Toyota, is very unlikely.

A viable investment

Toyota’s early commercial lead with its Prius model also helped it to build its ‘hybrid’ brand. Up until recently, only hybrids sold by Toyota, or its licensees Ford and Nissan, featured the capacity to

The technology field of hybrid cars is still relatively new, even if fast growing

drive by one or both of an electric or conventional motor. Toyota's early promotion of the dual-mode capability may have convinced some consumers that all hybrids need this capability, possibly making commercialisation of alternative drivetrains – such as the Honda drivetrain, where the electric motors assist the petrol motor – more difficult.

Toyota's hybrid vehicles have been a commercial success and “undoubtedly contribute to the success of the entire Toyota range and help Toyota meet the CAFÉ standards” (US corporate fuel economy standard), as expressed in one of the *Paice v Toyota* judgments¹¹. On the other hand, Toyota hybrid vehicles were found in the same judgment to be less profitable than other Toyota vehicles, but still profitable.

Nonetheless, the technology field of hybrid cars is still relatively new, even if fast growing, and the long-term commercial value of Toyota's patent strategy may take many years to be fully clear.

Patenting strategies

A significant majority of Japanese patents, and even a sizeable minority of non-Japanese patents, were only filed in the home country of the applicants. A secondary benefit of filing patents is to secure ‘freedom to operate’ by disclosing information in the

patent application, which may prevent other patent applicants from claiming the same inventions in future patent applications. Even an ungranted Japanese patent application can help secure freedom to operate in most countries around the world, and save the cost of the translation of the Japanese patent application into a second language.

In contrast, the majority of non-Japanese patent applicants had at least one foreign patent filing. Many of these patents would have been drafted in English, which is commonly used in patent applications around the world.

No one-size-fits-all approach

It should be noted that the strategy of achieving operating freedom and protecting worldwide commercial interests by only filing some of your patents in your home country may not work in all industries. New cars are very capital intensive to develop, and car companies may be reluctant to develop new models where freedom to operate may be restricted in even one or two major markets. However, in other industries where the development cost is lower, competitors may be willing to develop and commercialise new technologies even if some potential markets are restricted by blocking patents. Patent owners need to consider these factors when making

decisions about which countries to file patents in.

Role of independent developers

Paice Corporation was founded in 1992 by Dr Alex Severinsky to develop hybrid drivetrains. Paice started drivetrain development before Toyota and other Japanese car companies got serious about hybrid cars around 1994. As a result, Paice has been able to file some important patents, including four out of ten of the most dominant patents identified in the list of key patents (see Table 3, page 12).

Paice has attempted to litigate three of these patents against Toyota, and Toyota was held to infringe Paice's US patent 5,343,970¹². Damages for this infringement were assessed to be \$US4.3 million, plus \$98¹³ per car for future cars.

It is hard to assess if these patents have paid off for Paice. On the other hand, a royalty of \$US98 per car sold should exceed \$2 million per year in annual revenue, and Paice is continuing legal action against Toyota. A more favourable outcome for Paice is possible.

Independent developers have made significant returns in other technology areas, with the \$US612 million paid by the makers of the BlackBerry email device to settle a patent dispute with an independent patent developer

There is a worldwide acceptance of the need to reduce fuel consumption

providing an indication of what is possible. Australian examples of the success of independent developers include:

- CSIRO in enforcing its 1993 Wi-Fi patent against Hewlett-Packard and other technology firms¹⁴.
- Uniloc, a company founded by Australian inventor Ric Richardson, in seeking a \$US388 million patent infringement judgement against Microsoft. Richardson is believed to be entitled to a sizable share of any payout,

which would be related to a patent for the prevention of software piracy.

Paice Corporation has not been the only company to allege patent infringement by Toyota hybrids, but Paice is the only company where published evidence of a successful outcome exists (Table 3).

One possible reason for the apparent poor success rate of litigants against Toyota is that Toyota may have helped secure

freedom to operate for their technologies via their prolific patent filing strategies and resultant patents publication.

The role of the patent system

As previously noted, hybrid cars have been around almost as long as the car itself, and many of the key concepts have been known for many years. However, the majority of car manufacturers did not appear to regard hybrid cars as commercially viable¹⁶ until after the lead taken by Toyota. Some companies even then resisted the growth of hybrid cars, until quite recently¹⁷. Instead, non-Japanese car manufacturers appear to split between the development of high profit margin but uneconomical SUVs in the US, and the development of advanced diesel cars in Europe.

