

Leading The Charge

Top Innovators in the drive to solve EV range anxiety

It is becoming clear that the future of the car is electric. From humble beginnings in the early 2000s, electric cars are now driving faster and further towards market dominance by promising superior performance to the enthusiast, and a more sustainable commute to an increasingly environmentally aware society. Yet despite an almost continuous flow of media articles announcing new models and promises to phase out all new petrol vehicles, less than 1% of all cars on the road are purely electric. It must be asked then, in a world fully embracing technology in other aspects of life, why has it taken more than two decades to reach just a 1% market share?

The answer lies in infrastructure. Crucially, there are two huge questions in the mind of anyone considering the switch: *What happens if I run out of battery? How long is it going to take to charge?* For the average driver, the reliability of a five-minute visit to one of many local filling stations in return for a 500-mile range wins out over a hunt for a plug and a couple of hundred miles of sensible battery conscious driving. This balance however is shifting. In the UK for example, the number of publicly available charging stations increased by 220% between 2016 – 2020. Vehicle charging stations were historically labelled as either 'Fast' or 'Slow'. We can now add 'Rapid' and 'Ultra-rapid' to the list, and technology is in development to enable 'Continuous' charging technology, which could spell the end of so-called range anxiety altogether.

In this article we explore the pace and scale of innovation and put patent a lens on the key players breaking new ground in this field. We then take a detailed look at the company leading progress in induction charging, WiTricity. The focus technologies are:

- **Alternating Current (AC) Charging:** The traditional charger, this technology requires vehicles to make use of an onboard rectifier to convert the AC into DC for storage. An AC charging station typically runs at a relatively low output of around 6kiloWatts. This readily available technology works well on driveways or office car parks but is limited as you can expect a full charge to take several hours, making it impractical for 'on the road' usage.
- **Direct Current (DC) Charging:** The technology found in faster charging stations, which allow for DC-DC charging without in vehicle conversion. A DC charging station delivers a higher output of around 50kiloWatts but can be substantially higher. This method delivers a high output of power directly into the battery and can deliver up to an 80% charge within 20-30 minutes. This speed makes it perfect for 'on the road' use mid-journey, and a viable option for opportunistic charging.
- **Induction Charging:** A simple yet currently underdeveloped technology, that involves generating an oscillating magnetic field that can deliver charge through a vehicle mounted receiver. Induction charging roll out would see the rise of 'opportunistic' charging and could be the answer to ending range anxiety altogether.

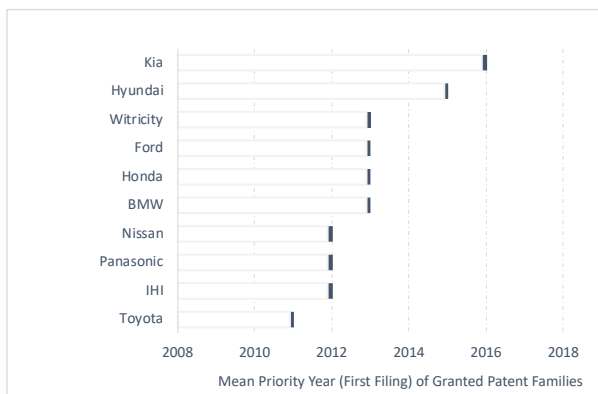
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Addressing Range Anxiety – Innovation in Charging Technologies

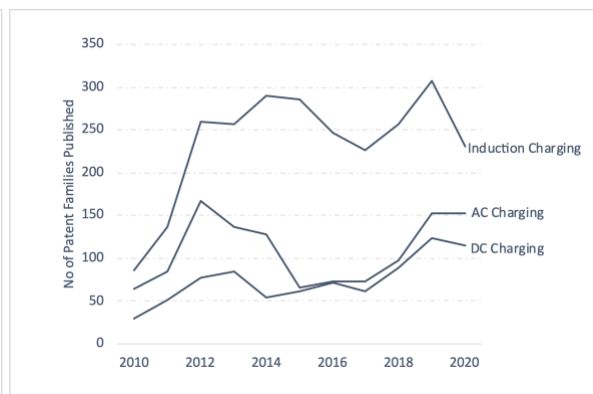
In recent years within the automotive industry, the spotlight has been on improvements in [battery technology](#). When it comes to easing consumer concerns around range, a continued increase in the energy density and a reduction in the cost of batteries will be crucial. The infrastructure must also keep pace, to provide a variety of fast and reliable charging options.

