POWER MOVES

The IP playbook for the future of renewables and energy storage

IAM SPECIAL REPORT

FOREWORD

As energy innovation accelerates, feeding the world's demand for green power, the stakes are higher than ever to ensure corporate intellectual property strategies can keep pace. Recent months have been highly instructive: for instance, several solar industry giants put an end to global patent disputes with their closest rivals in a series of cross-licensing deals, while lithium-ion battery manufacturers have not hesitated to pursue licensees in court.

As 2025 unfolded more and more disputes came to light, revealing an intricate web at the intersection of competition, technological breakthroughs and intellectual property protection. This Special Report is designed to help readers make sense of this complex and evolving landscape and enable you to strategically position your organisations to maximise opportunities in a fast-changing market.

We begin by unpacking the concept of the energy transition as a large-scale industrial endeavour more than as a creature of climate diplomacy. In "The energy transition through the IP lens", our contributing authors address important questions around the makeup and ownership of critical green energy technologies. China emerges as the global leader, its ascent driven by policy and now by intense market competition that is increasingly playing out in the intellectual property arena.

"The battery race is an IP race" turns the spotlight on the world of energy storage, focusing on automotive batteries and the innovators driving the rapid development of lithium-ion technologies and the next-generation chemistries that will power the cars of tomorrow. Strategists from industry titans CATL, Panasonic Energy and EVE Energy offer insights on the state of the battery sector, the balancing act between aggressive IP protection and a culture of collaboration, and how IP teams can prepare for the sector's future.

Finally, "Shining a light on solar" takes a deep dive into the patent disputes that have rocked the solar industry and the two competing solar cell technologies underpinning what has been an extremely eventful few years for solar module manufacturers. An era of IP-backed cooperation, in the form of patent cross-licensing agreements, has taken shape – a potential key feature of the future of an industry undergoing massive consolidation.

Throughout the Special Report, the contributing authors draw lessons from patent filing and enforcement data, and from recent legal and technological developments, and distill those into actionable tips for in-house IP teams keen to derive maximum value out of their energy innovations.

IAM would like to thank all of the Special Report's contributors for their time and expert insights. IAM

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EXECUTIVE SUMMARY

1. Success for companies working in the energy transition space is found at the intersection of advanced technological innovation, robust manufacturing capabilities and strong intellectual property strategies. As competition intensifies patent litigation has proliferated in the solar and battery industries where some player will not hesitate to enforce globally in pursuit of licences.

2. Real leverage in the energy transition will be gained from strategic technology development and ownership and standard-setting. Sophisticated portfolio structuring, risk management and enforcement strategies will place nations and companies in a more advantageous position to lead green industries.

3. China has emerged as the global leader in clean energy innovation, manufacturing and trade, and its energy titans are increasingly adopting global patent enforcement strategies to stay on top. Patents have transformed from legal tools to strategic assets and will be more crucial as companies jockey for control of entire industrial ecosystems.

4. In the dynamic battery industry, there is space for both fierce IP protection strategies and a culture of collaboration, and companies must carefully weigh the balance if they are to keep ahead of the competition. Major players have turned to various licensing models to maximise the value of hard-earned IP while closely guarding the latest battery chemistry knowhow as the innovation landscape shifts by the day.

5. The massive growth of the solar photovoltaic industry has resulted in cutthroat competition, fostering an environment of widespread patent litigation, pitting major players against one another. However, recent deals involving solar giants indicate that the market is developing a taste for patent cross-licensing and IP-backed cooperation.

THE ENERGY TRANSITION THROUGH THE IP LENS

In the background of the world's search for a sustainable energy future is a dynamic industrial battlefield where the winners are determined not only by technological supremacy and manufacturing prowess, but also by robust intellectual property strategy.

This chapter features four articles that explore the evolving landscape of clean energy innovation and offer strategic tips for mitigating IP risks in the fast-moving space. Furthermore, a highly detailed review of China's clean energy innovation story is followed by a discussion of a growing European dimension to the biggest Chinese players' competitive strategies.

Arun Hill and Aditi Varshney of Clarivate open this Special Report with "The industrial logic of the energy transition", identifying nations and companies investing the most in developing renewable energy technologies. Crucially, the authors reveal that real leverage in the energy transition lies no longer in climate diplomacy but in technology ownership, standard-setting and licensing power.

In the second article, Li Mi and Jensen Li of Lusheng Law Firm, take a deep dive into China, the global leader in clean energy manufacturing and trade, and its renewable energy innovation landscape. As China's energy sector transitions from being driven by policy to being steered by technology and efficiency, patents have evolved into pillars of competitiveness and will continue to play a critical role in determining clean energy leaders in the years to come.

The third article, "Innovation governance: a framework for managing energy patent risks" by Hilary Preston, Eric Klein and Steven Moore of Vinson & Elkins presents a structured approach to managing patent risks in the rapidly evolving energy sector, advocating for cross-functional collaboration to mitigate litigation exposure.

Finally, Russell Woolley, Alexander Hackett and Harry Shaw of Carpmaels & Ransford analyse three key technological areas – solar, electrochemical and wind – and the disputes filed at the Unified Patent Court. A large proportion of the energy-technology disputes so far before the UPC have been brought by East Asian firms, they note, while observing a parallel willingness to settle cases. IAM

THE INDUSTRIAL LOGIC OF THE ENERGY TRANSITION

A new energy race means the regions and companies that can convert invention into industry will set the barriers to entry while others will find themselves in a race to the bottom, write experts from Clarivate.

This year marks a phase change in the energy transition. A decade after the Paris Agreement, global emissions have still not peaked and the diplomatic scaffolding that underpinned early climate action is showing strain. The first phase of decarbonisation was defined by deployment targets and treaties; the next is being carved out by industrial policy, manufacturing depth and technology competition, with IP increasingly acting as the organising principle.

Climate ambition is now expressed through procurement, subsidies and standards rather than international alignment alone, with subsidy disputes beginning to resemble those in semiconductors and AI.

In 2026, the EU's Carbon Border Adjustment Mechanism takes effect, exporting carbon rules through trade. The US Inflation Reduction Act is reshaping clean-technology supply chains by underwriting domestic manufacturing. The brief US withdrawal from the Paris Agreement in 2020, rapid re-entry, and departure again this year underline the fragility of the treaty framework.

Manufacturing strength and ownership of enabling technologies, by contrast, are proving more durable sources of influence as countries move from announcing targets to reducing emissions and diversifying the energy mix. A common misunderstanding, however, is that decarbonisation is mostly about clean power.

Power production accounts for only about 20% of final energy use. The rest lies in industry, transport and heating, and these sectors require far more than additional renewable generation. Industry alone represents half of global final energy use and cannot be decarbonised simply by expanding the grid. These sectors need electrification, cleaner fuels and major efficiency improvements rather than solar and wind alone.

The real constraint is economic and infrastructural. Modern technologies must meet the combined test of affordability, security and emissions, that is, the energy trilemma.

There has been genuine structural progress. Renewables now dominate new power additions worldwide, electric vehicles continue to scale and technology costs have fallen sharply. Even so, the world remains off pace for the Paris Agreement. The first Global Stocktake confirmed that current national plans do not align with a pathway to limit warming to 1.5°C.

Increasingly, the future of green energy is defined by industrial durability. The critical questions are who owns the technologies, who sets the standards that govern their use and on what terms they are adopted.

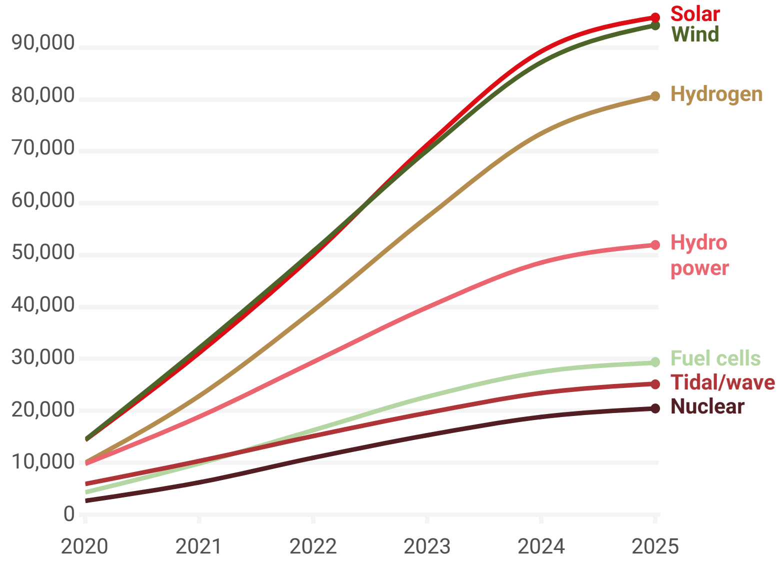
Seen through this lens, the transition takes on its real character. It is not only an environmental endeavour but an industrial one, shaped by the manufacturability, standardisation and exportability of enabling systems. These dynamics are now visible in patterns of clean energy patenting, including batteries, power electronics, hydrogen systems, turbines, and the software and materials layers that integrate these technologies into grid assets, vehicles and industrial machinery.

The scale of the shift

The global patent timeline makes the scale of the shift unambiguous. Invention activity in clean energy has accelerated six-and-a-half times since 2020, reflecting that roughly one-third of required 2050 abatement depends on technologies still at prototype or demonstration stage. As expected, invention appears as a perquisite for deployment rather than a derivative of it.

Figure 1: Solar leads renewable energy innovation

Patent families filed in top 7 renewable energy forms per year, 2020-2025



Source: Clarivate

Most of this growth is driven by Mainland China, which now accounts for roughly 80% of global inventions and targets carbon neutrality before 2060. Mainland China appears in the top ranks across almost every major category, reflecting the breadth of its industrial thesis.

The institutional mix combines upstream research, applied engineering and OEM manufacturing within a coordinated policy architecture. In patenting terms, Mainland China is not only large in absolute volume; it incubates industrial self-sufficiency.