The price of oil was not especially high during the 1990s when Toyota started its hybrid car program¹⁸. Oil prices were below \$US20 barrel in 1994 (in 2007 dollars), and were to fall to a 50-year low around 1997 when the Toyota Prius was first sold in Japan. Clearly something else was driving Toyota and other Japanese companies to invest so heavily in hybrid car development. There are three probable reasons:

- 1) High petrol taxes in Japan, due to the Japanese government wanting to reduce the dependence of Japan on

Table 3: Known patent infringement litigation against Toyota Hybrid technologies

<u>Patent owner</u>	<u>Patent numbers</u>	<u>Priority year</u>	<u>Not known, but no available evidence of success</u>
<u>Paice Corporation</u>	US 5,343,970 US 6,209,672 US 6,554,088	1992 1998 2001	Infringement held of US 5,343,970 and damages awarded. Infringement not found of other patents
<u>Field Hybrids LLC¹⁵</u>	US 6,481,516 US 6,668,954	1992 1992	Patent held to be abandoned during prosecution
<u>Conrad Gardner</u>	US 7,290,627	1992	Not known
<u>Solomon Technologies</u>	US 5,067,932	1990	Not known
<u>Antonov PLC</u>	EP 0414782 (US 5,309,778)	1988	Infringement not held in German court

imported oil¹⁹. While this would have certainly driven the Japanese development of hybrid cars, petrol was cheap in the key US market at this time (a similar regulatory driven effect might be seen in other technologies as the price of emitting carbon dioxide rises in response to emission trading regulations being introduced around the world).

- 2) The potential to gain a market advantage by developing the key technologies required to successfully commercialise hybrid cars, and then owning these developments via patents.
- 3) The expectation that ownership of these key fuel savings technologies would become very valuable when world oil prices rise from the lows of the mid-1990s, which was a fair long-term assumption to make during this period.

Toyota's innovation and patent strategy appears to have been successful in achieving these objectives. Toyota's extensive patent portfolio has slowed car manufacturers not licensing from Toyota from selling dual mode vehicles, and enabled Toyota to capture three quarters of the US hybrid market. Toyota's early and strong patent position probably also helped it to avoid allegations of patent infringement by other parties. Strategic use of the patent

system appears to have protected Toyota's investment into hybrid car technology.

An eye for opportunity

Worldwide oil prices started increasing strongly from 2002, and more recently there is a worldwide acceptance of the need to reduce fuel consumption for environmental as well as economic reasons. If Toyota had not heavily invested in hybrid cars in the 1990s, it is likely that others companies would be doing so at the moment. However, Toyota's patent-supported initiative has probably brought forward the introduction of hybrid car technologies by around ten years, and competitive pressures may have also encouraged other car companies to either develop or license hybrid technologies ahead of the current oil price levels.

There is a secondary effect of the patent system on innovation. Nissan and Mitsubishi have recently announced the commercialisation of pure electric vehicles. Besides providing a unique marketing advantage, the production of electric vehicles may help these companies avoid many of Toyota's patents. In this case, the patent system may help encourage overall innovation by forcing companies wanting to compete with market leaders to innovate in new areas.

Open innovation

An example of the history of hybrid vehicles illustrates the value of patents in the commercialisation of new inventions. In 1979²⁰, US fuel economy enthusiast David Martin developed a hybrid vehicle powered by a lawn mower engine. A top speed of 90 mph (145 km/hr) and a fuel economy of 75 mpg²¹ (3.1 l/100 km) was claimed. There is no record of a patent being filed by Martin, who made his plans freely available shortly afterwards in a US alternative lifestyle magazine²². However, there appears to be no commercial adoption of this technology within the US, as companies would have no competitive advantage.

'Lead Users'

'Lead User Innovation' is defined by Von Hippel²³ as innovation by an advanced user of a product who wants more from the product than their supplier is currently providing. The lawn mower hybrid invented by David Martin is an example of a non-commercial lead user. Demand by lead users can also encourage new suppliers to offer improvements of the underlying product. We can see an excellent example of this in the hybrid using commercial plug-in conversion kits offered by new suppliers²⁴, components of which are even the subject of patent applications²⁵.

The Lessons

Formulate the right strategy

So what lessons should companies hoping to innovate in the clean technology space draw from the strategies of Toyota and other companies in the hybrid car industry? One way of considering this is that companies or organisations developing IP strategies need to consider the following factors:

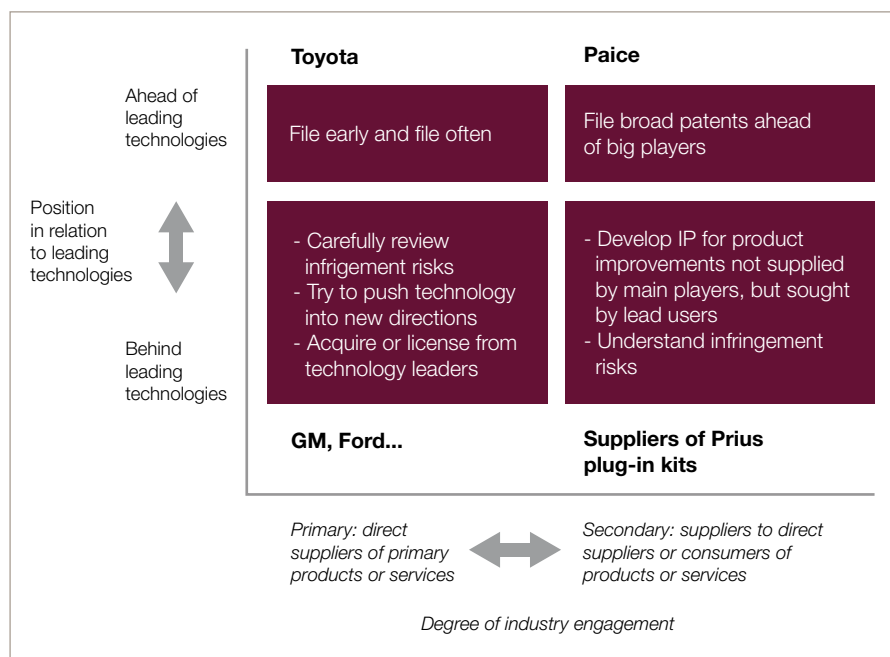
- How does the technology being developed compare to the technology being used or patented by the industry leaders? Are you ahead of or behind the leaders? If you are not sure of this, a sophisticated patent search may help you understand your position further.