The majority of the Top 10 Innovators in this field are in the automotive sector, with a small number of exceptions such as Panasonic, which supplies the automotive industry and IHI, which is working closely with WiTricity, the only EV Charging ‘pure play’ on this list. The average age of invention amongst the innovation leaders is 8 years – a reasonably recent technology for sure, but not one that on a first glance is working on the cutting edge of the field. However, when taken in combination with data on the pace of inventions, a recent drive does start to emerge. Starting in 2017, innovation across all focus technologies has experienced noticeable resurgence, with induction charging leading the way both in terms of pace and quantity of inventions.

Mean Age of Inventions: (US & Europe)



Pace of Inventions (US & Europe)



Source: Cipher, As measured by patent families either granted or pending.

With the oldest average invention, Toyota was one of the earliest adopters of EV Charging technology. A number of organisations entered the AC & DC space in the early to mid-1990’s, however Toyota & Honda were true pioneers in the **induction charging** space, with the first inventions described in 1992, over a decade before any of the other current top players were innovating in this area.

Of the Top 10 Innovators, Kia & Hyundai own the newest portfolio of inventions in this area, explained by the recent surge of innovation by these companies. They also both have a significant number of inventions in the pipeline, with 63% and 42% (respectively) of their invention portfolio still pending. A strong show, but it should be mentioned that the recent drive does not necessarily translate to the best inventions. Kia and Hyundai sit at the bottom of the list when measured against a metric indicative of invention quality. In contrast Toyota, one of the longest standing organisations in this group, ranks within the top 5 for invention quality.

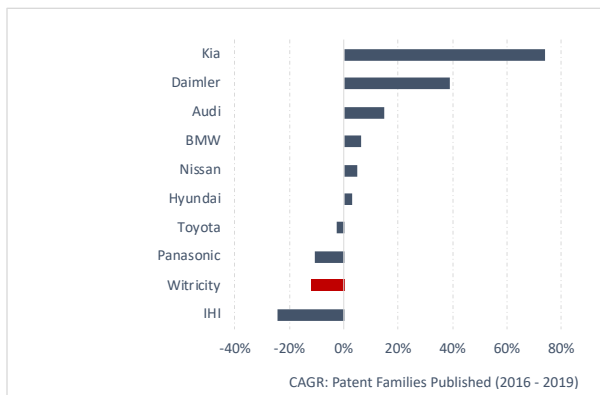
Clearly, there is innovation taking place. Data aside, the number of charging points is visibly increasing, and at an accelerating pace. The ‘Fast Charge’ network (DC) is continuing to expand, whilst the AC ‘Slow Charge’ network continues to benefit homeowners and office workers who can afford the time to plug in and leave their car. Induction technology is only currently available in various small-scale trials. However, with those inventions making up the bulk of investment, this technology is one to watch as the infrastructure continues to develop.

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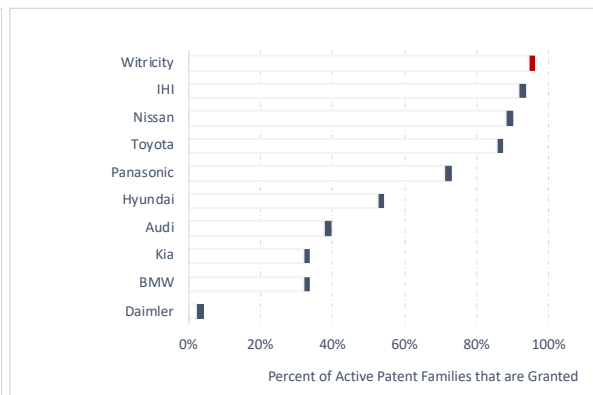
Oscillating Magnets and Wireless Cars: Is this the future of charging?

Stopping to refuel has been a mainstay of the driving experience for decades. It is no stretch to assume that when the electric revolution comes, we will simply switch out pumps for cables and hope that the charge times start to decrease as the technology matures. Induction charging technology has the potential to break this cycle and promises wide ranging solutions – from charging pads at traffic lights to electrified highways that charge whilst you drive.

Pace of Invention: CAGR 2016-2019, Induction Charging



Percent Inventions Granted: Induction Charging



Source: CIPHER

For a technology that is dominating the innovation landscape, induction charging is currently relatively low profile from a consumer's perspective, with only a few projects up and running. As shown on the CAGR graph above, the top contenders in this technology are well established automotive companies, and all except Toyota are growing their portfolios in this space.