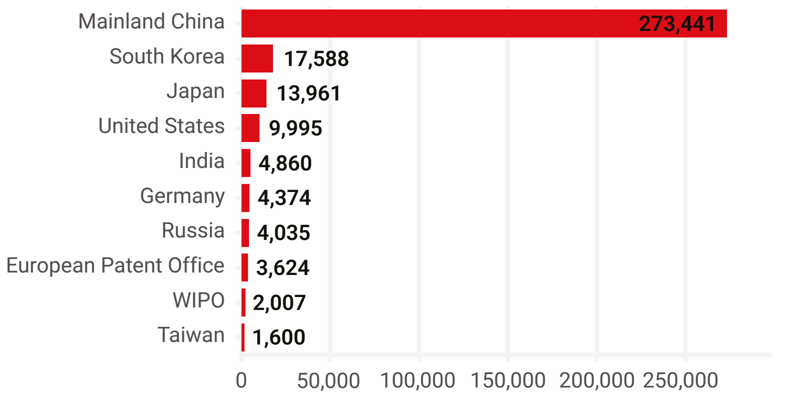
Outside Mainland China, inventive activity expands but without comparable scale. South Korea, Japan and the United States form a second tier anchored in batteries, hydrogen equipment, fuel cells, power semiconductors and precision machinery. These domains require deep chemistry, materials and process know-how rather than high-output domestic deployment.

Europe, led by Germany, forms a third tier, consistent with strengths in turbines, industrial machinery, hydrogen and engineered systems rather than mass manufacturing.

India stands out as a fast mover, expanding more than ten-fold over the period. Unlike Japan or South Korea, where filings map to export supply chains, India's profile reflects deployment-led electrification in solar, grid modernisation and storage with localisation potential. Russia also grows, but filings remain concentrated in nuclear and legacy power systems.

Figure 2: 80% of clean energy global inventions come from China

Top venues for clean energy patenting



Source: Clarivate

Protection strategies confirm this asymmetry. Filing locations skew decisively toward Asia. Europe is similar in aggregate but fragmented across national offices and the EPO.

Structurally, the jurisdictions filing most intensely are those that manufacture the relevant equipment, not those with the highest deployment targets. Emerging markets underline the split between demand and supply: emissions may be reduced where power is deployed, but value is captured where technology is made.

Technologies behind decarbonisation

Geography tells us who is building the transition; technology tells us what and over what timeline. Across categories, the largest expansion by volume has been in solar and wind. In 2025, these categories reached roughly 96,000 and 94,000 inventions, respectively, after six- to eight-fold growth since 2020. Hydropower, fuel cells and tidal and ocean power also expanded, signalling interest in baseload and system balancing. Nuclear, geothermal, waste heat-to-power, biomass and synthetic fuels exhibited strong percentage growth from smaller baselines, consistent with long-horizon industrial applications and sectoral decarbonisation rather than utility-scale substitution.

Hydrogen highlights the divide between technical potential and commercial reality. Across all colours of hydrogen, more than half of the 80,000 recent patents focus on production methods, with activity shifting from automotive fuel cells toward upstream processes, such as electrolysis.

Green hydrogen, produced using renewable power, is strategically important for industrial decarbonisation, but remains expensive and highly energy intensive, with substantial losses between production, storage and reconversion. The patent landscape is led by major gas and chemical equipment companies including State Grid China, China National Petroleum Corporation, Bosch and Toyota, supported by strong research output from institutions such as the Chinese Academy of Sciences. Mainland China, South Korea and Japan dominate regionally, reflecting strengths in membranes, catalysts, storage materials and balance of plant equipment.

The overall picture is of a technology with significant promise but constrained by cost, efficiency and limited infrastructure.

Across all energy sources, there is an observable shift away from new supply toward efficiency, integration and modularity. Several of these technologies can be enumerated from patent filings. For instance, waste-heat recovery reflects industrial efficiency and carbon-pricing logic, solar cell innovation shows second wave, and Small Modular Reactors (SMRs) are consistent with the return of firm, zero-carbon power. A notable share of activity is also in fundamental science and materials substitution, such as electrolytes, catalysts, membranes and conductors.

Digitalisation could also exert a similar effect behaving like software markets, with interoperability and protocol competition creating preconditions for future standards battles. In practical terms, the bottleneck is less about fundamental science than the rate at which grids, pipelines, certification regimes and capital markets can absorb new technologies.

Who is investing?

The identity of the top filers reinforces this structure. With Mainland China included, the global list is dominated by universities, state-owned enterprises and industrial groups, such as Tsinghua University, Tianjin University, Harbin Institute of Technology, Sany and CNPC. This university–Sequence of Events (SOE)–OEM pipeline channels upstream research into energy infrastructure, and no other region presently displays the same degree of vertical coordination.

This is corroborated by this year's Top 100 Global Innovators. The number of companies in the Energy & Electrical industry segment increased from four to seven, suggesting the importance of energy innovators.

The firms recognised, such as Sumitomo Electric (Japan), GE Vernova (United States) and Siemens Energy (Germany), track closely to this narrower view of clean energy. None are utilities, all sit upstream in power electronics, hydrogen systems, heavy engineered machinery, industrial controls and advanced materials, reinforcing the thesis that the transition's IP leverage resides in enabling systems rather than in commodity renewables or asset ownership.

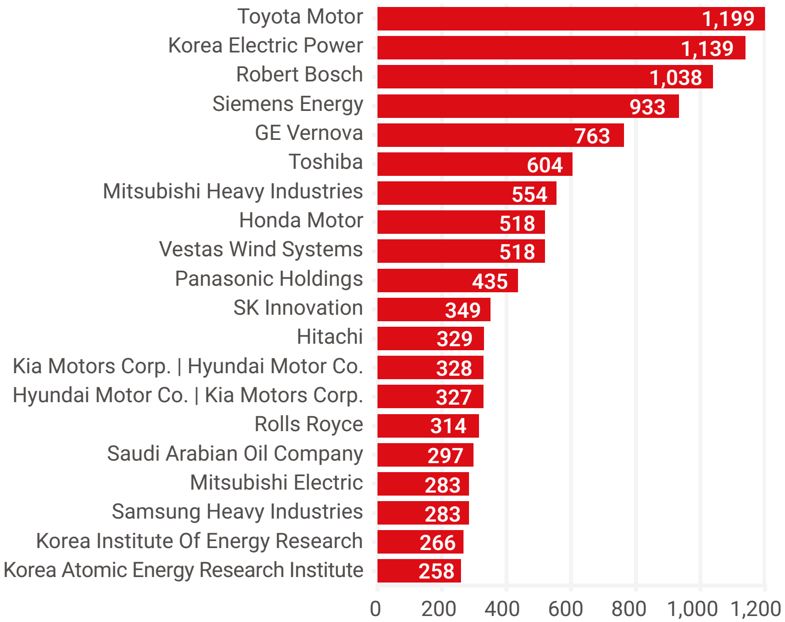
> "The relevant question is no longer whether firms are 'green', but how energy mix, exposure and efficiency gains can be captured across the portfolio"

Mainland China's share of global filings is now so large that it flattens the picture. The trend itself is important, especially when understanding industrial self-sufficiency, but it also makes comparative analysis among non-Chinese firms difficult.

A second view, therefore, removed Chinese activity to reveal where technological leadership is concentrated elsewhere. Doing so, suggests a different centre of gravity.

Figure 3: OEMs are investing heavily in clean energy R&D

Top energy transition patent filers, 2020-2025 (excluding mainland China)



Source: Clarivate

Without Mainland China, invention output sits almost entirely with OEMs, engineered systems firms and advanced materials companies. Toyota, KEPCO, Bosch, Siemens Energy and GE Vernova lead, consistent with the industrial stack required for electrification: turbines, hydrogen systems, power electronics, fuel cells, batteries and vehicle integration. Oil and gas majors also register but at lower volumes, consistent with hedging strategies in hydrogen and carbon capture.

Notably, universities largely fall out of the picture once Mainland China is excluded, indicating a structural difference: in OECD economies, R&D that converts into patents resides downstream in firms that manufacture equipment rather than upstream in academia.

Invention output

The de-emphasis of commodity renewables is evident in the cohort of frontier start-ups that are filing patents. They target the harder segments of the energy system. In the United States, start-ups such as Prometheus (synthetic fuels), Infinium (power-to-liquids) and Zap Energy (fusion) target TRL-heavy industrial decarbonisation backed by deep capital pools and federal industrial strategy.

Europe's frontier, including Seaborg (molten-salt SMRs) and Blue World Technologies (methanol fuel cells), reflects an export-grade engineered systems thesis aligned with CBAM, SAF mandates and maritime decarbonisation. Israel's H2Pro illustrates an IP-first model in electrochemistry, optimised for licensing rather than domestic manufacturing. These portfolios are modest in volume but concentrated in catalysts, thermal management, power electronics and control software.

To increase the resolution further, invention strength (measured using the Derwent Strength Index) can be profiled against age and volume. This differentiates between recent frontier portfolios, mature incumbents tied to installed assets and emerging research pipelines. Mainland China's activity clusters in younger, mixed-strength portfolios concentrated in universities and research institutes, consistent with an R&D-first model in which commercial conversion occurs later through SOEs and OEMs. Sungrow is an exception with a young and strong portfolio aligned with Mainland China's leadership in inverters and power electronics.