- Where does your organisation sit in the industry? Are you a ‘primary’ supplier to the consumers in the industry (for example, a car company in the hybrid car industry)? Alternatively, are you a secondary supplier (for example, either supplying products to the primary suppliers, such as a component supplier to the car companies, or a supplier of ancillary products and services to the consumers of the primary supplier, such as supplying plug-in kits and improved batteries to existing owners of Toyota Prius cars).

Knowing where you sit in relation to the above factors can in turn help suggest an optimal IP strategy, as illustrated in Figure 9. These strategies are based on the apparent strategies used by some of the companies in the hybrid car field profiled in this article.

The implications for innovators are clear. Companies wishing to succeed in commercialising new technologies need to understand where they sit with respect to their competitors patent and technology portfolios, and to fully understand their competitors as opposed to their own business strategy. This can help them choose an appropriate IP strategy. Failure to understand how companies compare to their competitors may lead to wasted investment, infringement and a lack of commercial success.

Figure 9: Recommended IP strategies depend on technology and industry position



Implications for Australian companies

In April 2009, the Australian Federal Government launched the Green Car Innovation Fund, which will provide \$1.3 billion over ten years for car companies and suppliers operating in Australia for projects that ‘significantly reduce fuel consumption and/or greenhouse gas emissions of passenger motor vehicles’.

This study would suggest that car companies and suppliers who plan to invest in projects related to hybrid cars consider the significant

number of patents already filed in this area. Of note, this study only identified 271 hybrid car patents filed in Australia (and with a mere 23 of these filed by Australian applicants). However, it's likely that any invention of commercial value developed in Australia would attract export interest, and hence the developers of these inventions would need to consider the extensive number of hybrid car patents filed outside of Australia as well as within Australia. **GH**

Need to know more?

To learn more about this study, please contact Mike Lloyd, Griffith Hack's IP Portfolio Management Consultant, on (03) 9243 8315 or mike.lloyd@griffithhack.com.au

To use patent data to determine technology trends in your industry, please contact George Mokdsi, Griffith Hack's Information Services Manager, on (02) 9925 5975 or george.mokdsi@griffithhack.com.au

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The patent data in this report was taken from the patent collections available through Thomson Innovation provided by Thomson Reuters. Doris Spielthener of Optimice is gratefully acknowledged for her network analysis of these patents.

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14. <http://www.abc.net.au/news/stories/2009/04/02/2533653.htm>
15. <http://www.nysd.uscourts.gov/courtweb/pdf/D08MNXC/05-00525.PDF>
16. Former GM employee Ted Louckes, now employed by Paice Corporation, claimed in 2001 in reference to his former industry experience, 'It's accepted in the industry that hybrids are environmental band aids and economic disasters'. 'Saviors or Snake Oil Salesmen? – Paice Corp – Hyperdrive, hybrid vehicle technology' (Christopher A. Sawyer, Automotive Design & Production, November 2001): http://findarticles.com/p/articles/mi_m0KJl/is_11_113/ai_80617833/
17. Robert Lutz, then GM's vice chairman of product development, claimed in 2004, "It just doesn't make environmental or economic sense to try to put an expensive dual-powertrain system into less expensive cars which already get good mileage". See http://money.cnn.com/2004/01/06/pf/autos/detroit_gm_hybrids/
18. http://www.wtrg.com/oil_graphs/oilprice1947.gif
19. *The Clean Industrial Revolution*, Ben McNeil, Allen and Unwin 2009, page 178
20. <http://www.motherearthnews.com/Green-Transportation/1979-07-01/Electric-Car-Conversion.aspx>
21. Which still compares favourably with the 50 mpg claimed for the 2009 Toyota Prius.
22. <http://www.motherearthnews.com/Green-Transportation/1980-01-01/Update-David-Arthurs-Hybrid-Electric-car.aspx>
23. See Von Hippel on Democratizing Innovation (2005), <http://web.mit.edu/evhippel/www/books.htm>
24. <http://www.calcars.org/vehicles.html>
25. US company, A123 Systems Inc., has filed patent applications for improved batteries, some of which are provided as part of a Toyota Prius plug-in conversion kit offered by its subsidiary Hymotion, see <http://www.a123systems.com/hymotion/products>



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