Kia invested heavily in the run up to 2019, before unveiling the concepts for a joint venture project with Hyundai. Called the Automated Valet Parking System (AVPS), with a commercial release scheduled for 2025, this futuristic concept will combine wireless charging with autonomous driving – by allowing a parked car to cruise to a vacant wireless charging space when available, and then automatically relocate to a standard bay once complete to make way for another vehicle.

Daimler and BMW are the innovators with the most pipelined inventions and have joined forces to reach agreement on standardised induction technology, paving the way for universal charging pads that will increase the appeal of their growing electric fleet. Using a birds-eye-view camera system integrated into the already commonplace parking cameras, drivers will simply have to park over a ground pad and turn off the engine for charging to automatically begin.

These charging pads could mark the start of a transition with far more ambitious aims. Dynamic charging is a technology still in the developmental phase, but it perhaps offers the best glimpse of what lies ahead for induction innovation. The process involves installing subterranean pads a few centimetres beneath the road that will wirelessly transmit electricity to receivers installed underneath the vehicle. Once installed, a driver running low on charge would simply have to pull into the designated charging lane to top up their battery on the move – a convenience impossible with the traditional fossil-fuel powered car.

Successful trials are ongoing, but currently the technology is prohibitively expensive. To be commercially viable, businesses need to figure out how to monetise the service whilst simultaneously bringing down the

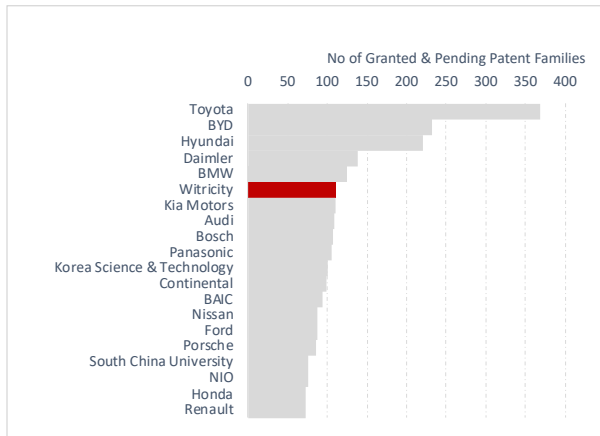
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estimated cost of \$2.5 million per kilometre of electrified highway. The jury is out amongst experts on how the economics will play out, but it is certainly a technology with potential to change the way we charge.

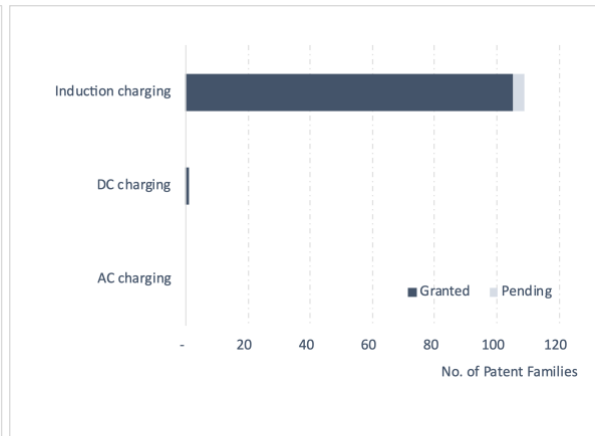
On the radar: WiTricity, driving forward induction innovation.

Search for 'Induction Car Charging', and press releases from internationally recognised automotive manufacturers dominate the results. However, when you look closer into the technology boasted by the likes of BMW, you can trace a significant proportion of induction charging innovations back to licences bought from one company: WiTricity.

Number of Innovations: (US & Europe)



Number of Inventions (US & Europe)



Source: Cipher

Across the US & Europe, WiTricity ranks 6th when looking at innovators across all three technologies. This is an achievement by itself, when you consider the overwhelming majority of their portfolio lies in just one technology area, whilst the rest of the list is spread across three. What makes this ranking even more impressive, is that WiTricity has an estimated annual revenue of just \$21.1 million per year. BMW, the company that takes the 5th position in this region, reported global revenues of \$98.9 billion.

With this portfolio, WiTricity owns several of the underpinning technologies that will enable induction charging to become ubiquitous. Their technology is licenced by key suppliers to the automotive industry and is already installed on some impressive cars – the McLaren Speedtail Hyper-GT to name one. Through their partnership with IHI Corporation, WiTricity plans to supply wireless charging solutions for both automotive and industrial customers globally, and IHI have promised collaboration with the aim of accelerating this rollout.