"The transition is not only an environmental endeavour but an industrial one, shaped by the manufacturability, standardisation and exportability of enabling systems"

Figure 4: Part 1: Among established players, Huawei and GE Aerospace have the strongest inventions

Derwent Strength Index score of inventions vs age of portfolio of top 50 players (excluding China)

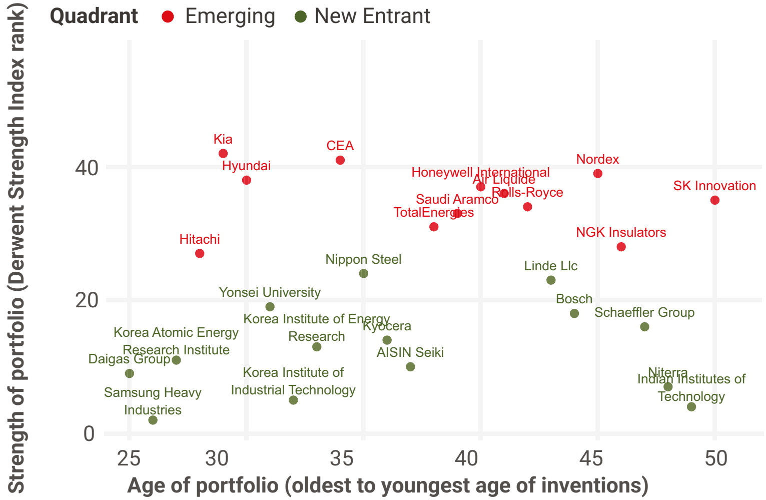
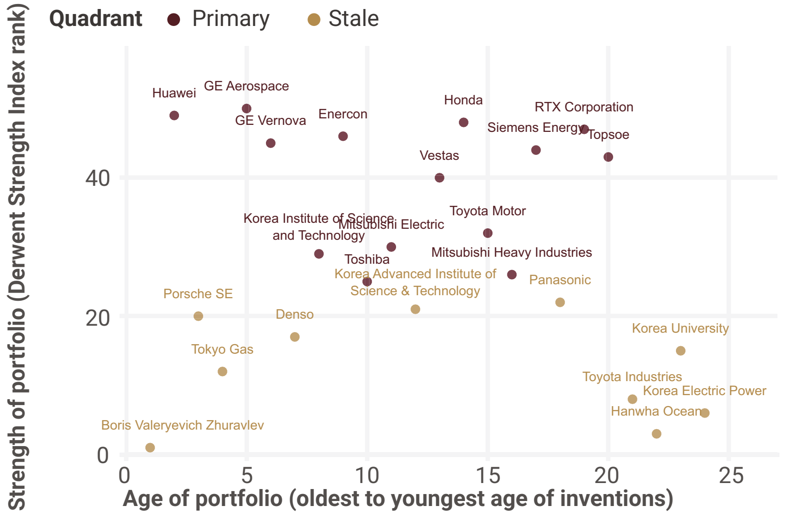


Figure 4: Part 2: Among newer entrants, Korean presence is notable

Derwent Strength Index score of inventions vs age of portfolio of top 50 players (excluding China)



Source: Clarivate

With Mainland China removed, higher-strength portfolios cluster in OEMs and engineered systems firms across Japan, South Korea, Europe and the United States, consistent with export-grade hardware in turbines, hydrogen systems, vehicle platforms and industrial machinery.

A second cluster of older but strong portfolios span automotive and industrial gases, reflecting decades of process innovation in chemistry and materials. Lower-strength older portfolios sit around heavy industry and oil and gas, tied to long-cycle innovation centred on safety, reliability and installed capacity rather than frontier IP. In aggregate, Mainland China produces research volume and incubates integrated supply chains; Japan, Korea, Europe and the United States produce commercially monetisable portfolios linked to certification regimes, export markets and standards. Utilities and fuel incumbents barely register in the inventive frontier. IP leverage in the transition sits upstream in components, chemistry, materials and machinery rather than downstream in asset ownership.

Where the transition will be won (and disputed)

Several implications follow for patent strategy. First, IP leverage in the transition sits closer to enabling technologies than to generation itself. Solar and wind show deployment scale, but competitive advantage now lies in batteries, power electronics, hydrogen equipment, industrial machinery and control software. These layers set the pace (and the margins) of electrification. As deployment bottlenecks are addressed, the real competitive moats will become more visible. Interoperability, grid connectivity, access to capital and infrastructure are already reflected in patenting behaviour. Industries that can turn energy and efficiency inward reduce their exposure to commodity volatility and can build new revenue streams.

Second, industrial policy is reshaping the geography of invention. The United States, the European Union and Mainland China are no longer competing primarily on emissions trajectories but on technology ownership, manufacturing depth and supply chain integration. Emissions will peak at different times, but policy sits upstream and influences where technologies are invented, produced, licensed and certified. Patents are becoming an instrument of industrial strategy. Accelerated "green" examination at the China National Intellectual Property Administration and the Japan Patent Office links processes to manufacturing speed. In batteries and electrolysers, trade secrets could be favoured over patents for formation steps, catalysts and materials. As power systems digitalise, more value is shifting into modular components and integration, where semiconductor and machinery firms already have an advantage.

Taken together, the locus of the transition has shifted toward the systems that make decarbonisation viable at scale.

The regions and firms that can convert invention into industry will set the barriers to entry; others will find themselves in a race to the bottom, competing on rollout margins alone. The transition is global in its environmental logic but asymmetrical in its industrial impact.

This leads to a final implication for patent owners. The relevant question is no longer whether firms are "green", but how energy mix, exposure and efficiency gains can be captured across the portfolio. Decarbonisation has become an allocation problem: hedging across technologies, developing infrastructure, participation in standards-setting and using IP to shape deployment.

As governments look ahead to the next UN climate conference in Antalya, the effectiveness of the COP process itself is increasingly contested, but the need for coordination is not. It is a future that resides in the quiet consensus about who owns, and who controls, the enabling technologies of the transition; where standards are set, how systems interoperate and on what terms they are licensed. And a transition that rewards positioning, not virtue. IAM

Arun Hill, lead consultant, Clarivate and Aditi Varshney, patent search principal lead, Clarivate.

CHINA'S CLEAN ENERGY INNOVATION LANDSCAPE

China's clean energy industry has undergone a remarkable transformation, reflected in the country's patent dynamics and policy evolution, write Lusheng Law Firm's Li Mi and Jensen Li.

China's clean energy industry has undergone a historic transformation from a technology follower to a global leader over the past two decades. According to the latest data from the International Energy Agency (IEA), China currently dominates the manufacturing and trade of most clean energy technologies, accounting for at least 60% of global manufacturing capacity in key technology areas, such as solar energy, wind energy and batteries.

This transformation has not only reshaped the global energy industry landscape but also laid a solid foundation for China's energy transition under the guidance of the "dual carbon" goal.

In terms of intellectual property, China maintains a global lead in green/low-carbon patent applications and authorisations, and the proportion of high-quality and overseas patents continues to rise, reshaping the global pathways for accessing, licensing and complying with clean energy technologies. This means a denser patent landscape, more active overseas patent protection efforts and a systemic intellectual property battle surrounding clean energy and energy storage technologies.

This article provides a comprehensive analysis of China's clean energy technologies over the past 20 years in terms of patents and related policies, covering eight major clean energy types, including solar, wind, hydro, nuclear, geothermal, hydrogen, ocean and biomass energy.

By analysing patent application trends, technological development and policy evolution over the past two decades, this study reveals the complete journey of China's clean energy industry from technology import to independent innovation and then to global export, providing decision-making references and forward-looking insights for participants in the clean energy industry in terms of market competition, technology planning, patent operation and risk prevention.

China's clean energy industry is shifting from a policy driven model to a new stage powered by technology and efficiency. In this process, patents have evolved from supportive assets into strategic pillars of core competitiveness.

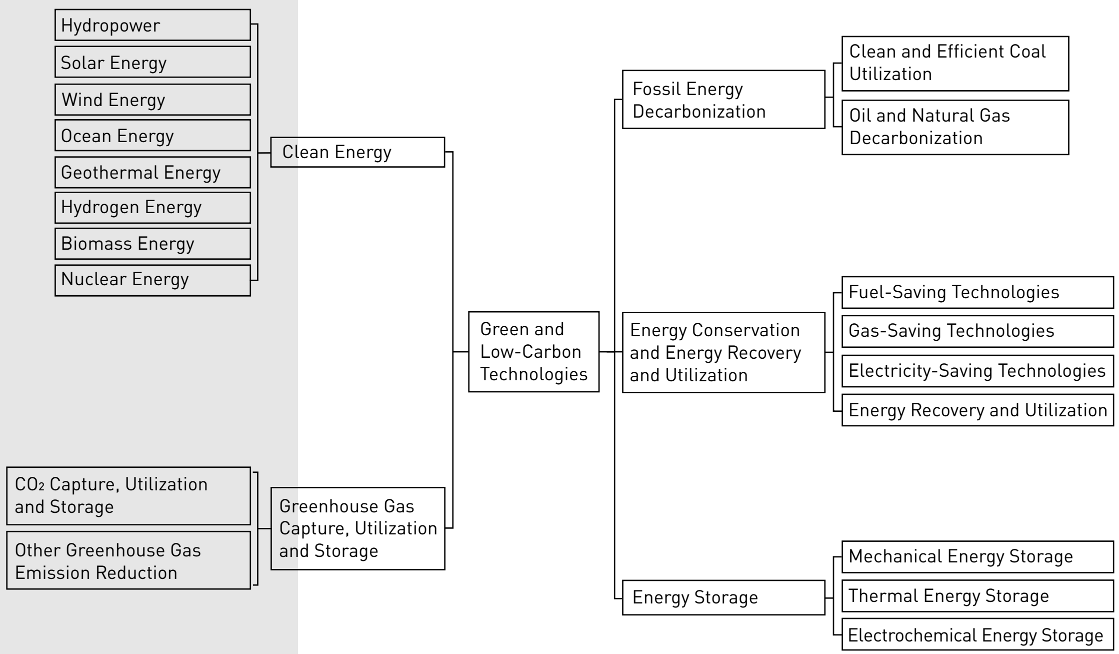
The key challenge for corporations lies in building high quality patent portfolios in high-barrier fields, such as hydrogen, advanced photovoltaics, offshore wind and storage, while establishing localised compliance frameworks to meet increasingly stringent regulatory demands. At the same time, the global competitive landscape is moving beyond product rivalry toward the construction and control of industrial ecosystems, where the deep integration of technology, standards and patents will be decisive in shaping leadership positions.

Scope and Methodology

In this article, the definitions of clean energy and the three types of energy storage technologies are derived from the "Green and Low-Carbon Patent Statistics Report" released by the CNIPA in November 2025, as shown in Figure 1.

This article focuses on clean energy technologies and supporting energy storage technologies within the green and low-carbon technology framework. It retrieves and analyses data on Chinese invention patents from 2006 to 2025 over a period of 20 years and interprets this data in conjunction with the evolution of China's clean energy policies during the same period, aiming to gain meaningful insights for participants in the clean energy industry. The data presented is sourced from the author's patent search results in the PatSnap database, with the last update date being 20 January 2026.

Figure 1: Classification of green and low-carbon technologies



Source: Green and Low-Carbon Patent Statistics Report released by CNIPA in November 2025

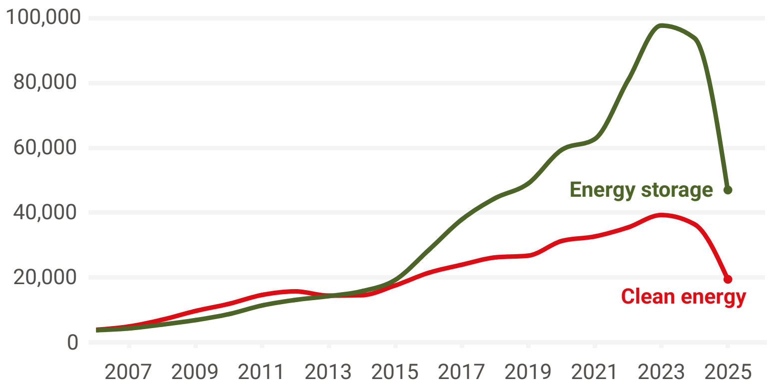
Overview of Chinese clean energy and energy storage technology patents

1. Overall trends in Chinese patent applications for clean energy and energy storage technologies

Patent applications for clean energy and energy storage technologies in China have shown a continuous upward trend over the 20 years from 2006 to 2025, with the energy storage sector showing a significantly leading growth momentum, as shown in Figure 2.

Figure 2: Energy storage outpacing clean energy in patenting

Chinese patent applications in clean energy and energy storage technologies, 2006-2025



Source: PatSnap database

Patent applications in the field of clean energy numbered less than 4,000 in 2006 but have since shown a continuous and stable growth trend. As of 2023, the number of annual applications had reached nearly 40,000, representing a roughly tenfold increase compared to earlier periods, demonstrating the remarkable innovation activity in this technology field. It should be noted that, due to the statutory publication lag of 18 months from the date of filing of a patent application, some applications have not yet entered the publication stage in the past two years, which may appear to be a slight decline in the number of applications based on the statistical results. Therefore, the exact data for 2024-2025 is still being gradually completed.

Overall, the number of patent applications, as an important indicator of R&D investment and innovation output, shows that the field has maintained a steady expansion over the past two decades.

In contrast, patents for energy storage technologies are growing much more rapidly. Since 2014, the annual number of patent applications for energy storage has surpassed that for clean energy. By 2023, the number of applications had climbed to 97,677, more than 30 times that of 2006, and continued to remain at a high level in 2023. This trend indicates that energy storage technology has become a key innovation direction for driving the transformation of the energy system.

Between 2006 and 2025, the annual patent application scale for clean energy and energy storage technologies in China showed continuous expansion and step-by-step leaps. Its distinctive features and growth drivers are highly consistent with the evolution of the national low-carbon transformation policy system.

At the institutional level, the state has continuously strengthened the incentive structure for low-carbon energy development through policy tools such as industrial planning, R&D subsidies, pricing mechanisms and energy storage requirements.

This has not only promoted the growth of R&D investment but also prompted various innovation entities to build technological barriers, reduce compliance risks and participate in industrial competition by strengthening patent layout. Policy and technological innovation thus form a positive interaction, accelerating the continuous rise in patent applications.

Overall, the patent trends in clean energy and energy storage technologies are highly aligned with the national "dual carbon" goals and renewable energy policy orientation, reflecting the increasing awareness among innovation entities in building a systematic and forward-looking intellectual property layout in the Chinese market.

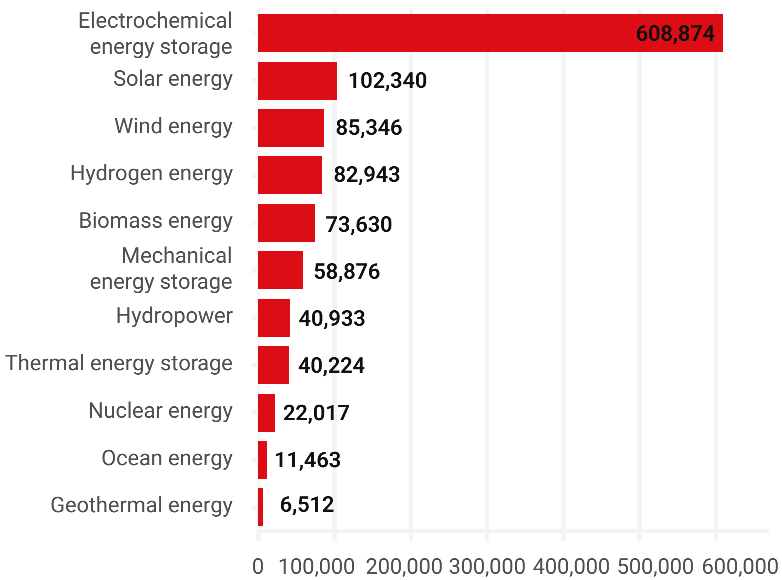
"China's clean energy industry is shifting from a policy-driven model to a new stage powered by technology and efficiency"

2. Ranking China's total patents for clean energy and energy storage technologies by type

Between 2006 and 2025, the total number of patent applications for clean energy and energy storage technologies in China shows a clear tiered distribution pattern. Among them, electrochemical energy storage holds an absolute dominant position with a cumulative application volume of 608,874; solar energy, wind energy, hydrogen energy and biomass energy rank in the second to fifth tiers, respectively. Mechanical energy storage, hydropower and thermal energy storage are at an intermediate level, while nuclear energy, ocean energy and geothermal energy have relatively low patent scales, forming the lower tier in terms of patent quantity.

Figure 3: Energy storage the top focus of Chinese innovators

Ranking of China's total patents in clean energy and energy storage technologies, 2006-2025



Source: PatSnap database

From a patent perspective, the above structure reflects the comprehensive differences between different technologies in terms of industrial maturity, application scope, policy incentive intensity and R&D threshold.

- Electrochemical energy storage has become a core supporting technology for new power systems. Driven by both mandatory energy storage policies and large-scale application scenarios, it has attracted continuous investment from diverse stakeholders, including battery manufacturers, grid companies, equipment manufacturers, and internet energy companies, resulting in highly active patent innovation.
- China has an early start in the commercialisation of solar and wind energy and possesses a leading global advantage in the entire industrial chain manufacturing process. Coupled with long-term and stable policy support, it has accumulated solid technological expertise. Hydrogen and biomass energy, on the other hand, have continued to expand based on the "dual carbon" strategy, but are still in a steady development stage overall.
- Hydropower and nuclear power technologies are mature, with strict industry access and regulatory standards. The focus of innovation is gradually shifting from original equipment to intelligent and digital operation and maintenance. Ocean energy and geothermal energy are limited by resource endowment and commercialiation process, resulting in fewer technology layout entities and a smaller patent scale.

From the perspective of intellectual property law, the differences in patent tiers have also created a significant stratification in the technological competition landscape: in leading sectors such as electrochemical energy storage, photovoltaics and wind power, high-density patent clusters and cross-patent layouts have emerged, becoming the core areas for infringement disputes, licensing operations, and standard essential patent regulation, which have a significant impact on market entry and technology diffusion.

3. Trends in patent applications for clean energy and energy storage technologies

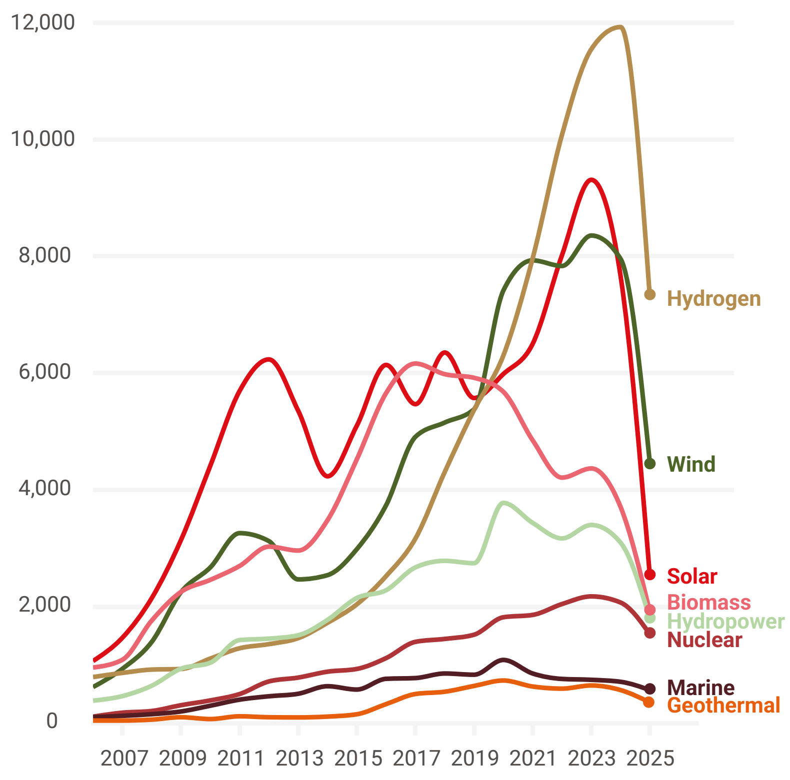
Clean energy technology

Chinese patent applications exhibit a structural growth pattern driven by the top, stable in the middle, and limited at the bottom. Among them, hydrogen energy, solar energy, and wind energy constitute the core driving force for the growth of industry patents, forming the "three main engines" for the development of clean energy technologies. The annual application volume and growth rate of these three types of technologies have consistently maintained a leading position in their respective sub-sectors.

Their rapid expansion is mainly due to the strong impetus of the "dual-carbon strategy", the continuous increase in downstream installation scale, and the continuous maturation of the commercialisation of the entire industry chain. Enterprises are continuously developing patent portfolios around these three areas to build technological barriers and establish a foundation for compliant competition.

As shown in Figure 4, within the three main engines, the evolution paths of each technology direction show a clear divergence.

Figure 4: Hydrogen, solar and wind are powering renewable energy innovation.
Chinese patent applications for renewable energy technologies, 2006-2025



Source: PatSnap database

Top tier:

- Hydrogen energy technology has seen the most rapid growth, maintaining a continuous high-speed expansion in recent years. In 2024, it ranked first among sub-technology categories with 11,924 annual applications, officially surpassing solar energy to become the most active clean energy innovation direction.
- Because solar energy technology was commercialised early and formed a mature industrial system, its annual patent applications peaked in 2023 and then saw a slight decline, reflecting that the industry's focus is gradually shifting from large-scale expansion to the refined layout of high-quality, high-value patents.
- Wind energy technology has maintained steady growth, driven by the demand for large-scale and offshore technological iterations. Patent applications and technology upgrades have continued to move in tandem, showing a stable upward trend.