Having recently secured an additional \$52 million in funding, WiTricity is a company to watch. Their technology is already being deployed worldwide in cars, busses, bikes and robots and they envision a dynamic charging solution in the not-too-distant future. With investment from some of the largest automotive companies in the world, there is no doubt their technology will soon see the company become a household name.

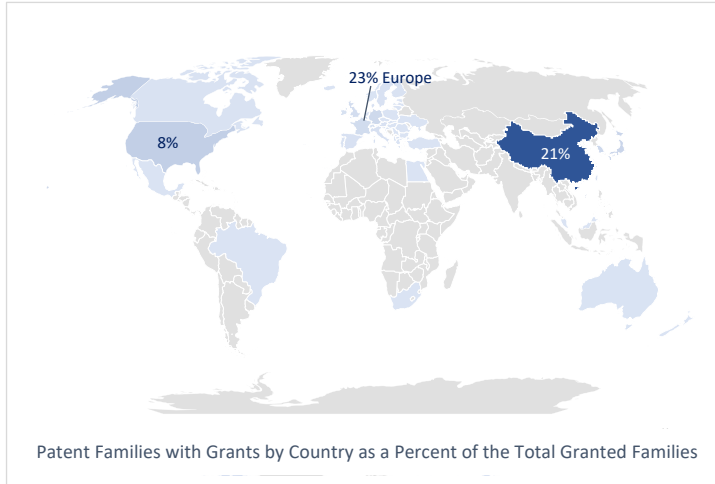
For reference & attached: Innovation Lens Snapshots

- Technology Screening: AC Charging, DC Charging, Induction Charging
- Company Screening: Induction Charging
- Company Snapshot: WiTricity

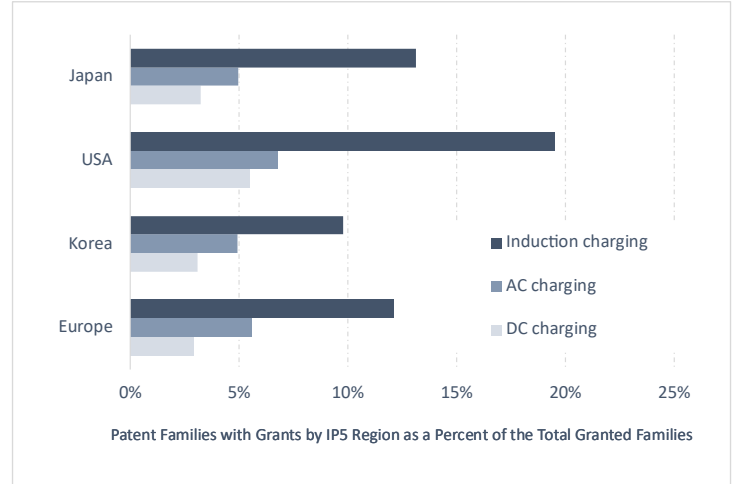
Technology Screening: Electric Vehicle Charging Technology

Technology Areas: AC Charging
DC Charging
Induction Charging

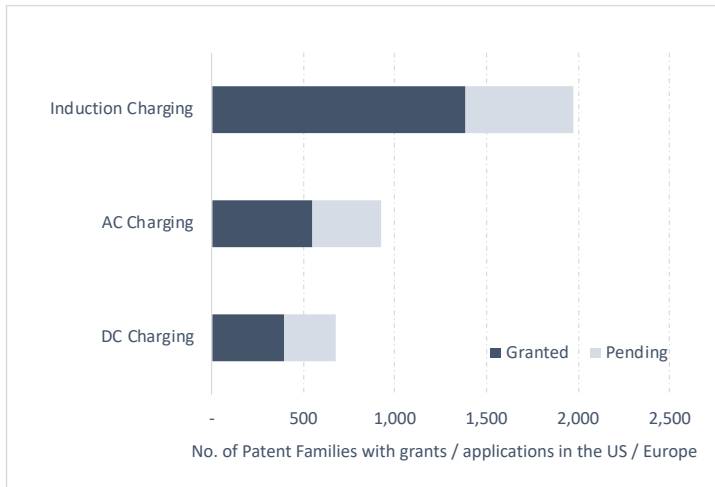
Geographies Protected: By Country across all 4 Tech Areas