Middle tier:

- Biomass energy, hydropower, and nuclear energy constitute the middle echelon of clean energy technologies.
- The number of patent applications for biomass energy technology has been declining since reaching a peak in 2017, mainly due to the combined effects of limited application scenarios and the phasing out of subsidy policies.
- Hydropower and nuclear power technologies have maintained a slow and steady growth trend for a long time. Their innovation focus has gradually shifted from traditional equipment research and development to intelligent monitoring, digital operation and maintenance and safety optimisation. There is still potential to further release patent increments in the future.

Niche groups

- Ocean energy and geothermal energy are in a niche market, with a consistently low number of patents. Both types of technologies are constrained by multiple factors such as differences in resource endowment, engineering construction barriers, and slow commercialisation processes, resulting in insufficient R&D investment and a limited number of innovation entities, making it difficult to form a high-density patent cluster and an industrial scale foundation.
- This characteristic also indicates that, prior to future policy support and technological breakthroughs, patent growth in these technological areas will remain limited.

Energy storage technology

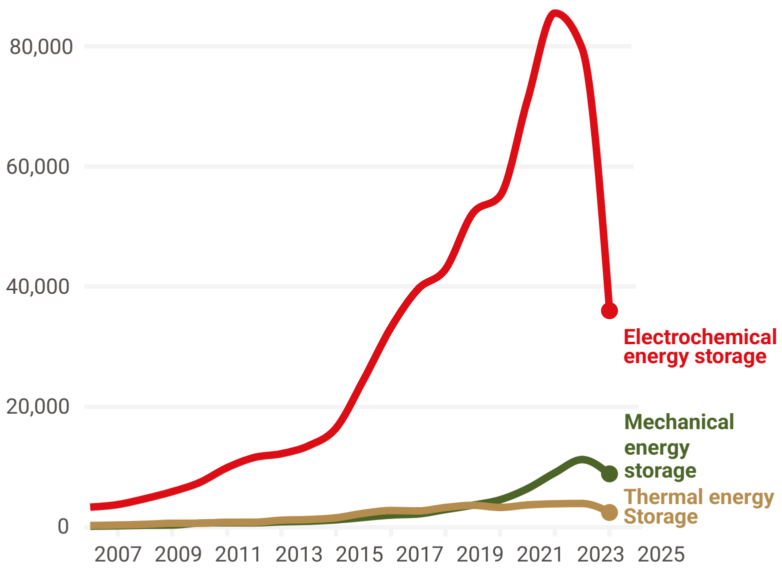
From 2006 to 2024, China's energy storage technology patent applications were dominated by electrochemical energy storage, mechanical energy storage accelerated significantly after 2021, while thermal energy storage patent applications remained relatively slow.

- Electrochemical energy storage remains the dominant force, driven primarily by mandatory energy storage policies for new energy sources, and is a core area for domestic and foreign companies to build intellectual property barriers.
- Mechanical energy storage has seen a continuous increase in growth rate in recent years. Relying on the grid's peak-shaving demand and technological breakthroughs, companies are gradually increasing their intellectual property investment, highlighting its potential.
- The patent layout for thermal energy storage is relatively lagging behind, due to reasons such as limited application scenarios and bottlenecks in core technologies, resulting in relatively low activity in intellectual property competition.

The overall data from 2006 to 2025 shows that energy storage technology patents have shown a long-term high-speed growth trend, especially after 2015 when they accelerated. It peaked in 2023 and remained at a high level overall in 2024–2025. The growth curve is generally highly consistent with the timeline of global expansion of new energy installations, decline in energy storage costs, and the intensive rollout of national policies.

"China's clean energy industry is forming a new development pattern with technological breakthroughs at its core and market-oriented governance as its support"

Figure 5: Battery patents leapt astonishingly over the last few years
Chinese patent applications for energy storage technologies, 2006-2025



Note: Data from 2024 and 2025 may not reflect all patent applications because of patent publication delays.

Source: PatSnap database

Electrochemical energy storage is the fastest growing field, with the number of patents increasing from approximately 3,300 in 2006 to 85,000 in 2023, making it the absolute dominant type. Its rapid growth is mainly driven by power batteries (lithium batteries), large-scale electrochemical energy storage systems, and new types of batteries (sodium-ion and solid-state batteries). The number of patent applications remained high in 2023-2024, indicating that innovation continued to deepen in the direction of material systems, cycle life improvement, and integrated system optimisation.

The number of patent applications for mechanical energy storage (mainly including pumped hydro storage, flywheels, compressed air, etc) entered a stable growth channel after 2010, and accelerated significantly from 2015, reaching approximately 11,254 applications in 2024. While its growth is not as steep as that of electrochemical energy storage, innovations are mostly focused on improving equipment efficiency, enhancing regulation flexibility, and optimising costs against the backdrop of increased peak-shaving demand in large power systems and the national push for the construction of pumped storage power stations (such as key projects in the 14th Five-Year Plan).

Thermal energy storage saw relatively stable growth overall, but experienced rapid growth between 2013 and 2016, driven by applications such as industrial waste heat utilisation, integrated building energy systems, and concentrated solar power. The growth rate slowed down after 2018 but remained stable. Innovation in this field relies more on specific scenario requirements, so the technology is characterised by decentralisation, with continuous patent contributions in areas such as phase change materials, molten salt thermal storage and cryogenic thermal storage.

The systemic impact of policies on energy storage innovation trends

The inflection point in the growth of energy storage patents is highly correlated with the intensive rollout of national policies. For example, since 2015, the national government has introduced a number of policies on the energy internet, renewable energy storage, pumped storage power station planning and new energy consumption, which have directly promoted technological research and development and industrial investment. In addition, innovation has accelerated significantly since the release of the carbon neutrality strategy (starting in 2020). The policy effects are reflected in:

- electrochemical energy storage has become a continued policy focus, driving an explosion of patents related to materials and systems;
- pumped storage construction plans have spurred a continuous rise in innovation in mechanical energy storage; and
- industry standards and subsidy mechanisms promote the simultaneous development of energy storage technologies across multiple scenarios.

Typical cases of clean energy industry entities

State-owned enterprises, taking Shanghai Electric as an example

In China's clean energy industry system, state-owned enterprises undertake the core functions of strategic execution, technological breakthroughs and engineering implementation, and maintain a two-way effort between domestic deployment and international export. Taking companies such as Shanghai Electric, State Power Investment Corporation, and China General Nuclear Power as examples, their businesses cover major energy types such as photovoltaic, wind power, nuclear power, and hydrogen energy, reflecting the systematic participation of state-owned capital in the entire industrial chain.

Shanghai Electric's clean energy transformation process can be divided into three stages: In 2006, relying on state-owned enterprise resources, the company entered the wind power and photovoltaic equipment field, mainly by introducing and absorbing technologies, in line with the incentive policies of the Renewable Energy Law. In 2016, the grid parity of photovoltaic power promoted its shift to independent research and development, with a focus on high-efficiency components and system integration. From 2021 to 2025, focusing on the "dual carbon" goal, the company further upgraded to a "zero-carbon solution provider for the entire industry chain", forming a development model of parallel development in domestic and overseas markets.

In terms of technological innovation: Its self-developed *Bristack Electrolyte*. Through improvements in electrode materials and flow field structure, an industry-leading energy consumption of 3.94 kWh/Nm^3 is achieved, reducing energy efficiency by approximately 15% compared to traditional solutions. In the field of solar thermal energy, the company will develop technologies such as wireless control of heliostats and high-efficiency heat-absorbing materials to enhance system efficiency; on the energy storage side, it will introduce technology combinations such as air energy storage, flywheel energy storage, and synchronous condensers to improve the stability of grid connection of high proportion of renewable energy.

In terms of business model: In China, the development of multi-energy complementarity and zero-carbon industrial parks, including solar thermal, photovoltaic and energy storage, is being promoted. A typical example is the Taonan wind power coupled biomass green methanol demonstration project. Overseas, in the Middle East, Asia, Africa and Europe, an integrated "technology export EPC operation and maintenance" model is adopted to provide targeted solutions such as "photovoltaic energy storage and seawater desalination" zero-carbon hydropower cogeneration solutions.

Policy compliance and patent layout: Actively responding to the market-oriented reform of new energy and the requirements of international carbon footprint and ISCC EU certification, the project is promoted to enter the global green fuel system; multiple bases have been rated as "national green factories". In terms of intellectual property protection, Shanghai Electric has formed a multi-technology matrix in the field of clean energy and energy storage, covering deep-sea wind power, photovoltaic and solar thermal equipment, flow and multi-route energy storage, the entire hydrogen energy chain, and supporting intelligent energy management systems. This matrix enables comprehensive innovation capabilities from equipment manufacturing to system integration, providing legal and patent barriers to support its overseas projects and technology exports.

Private enterprises, taking LONGi Green Energy as an example

LONGi Green Energy's development can be divided into three stages: Founded in 2006, the company focused on silicon wafer manufacturing and completed technology introduction and domestic substitution with policy subsidies. From 2016 to 2020, in response to grid parity for photovoltaic power, it increased its R&D investment and achieved scale expansion by reducing the cost of silicon wafers and modules. From 2021 to 2025, it focused on the "dual carbon" goal and deployed high-efficiency battery technologies such as TOPCon, HJT, HPBC and perovskite, and accelerated the global capacity allocation to cope with trade barriers from Europe and the United States.

> "The development logic of clean energy in China is shifting from 'policy and scale-driven' to a dual-driven model of 'technology maturity, marketisation and efficiency"

In terms of technological innovation: LONGi has driven the efficiency of PERC cells from 22% to 24.5%, TOPCon mass production efficiency to break through 26%, and HPBC mass production efficiency to reach 26.8%, reducing the cost per watt by about 12%. The company has completed iterations from 166mm and 182mm to 210mm on the silicon wafer side to improve module power and production line efficiency; at the same time, it has developed photovoltaic inverters to adapt to different national grid standards and reduce its technological dependence on overseas suppliers.

In terms of business model: Domestically, the company adopts an integrated layout of "silicon wafers-cells-modules-power stations" and expands into distributed and residential photovoltaic systems. Globally, it adopts a "localised production and localised sales" strategy, setting up factories in Malaysia, Vietnam and the United States to avoid anti-dumping and countervailing duties. Its products are exported to more than 100 countries, while promoting scenario-based solutions such as "photovoltaic energy storage" and "photovoltaic buildings".