Geographies Protected: By Key Region / Countries



Number of Inventions: US & Europe

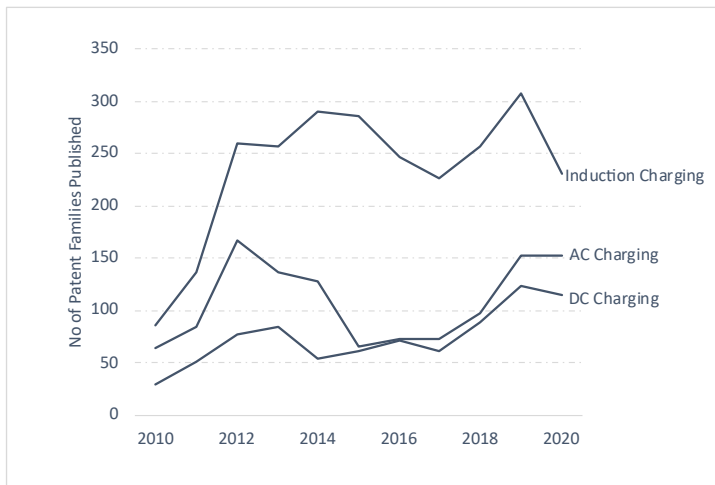


Companies: Top ranked by Inventions owned, US & Europe

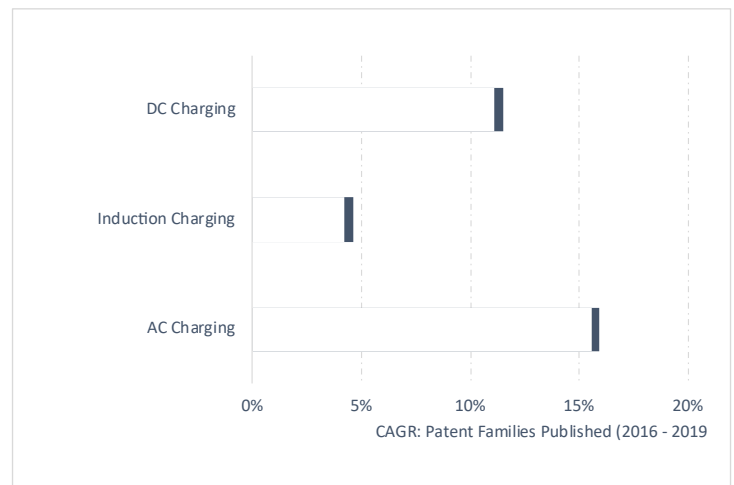
Rank	DC Charging	AC Charging	Induction Charging
1	Hyundai	Toyota	Toyota
2	Porsche	Daimler	Witricity
3	Daimler	Bosch	BMW
4	Bosch	Audi	Daimler
5	Continental	BMW	Audi
6	Volkswagen	Porsche	Ford
7	Kia	Renault	Bombardier
8	ABB	Hyundai	Continental
9	Audi	Volkswagen	Hyundai
10	BMW	Continental	IHI Corp
11	General Electric	Siemens	Nissan
12	Toyota	Innogy	SEW Eurodrive
13	Ford	Kia	Bosch
14	General Motors	Ford	Panasonic
15	Renault	General Motors	Honda

Top Owners of Patent Families with grants / applications in the US / Europe

Pace of Invention: Trendlines, US & Europe



Pace of Invention: CAGR 2016-2019, US & Europe

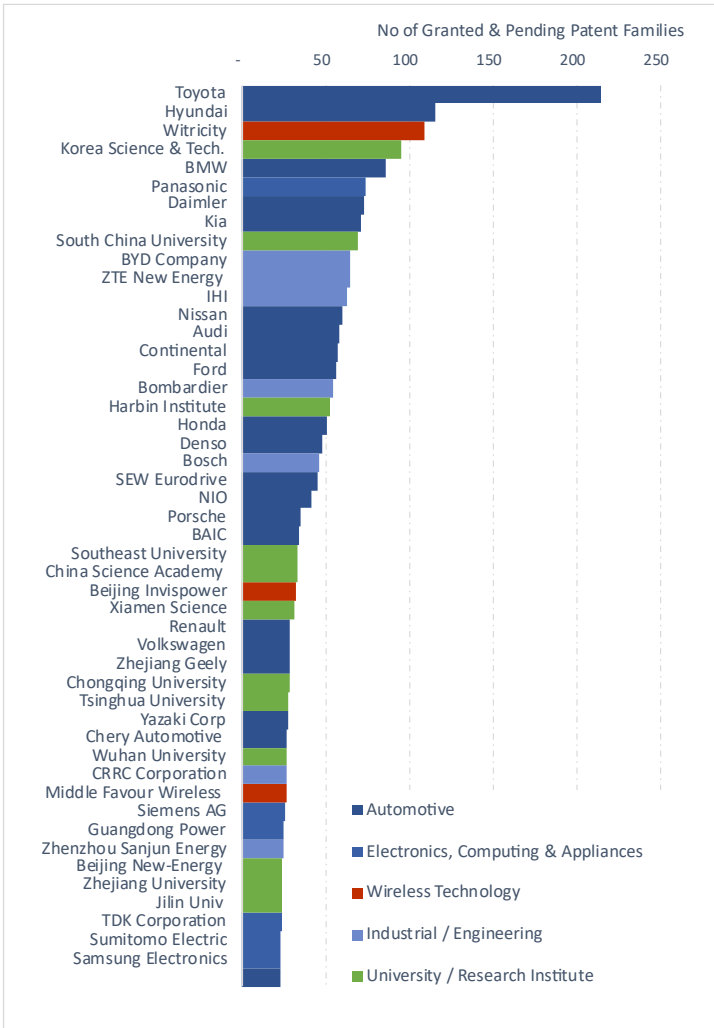


Company Screening: Induction Charging

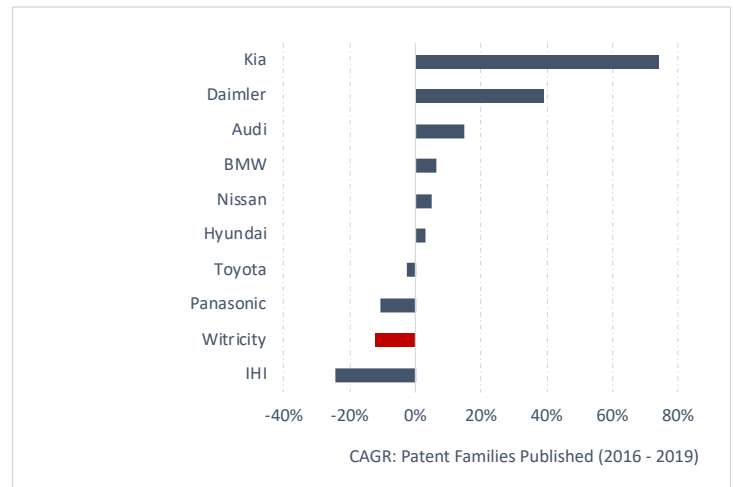
Technology Area: Induction Charging

Region: Global *granted/pending patent families (inventions)* (NB. State Grid of China has been omitted)

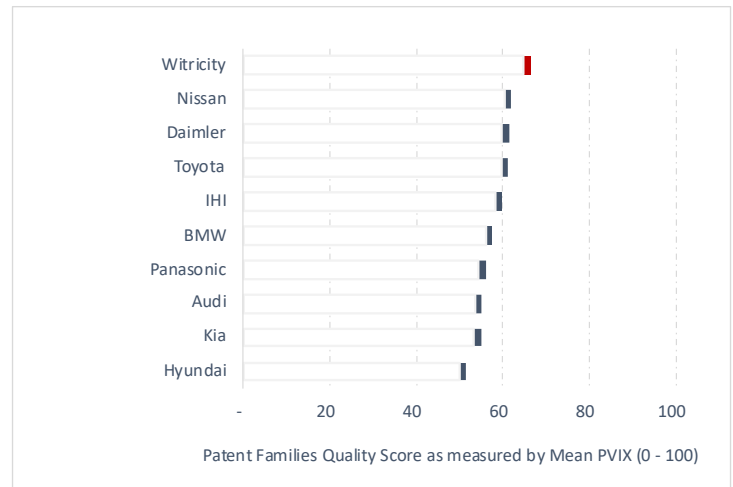
Companies: No of Inventions Owned, Induction Charging