Policy compliance and patent layout: Domestically, China actively participates in grid parity pilot programmes and green finance projects, and promotes cleaner production bases. Internationally, it addresses EU and US anti-dumping and countervailing duties and technical barriers through localied production, cross-licensing of patents, and participation in standards development. Drawing on industry cases of patent disputes involving South Korean companies, we will establish a global patent early warning system to reduce overseas infringement and compliance risks, and provide a protective barrier for the globalisation of their high-efficiency battery and silicon wafer technologies.

Foreign companies, taking Tesla as an example

Tesla's energy storage development in China can be divided into two stages: entering China in 2016 to focus on new energy vehicles, and accelerating the layout of energy storage business from 2021 to 2025 under the impetus of "dual carbon" goals and energy storage support policies. Construction of the energy storage super factory was launched in Lingang, Shanghai in 2024 and it went into operation in 2025, becoming the first energy storage super factory outside the United States. It achieved rapid implementation by relying on the local complete industrial chain.

In terms of technological innovation: It exports globally standardised energy storage batteries and system integration technologies. The large-scale commercial energy storage batteries mass-produced at the Shanghai factory are characterised by high efficiency, large scale, and adaptability to multiple scenarios. It promotes the integration of photovoltaic, energy storage, and charging to achieve synergy between energy storage, charging, and new energy vehicle businesses. It optimises battery manufacturing processes to improve production line efficiency and reduce costs in order to meet the economic needs under the background of China's energy storage market trading.

Business model: Adopting a localised production and supply chain model, the company aims to start construction and put the project into operation within the same year. It plans to produce 10,000 commercial energy storage batteries and approximately 40 GWh of energy storage capacity annually to supply the global market. Domestically, it will deploy industrial and commercial energy storage and large-scale energy storage bases through a "product sales and long-term operation and maintenance" model, and provide integrated "energy storage and charging" solutions in conjunction with its new energy vehicle business.

Policy compliance and patent layout: Leveraging China's open policy to foreign investment, the company has achieved wholly-owned factory ownership; responded to the "dual carbon" target and green finance policy to expand energy storage investment; strictly adhered to China's environmental protection and safety requirements, and promoted localised procurement to reduce costs; established core patents in China in areas such as energy storage batteries and system control, while complying with China's intellectual property system to avoid infringement risks; and participated in domestic energy storage market transactions to align with the direction of new energy electricity price reform.

Summary

The strategies employed by Shanghai Electric, LONGi Green Energy and Tesla in China demonstrate that the Chinese clean energy and energy storage market has entered a period driven by a triple force: policy certainty, accelerated technological iteration and intensified global competition. Against this backdrop, different types of market participants need to clarify their strategic positioning and build differentiated competitive paths during the policy window. State-owned enterprises need to continue to leverage their structural advantages in system integration, major projects and cross-energy chain collaboration, using policy guidance to drive innovation across the entire industry chain and strengthen international capabilities; private enterprises should focus on efficiency and technological iteration, consolidating their global competitiveness in key sectors through continuous R&D investment and cost leadership; foreign-invested enterprises need to leverage their technological and management advantages to achieve a balance between localised production, supply chain integration, and compliant operation, in order to adapt to China's policy and market pace.

From a horizontal perspective, all three types of entities need to establish forward-looking patent portfolios and global intellectual property risk management systems. This includes not only underlying patents for core materials, equipment, and system control, but also defensive and market entry strategies based on policy trends such as carbon footprint, subsidy rules, and anti-globalisation trade barriers. In the future, policy sensitivity, the speed of technological evolution, and the completeness of the patent system will jointly determine a company's position and upper limit in the global clean energy competition landscape.

Key insights and future outlook

Looking back at the development trajectory of the clean energy and energy storage industry from 2006 to 2025, we can clearly observe the deep coupling between policy system, technological innovation and intellectual property layout. China's clean energy industry is forming a new development pattern with technological breakthroughs at its core and market-oriented governance as its support.

As renewable energy continues to solidify its dominant position in the energy structure, the development logic of clean energy in China is shifting from "policy and scale-driven" to a dual-driven model of "technology maturity, marketisation, and efficiency". Future incremental competition will focus on hydrogen energy, advanced photovoltaic high-efficiency technology, large-scale and offshore wind power, and advanced nuclear energy, which will become innovation hotspots. These fields possess both high technological barriers and systemic value, making them key strategic high ground in future industrial and patent competition. At the same time, clean energy will shift from "single technology innovation" to a systemic innovation model of "integrated source, grid, load and storage". Enterprise competitiveness will increasingly come from the ability to collaborate across scenarios, devices, and technology systems.

Overall, the future structural changes in China's clean energy sector will manifest as a strategic leap from scale advantages to efficiency advantages, and from engineering-based expansion to systemic innovation. IAM

Li Mi, Principal, Lusheng Law Firm and Jensen Li, Senior Patent Attorney, Lusheng Law Firm.

INNOVATION GOVERNANCE: A FRAMEWORK FOR MANAGING ENERGY PATENT RISKS

Nearly every energy company can benefit from developing and implementing a plan to safeguard their prized innovations and the value they create, write experts from Vinson & Elkins.

Success in the energy sector depends on countless factors, but few matter more than a company's capacity to innovate. History brims with forward-thinking energy companies whose initiative and ingenuity enabled them to increase production, enhance infrastructure, optimise supply chains and reduce operations and maintenance costs, among numerous other competitive advantages.

Energy companies that accrue these advantages often stand out in even the most crowded markets, attracting talent and investment, boosting revenue and margins, securing partnerships and winning contracts. Yet for all the advantages that innovation can confer, it can introduce patent risks in equal measure, potentially undermining enormous investments of time, energy, and money – and even threatening a company's existence.

Energy innovators have wide-ranging needs and goals, and no two patent cases have identical facts and circumstances. But no matter their size, subsector or geographic market, nearly every energy company can benefit from developing and implementing a plan to safeguard their prized innovations and the value they create.

We call this energy innovation governance.

Just as sound corporate governance strengthens an energy company's ability to create long-term value, sound innovation governance is an essential counterpart, helping energy companies better understand what makes their business valuable – and what they can do to control it.

What does an energy innovation governance plan look like? Five pillars form the foundation.

Pillar 1: Take stock

Energy innovation governance begins with conducting a comprehensive patent audit. This is essentially a 360-degree inventory of every patent and patent pending application the energy company relies on: from core operational processes to bespoke equipment designs and everything in between. Indeed, before heading down any innovation path, energy companies must make sure they know where they stand. That includes an honest assessment of what their "secret sauce" is and whether it is protected already, or can be.

A patent audit aims to uncover who owns rights to each asset and identify any ownership gaps. It further examines the strength of the energy company's patent protections, where its patents are in commercial use across upstream, midstream, and downstream operations, how contractual obligations could affect its patent rights, where freedom-to-operate issues could emerge and which patents are most critical to the business.

Taking stock is always useful. But it is especially so in periods of rapid evolution, such as the one the energy industry is in today. Not only does this work align patents more closely with business goals and enhance monetisation opportunities as strategies shift, it also helps energy companies reduce legal and financial risk, strengthen contractual compliance and prepare for a dispute should one arise.

Pillar 2: Track competitors

Energy companies would also be wise to survey their competitors' patent portfolios. Think of this as an ongoing effort to glean market intelligence, centered on two key questions: do your competitors own or seek to own patent rights that could threaten your business? And, if so, what are you going to do about it?

This monitoring work should scrutinise not just patent filings, but any publicly available patent-related materials: dispute and enforcement records, regulatory filings, technical white papers, and investor presentations, just to name a few. The goal is to understand where competitors are investing R&D dollars across the energy value chain, which markets they are targeting and any steps they're taking to protect themselves.

With this information in hand, companies can evaluate it against their own R&D plans, scanning for both risks and opportunities. The insights that companies gain here can help them spot and capitalise on gaps in competitors' patent protection, determine where they need to design around existing patents or pursue licences, and decide whether to challenge any competitor rights that appear weak or overly broad.

Caution here is vital. To mitigate the risk of being found to have willfully infringed a competitor's patents, energy companies should centralise this monitoring work within their legal departments, so that engineering and R&D teams receive only curated landscape summaries, not raw patent documents.

"Focus on portfolio- and technology-level intelligence and public signals, while reserving claim-by-claim analysis for counsel-led freedom-to-operate or opinion work only"

Focus on portfolio- and technology-level intelligence and public signals, while reserving claim-by-claim analysis for counsel-led freedom-to-operate or opinion work only. Use legal-led clean-room design reviews for new products to separate technical development from third-party patents. If a patent appears facially relevant, escalate to counsel for structured analysis.

Pillar 3: Break down siloes

Energy innovation governance involves a range of teams: researchers, engineers, software developers, site workers, lawyers, financial analysts, accountants, marketers, cybersecurity professionals, and even the C-suite. But in many energy companies, these teams do not collaborate nearly enough to manage patent issues effectively, operating through a disconnected approach that inhibits information flow and creates serious strategic risks.

Weak cross-team communication can obscure patent ownership, raise infringement risks and waste resources. Opportunities to enforce and commercialise patents can go overlooked, and groundbreaking ideas can remain buried until it is too late to secure effective protection. Patent portfolios managed this way are needlessly fragmented, reactive and expensive.

But when companies break down siloes, information can flow freely. Consistent cross-team patent policies and procedures become easier to implement – both for collecting, sharing, and evaluating ideas as early as possible, and for detecting and responding to issues before they turn into leaks or disputes. Energy companies that manage their patent portfolio collaboratively make smarter decisions about where to invest, what to protect, and how best to manage risk and maximise commercial value.

Pillar 4: Plan ahead

Dynamic energy companies often aim to move quickly, sometimes embarking on long-term projects without fully considering the patent implications. Yet in today's energy industry, nearly every major strategic decision involves patents in some way. In many of these decisions, patents are the centerpiece.

So, future-focused energy companies would be wise to map where and how patent-related risks and opportunities fit into their long-term plans, just as they would for finance, operations or any other critical business area. This work is complex and wide ranging, and the examples below just scratch the surface.

Integrating a new technology. Energy companies will need to identify which of the technology's features are novel and valuable, weigh the pros and cons of various forms of protection, and coordinate closely to avoid early public disclosures that could limit protection options.

Entering a new market. Energy companies will need to review claims to patent rights in the jurisdiction they seek to enter, assess the strength of the jurisdiction's patent enforcement laws and determine whether holding patent rights there justifies the costs of securing and maintaining them. Jurisdictions whose regulatory regimes impose local content requirements on energy projects add another layer of complexity.