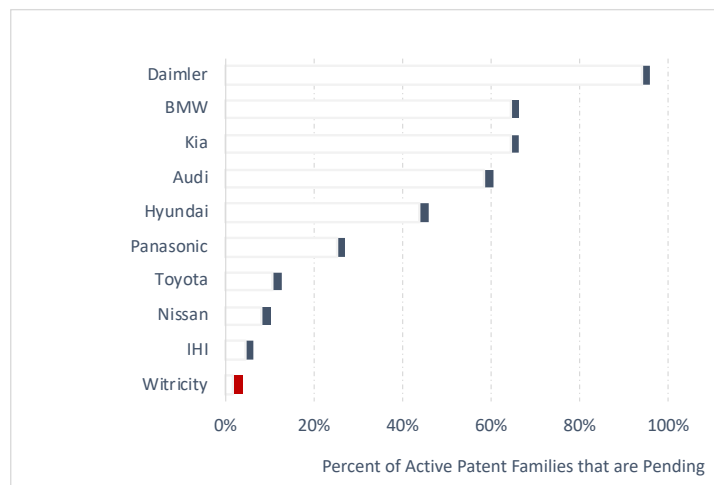
Pace of Invention: CAGR 2016-2019, Induction Charging



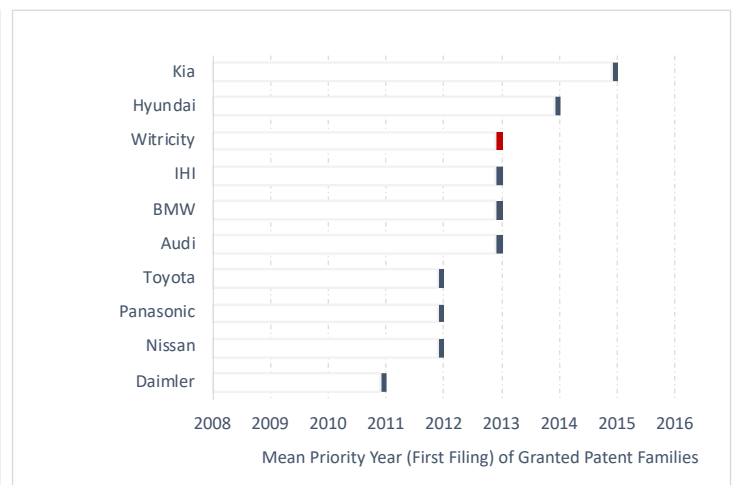
Quality of Invention: Induction Charging Technology



Invention Pipeline: Induction Charging Technology



Invention Age: Induction Charging Technology (First Filing Date)

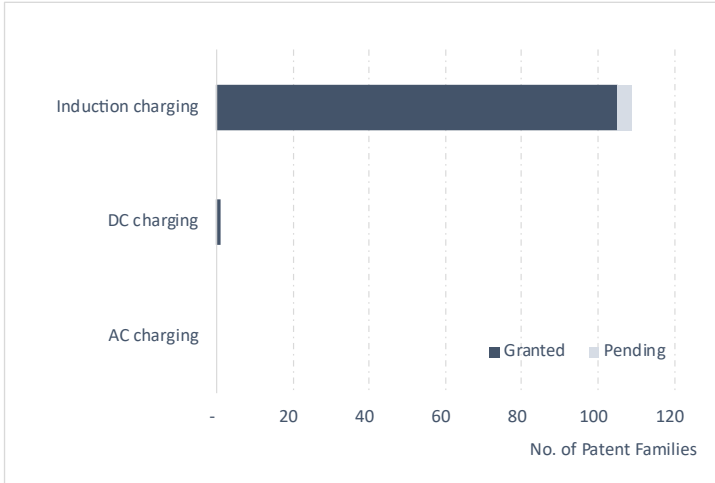


Company Snapshot: WiTricity – Induction Charging

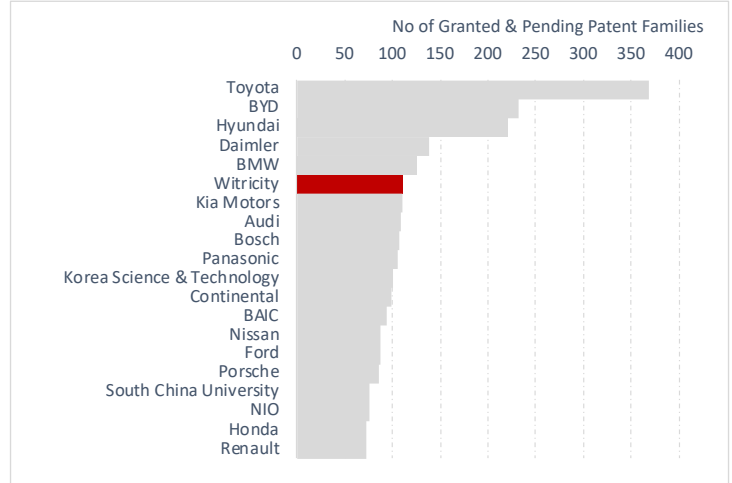
Technology Areas: AC Charging
DC Charging
Induction Charging