Contracting with third parties. Third-party agreements should clearly specify rights, especially around who owns patents developed during the life of the agreement, who can use the patented property, and for what purposes. Energy companies that fail to clearly define these terms could lose control over critical technology or face restrictions on future use.

Managing talent and knowledge retention. Employment agreements should clearly assign patent ownership rights, include strong and specific confidentiality obligations, and prohibit use of inside technical knowledge outside the company. Thorough documentation, training, and knowledge-sharing processes also help capture valuable know-how before it walks out the door.

> "Valuable energy innovation is likely to stem from incremental steps: a refined process here, a design tweak there, a smarter algorithm in one line of business, a novel use of data in another"

Navigating M&A and other transactions. Key areas of due diligence include confirming ownership and chain of title of the target's IP; determining the quality, scope and geographic coverages of the target's patent rights and how these rights support current and potential future business operations; reviewing the target's inbound and outbound licences; and assessing the target's patent-related legal exposure, among many others. Poorly defined terms regarding the allocation and scope of the target's patents can reduce deal value and spark disputes long after closing.

Pillar 5: Know the enforcement landscape

In recent years, the US patent enforcement landscape has shifted slowly but steadily in favour of rights holders. In 2024, US courts awarded patent holders a record-breaking $4.3 billion in damages, while patent infringement lawsuits surged 22%.

In the years ahead, energy companies should expect that patent enforcement will grow even more robust. Some of these reasons are energy-specific: technologies underlying the industry are becoming more commercially valuable and mature, policy incentives continue to direct capital flows into the energy transition and investors increasingly view strong patent portfolios as an indicator of value in energy startups.

Other reasons are broader. Non-practicing entities, for example, continue to become professional and sophisticated. Often well-funded and armed with broad portfolios, these companies increasingly assert rights across multiple plaintiff-friendly jurisdictions, applying pressure to secure settlements or licensing agreements.

Meanwhile, the US Patent and Trademark Office has proposed rules that would make it far more difficult to challenge the validity of patents through *inter partes* review. If adopted as proposed, the rules would likely dissuade companies from filing IPR petitions, increasing patent litigation in the process.

On Capitol Hill, numerous policy and advocacy groups have come out in support of the RESTORE Patent Rights Act. The bill has yet to make it out of committee. But, if enacted, it would restore the presumption of injunctive relief in patent litigation, making nearly every case an existential proposition for defendants.

Under the bill, alleged infringers would no longer be able to safely rely on eBay Inc v MercExchange LLC – the Supreme Court decision clarifying the standard that courts must apply before granting permanent injunctions to patent holders (and effectively making monetary damages and reasonable royalties the primary remedies in patent cases).

Instead, defendants that lose an energy patent case in court could be forced to stop operating key generation facilities, shut down critical infrastructure projects, redesign technologies under extreme time pressure or exit entire markets – all outcomes that could threaten their survival.

Where there are well-known, relevant patent pools or portfolios that are widely licensed in the energy industry, it is prudent to explore licensing as a cost-effective way to reduce risk and ensure freedom to operate, particularly for core technologies or standards aligned features.

Staying a step ahead

Innovation in the energy sector is often equated only with dramatic breakthroughs – the revolutionary ideas that redefine how the world generates, transmits or consumes power, or that unlock new sources of clean energy. But while quantum leaps draw the most attention, valuable energy innovation is far more likely to stem from incremental steps: a refined process here, a design tweak there, a smarter algorithm in one line of business, a novel use of data in another.

Innovations like these, sometimes modest on their own, often compound into indispensable competitive advantages. Yet they are also the hardest for companies to identify and value, and the easiest for competitors to quietly copy, reverse-engineer, or target for enforcement. Protecting these innovations from every angle – and deftly navigating the patent rights claimed by competitors and non-practicing entities – can mean the difference between losing your edge and leading your market.

For ambitious energy companies, patent risks are a fact of life: R&D personnel can leave for competitors, unclear chain of title can bust deals, vulnerabilities can hide within engineering teams, lawsuits can emerge out of nowhere.

That is why energy innovation governance is so important. Yes, the risks may be serious. But well-advised energy companies, especially those that are proactive in developing and implementing a sound innovation governance plan, can be confident in staying one step ahead. IAM

Hilary Preston, Eric Klein, Steven Moore, Co-heads of Intellectual Property & Technology Litigation Practice, Vinson & Elkins.

THE FORUM OF CHOICE? ENERGY AT THE UPC

Experts from Carpmaels & Ransford analyse three key technological areas – solar, electrochemical and wind – and the disputes filed at the pan-European forum.

The Unified Patent Court is fast becoming the forum of choice for energy technology litigation in Europe. Early filings show a notable concentration of East-Asian parties, both as claimants and as defendants, highlighting the worldwide engagement with the new European court.

In this article, we provide a tour of energy technology disputes at the UPC, broken down into major technological areas, before considering key takeaways for parties operating in the energy space.

Solar energy

There has been a particularly marked involvement from East-Asian firms in UPC solar energy litigation.

JingAo Solar (China) has been active in two separate actions against Chint New Energy (China), one enforcing EP2787541B1 before the Munich LD (UPC_CFI_425/2024) and another enforcing EP4092759B1 before the Hamburg LD (UPC_CFI_429/2024). The defendant brought a counterclaim for revocation in both instances.

UPC principles in action: front-loading essential and wide-ranging remedies possible

The patent brought before the Munich LD relates to solar cells that employ passivation films designed to passivate defects on the emitter and black surface field areas. The Munich LD found the patent both valid and infringed and, in doing so, highlighted the importance of parties putting their best foot forward under the UPC's front-loading principle.

In preparation for the hearing, the defendant was requested to indicate which of their 46 inventive step attacks presented thus far were most promising, but of the eight attacks selected, five were dismissed as late filed either because the combination of documents relied on, or the documents themselves, were not introduced in the first instance with the defendant's counterclaim.

The remedies awarded by the LD were wide-ranging, including an injunction for several commercial solar modules, recall and destruction of such modules, damages, and an interim costs order of €124,000. The appeal deadline has now passed and the parties have settled.

Market abuse and de facto standards – a defence v an injunction?

The defendants attempted to allege market abuse as part of their defence, asserting that TOPCon (the specific form of solar cell relevant to the patent) is a de facto standard within the field of solar energy, and pointing to forecasts predicting that TOPCon will capture 70-80% of the solar panel market by 2028.

According to the defendants, as consequence of this abuse of market power, the claimant was not entitled to an injunction for violation of Art. 102 TFEU. The UPC did not agree, with a forecast not deemed sufficient to show a dominant market position. Nevertheless, although unsuccessful, this attempted defence may highlight the growing impact of dominant technologies and the development of technological standards as European power grids become increasingly reliant on third party technologies as part of their shift towards diversified, green energy solutions.

Moreover, this defence may be a useful arrow in the quiver of European SMEs attempting to operate in fields of energy technology increasingly dominated by large, overseas entities.

Parallel UPC and EPO Proceedings: Strategic Coordination

Opposition proceedings regarding EP2787541B1 before the EPO were also running in parallel with the UPC proceedings. The opposition was originally brought by French entities Carbon and Semco Smartech France, with Chint New Energy intervening as an assumed infringer once the infringement action had been lodged with the UPC. The patent survived the opposition but was taken to appeal proceedings, with a preliminary opinion heavily in the patentee's favour issued by the Board of Appeal on 23rd October 2025. The UPC decision was issued on 28th November 2025, and the opponents at the EPO withdrew their appeals shortly afterwards on 2nd December 2025.

This timeline shows the important interplay between UPC and EPO proceedings, and highlights the fact that, despite the ongoing shift towards the UPC, EPO opposition proceedings remain an invaluable tool for gaining leverage over your competitors. The ability to effectively coordinate parallel proceedings between the EPO and UPC will therefore be a vital skill as Europe's new system of twin-forums develops.

> "A large proportion of the energy-technology disputes so far before the UPC have been brought by East Asian firms"

A second front leads to likely settlement

Turning to the action before the Hamburg LD between the same parties, the patent in suit provides solar cells aimed at reducing shading losses that result from the physical width of ribbons used to connect solar cells, and to improve the connection strength of those ribbons. Interestingly, since the decision from the Munich LD in favour of the claimant, the action before the Hamburg LD has closed with no public decision being issued, which may be an indication of settlement between the parties.

Further solar disputes and signs of settlement

In another dispute between Chinese firms over solar technology, Shanghai Jinko Green Energy Enterprise has brought proceedings against LONGi Green Energy Technology in the Munich LD (UPC_CFI_119/2025). The claimant alleged infringement of EP4372829B1, with the defendant bringing a counterclaim for revocation. The patent provides a solar cell aimed at improving open-circuit voltage, reducing contact resistance of the metal electrodes, and improving conversion efficiency by matching between texture structures on substrate surfaces of the solar cell. This case has subsequently been withdrawn, which again suggests a settlement between the parties.

Maxeon Solar (Singapore) initiated an action against Aiko Energy (China) (UPC_CFI_605/2024) and others in Düsseldorf, alleging infringement of EP3065184B1. This patent covers solar cells having P- and N-type doped regions separated by a "trench structure" that is said to improve solar radiation collection and increase efficiency. The case hearing was deferred several times before both the infringement action and counterclaim were withdrawn in February 2026, suggesting settlement between the parties.

> "Building a high-quality portfolio of robust intellectual property rights should be a key goal of European firms looking to compete in the energy technology space"

Electrochemical energy

The Dutch firm Plant-e brought infringement proceedings against Spain's Arkyne Technologies before The Hague LD (UPC_CFI_239/2023) regarding a patent for using plant matter to convert light energy into electricity (EP2137782B1), with Arkyne bringing a counterclaim for revocation. The patent in suit provided a Plant-based-Microbial Fuel Cell ("P-MFC") – a fascinating technology so worth a brief digression.

While microbial fuel cells, which use micro-organism to oxidise organic compounds and thereby supply electrons to an anode, were generally known, they suffer from the requirement to provide a constant supply of organic fuel to the microbes living in the anode reactor. The production and transportation of this fuel can be both costly and carbon intensive. The patent aims to overcome this shortcoming by planting a living plant in the anode reactor, which can then generate and supply the required nutrients to the micro-organisms via photosynthesis.