Region: Global *all granted/pending patent families (inventions)*

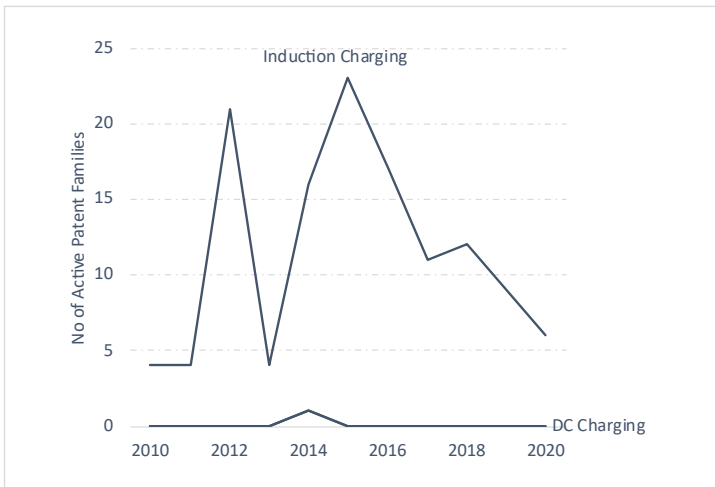
Number of Inventions: *WiTricity*



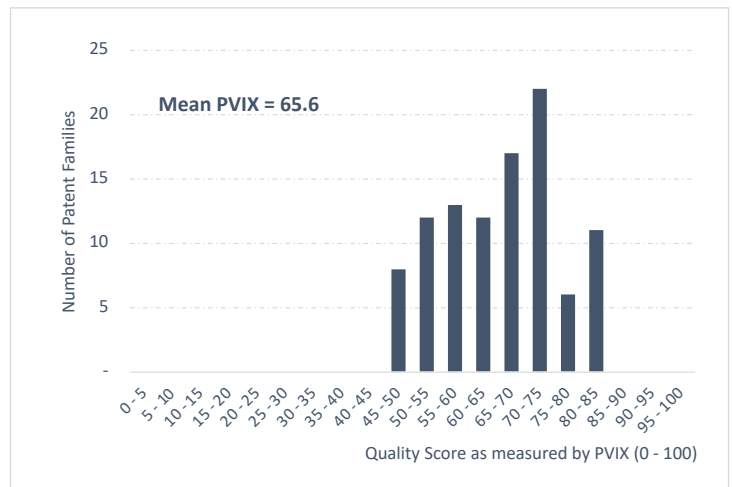
Companies: *Number of Inventions Owned*



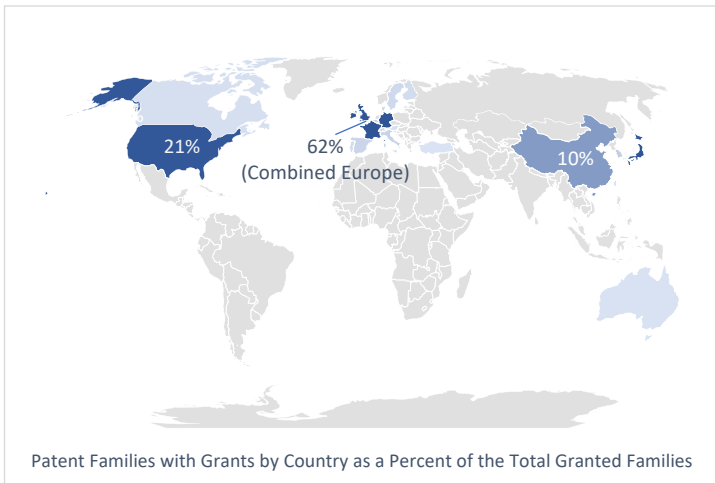
Pace of Invention: *WiTricity*



Quality of the Inventions: *WiTricity*



Geographies Protected: *WiTricity*



Invention Age: *WiTricity (Expiry Date)*