The UPC considers the doctrine of equivalents

Rather than seeding a plant in the anode reactor, Arkyne instead used a living plant in its cathode reactor. Nonetheless, the court found Arkyne to infringe via the doctrine of equivalents (DoE) because (i) a living plant was still the source of the organic fuel, and (ii) that fuel was still supplied to the anode as water flowed through the cathode reactor to the anode reactor, entraining the requisite nutrients. The court therefore granted an injunction in favour of Plant-e, with Arkyne subsequently appealing the decision – however, the parties settled before reaching the Court of Appeal.

The Plant-e decision was one of the early examples of the UPC considering DoE and led to considerable discussion amongst legal commentators at the time, in particular regarding the test for DoE used by the Hague LD – perhaps unsurprisingly, the test used was derived from Dutch case law. However, other LDs have since used different tests, and we are awaiting guidance from the UPC's Court of Appeal as to which DoE test should rule them all.

Further UPC dispute leads to order for preservation of evidence

Danish firm Hybridgenerator brought an infringement action against their Danish compatriots HGSystems and Infotech over EP4238202B1 in the Copenhagen LD (UPC_CFI_492/2024). The patent describes a hybrid generator system combining a combustion engine with a rechargeable battery to provide "grid-like" alternating current (AC) power to off grid locations. A hearing has been scheduled for 13th April 2026. However, in the interim the court granted a request from Hybridgenerator for preservation of evidence and inspection of property, which the Infotech failed to comply with and was issued penalty payments. In turn, these appear only to have been complied with for 36 days before further penalties were issued.

Wind energy

In the wind sector, German firm Wittenstein has filed a revocation action at the Munich CD (UPC_CFI_523/2025) against Danish firm Vestas. The asserted patent EP4226039B1 concerns wind turbines having a newly developed gearbox – rather than traditional rotating gears, the defendant's gearbox employs a large number of single tooth segments to connect input and output. The complaint was filed on 12 June 2025 and is in an early stage of proceedings.

Takeaways

A large proportion of the energy-technology disputes so far before the UPC have been brought by East Asian firms. Moreover, most of these in the above review have ended in withdrawal, which likely indicates settlement. A few key conclusions may be able to be drawn from these observations.

Firstly, the cases highlight both the growing dominance of East Asian entities in the energy sector and the importance of the European market to these entities.

Secondly, they also indicate a level of trust in the quality of the judgments expected to be handed down by the UPC, with firms willing to fight it out in an unfamiliar new foreign court rather than settling their differences over the negotiating table closer to home – even if settlement appears to have been the ultimate outcome in several cases.

Thirdly, the outcomes of these cases highlight the efficacy of the new forum of the UPC, but may also illustrate the difficulties faced when working in new and unfamiliar territory. The dawn of the UPC has introduced European patent attorneys and litigators to new workflows, short deadlines, and growing bodies of new and untested case law.

Chint New Energy's experience of having 46 inventive step attacks whittled down to just three shows the need for parties to familiarise themselves with the working principles of the UPC, and also of the value of appointing counsel with expertise and experience in working before this nascent court while coordinating parallel actions between the EPO and UPC.

Finally, European firms should take solace in the abundance of withdrawals and apparent settlements in the outcomes of the above cases, particularly those involving their increasingly dominant East Asian competitors. These outcomes suggest that, despite their dominant market position and often very large patent portfolios, these entities are nonetheless willing to negotiate and settle when faced with strong challenges founded on robust intellectual property rights.

In turn, this highlights the fact that quality, and not quantity, of patents is often a deciding factor in intellectual property disputes. Building a high-quality portfolio of robust intellectual property rights, even if budgets might not permit the sheer volume of filings seen from outside the continent, should therefore be a key goal of European firms looking to compete in the energy technology space.

Once armed with such a portfolio, European firms should not shy away from being aggressive with their larger competitors in this evolving field of technology. IAM

Russell Woolley, Partner; Alexander Hackett, Associate, and Harry Shaw, Legal Support at Carpmaels & Ransford

THE BATTERY RACE IS AN IP RACE

As electric vehicles begin to displace combustion engine cars as the king of the road, the race for supremacy over safe, durable, long-ranging and cost-efficient battery technologies is hotter than ever.

Industry goliaths like CATL and LG Energy Solution are doubling down on R&D to define the cutting edge of automotive battery chemistry and charging while other players keep pace or catch up, altogether creating a dynamic IP landscape that can, in turn, reshape the future of the industry.

This chapter reveals the leading patent owners in the rapidly evolving field of energy storage and discusses important strategic considerations as battery technologies approach standardisation. The chapter also illuminates the complex interplay between innovation, competition and collaboration – and how a well-designed IP strategy can help companies get ahead.

The first article, written by Anaqua's Matt Troyer, puts the microscope on the surge in patent activity within the automotive battery sector. It discusses the evolution of battery technologies, including advancements in solid-state batteries and fast-charging systems, and emphasises how patents not only mark innovation but serve as levers of market power.

Next, Daniel Tishman, Eli Svetlov and Tae Hong of Fish & Richardson caution automakers and suppliers of the rising cost of inaction as standardisation comes into EV and battery technologies. The authors outline strategies for building robust SEP portfolios while the sector appears to be approaching an inflection point reminiscent of the smartphone cross-licensing era.

Finally, in exclusive interviews, top strategists at CATL, Panasonic Energy and EVE Energy tell IAM about the state of the industry, the balance between aggressive IP protection and industry collaboration, and the path ahead.

FROM NEW INNOVATIONS TO PATENTS: HOW INTELLECTUAL PROPERTY REVEALS A SHIFT IN THE BATTERY TECHNOLOGY LANDSCAPE

In fast-evolving industries, IP teams should view patent analytics as a predictive intelligence tool, not just a historical record, writes Anaqua's Matt Troyer.

The global energy market is currently undergoing a significant transformation, illustrated by growth in overall demand, particularly for electricity, alongside a shift in investment toward clean energy sources.

According to the International Energy Agency (IEA), global energy revenues reached $1.89 trillion in 2024, with demand growing 2.2%, outpacing the historical average of 1.3%, over the prior decade.

Patenting in the energy sector

Historically, the oil and gas sector favoured a siloed, "go your own way" approach to innovation, characterised by low litigation and case-by-case licensing. The hurried transition to renewables and advanced energy storage technologies like batteries has fundamentally complicated the IP landscape.

Rapid breakthroughs in solar, wind and battery storage – and the need for these systems to work in an integrated manner – are driving a shift toward collaborative strategies like patent pools and cross-licensing. While these models are well-established in the information technology and telecommunications and networking industries, the energy sector is still in the early stages of getting comfortable with these collaborative standards.

It should be no surprise that technology vendors looking to address these newer, fast-growth parts of the energy sector are more sophisticated about patenting. In fact, the top six sectors within the energy market that are experiencing the most patent activity are Solar Photovoltaic, Wind Energy, Battery Energy Storage, Hydrogen / Electrolysis and Heat Pumps.

The Anaqua AcclaimIP team examined in greater detail one of the most dynamic sectors, the Automotive Battery Energy Storage industry. Our analysis found the global race for energy innovation is accelerating, with LG Energy Solution emerging as the overall top patent holder in automotive battery technologies.

Geographic filing patterns reveal domestic-first strategies and PCT (patent cooperation treaty) signals of global ambition, while breakthroughs in solid-state and lithium-sulfur chemistries hint at a post-lithium-ion future that will redefine mobility and energy ecosystems.

Automotive battery energy storage

This sector has emerged as one of the most actively patented technology fields globally, with Battery Pack and Module Design. According to Anaqua's research, Automotive Battery Energy Storage is leading the volume of patents with 309,328 unique filings, followed by Battery Management Systems (188,471) and Thermal Management (185,518). These innovations are being driven by the need to better supply the battle raging in vehicle electrification. The automotive battery energy sector is diverse – with critical domains such as solid-state batteries, pack design, thermal management, battery management systems and fast charging infrastructure.

An analysis of Automotive Battery Energy Storage patenting identifies clear industry leaders across specific technical categories. LG Energy Solution maintains a dominant intellectual property position, holding the top spot in Battery Pack/Module Design, Battery Management Systems, and Thermal Management.

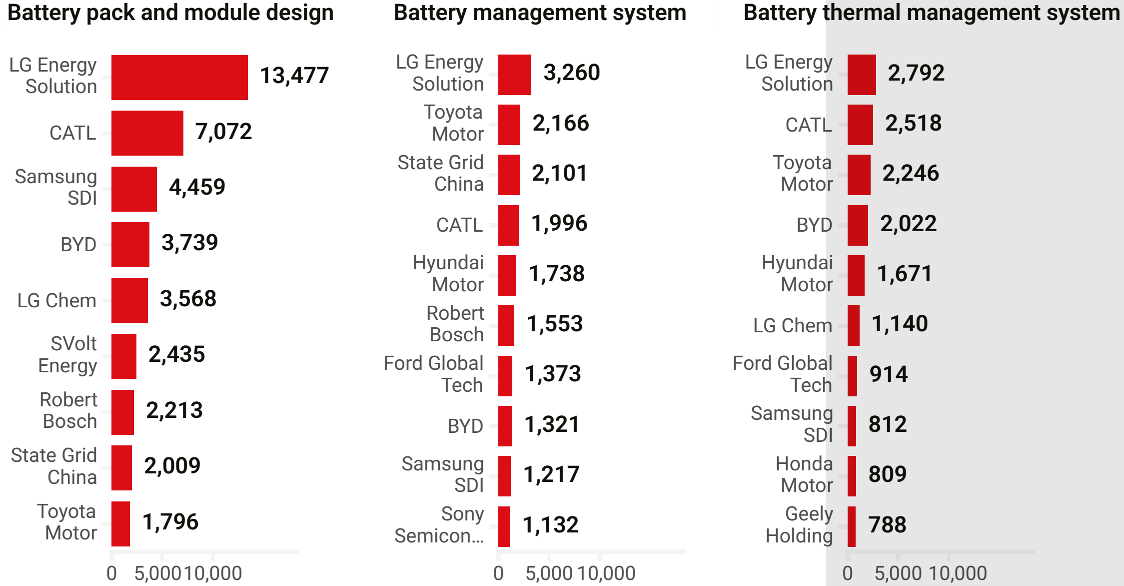
In the realm of core Cell Chemistry and the highly anticipated Solid-State Battery sector (74,114 filings), Toyota Motor remains the primary innovator. Meanwhile, CATL has established itself as the leader in downstream infrastructure and sustainability, holding the most unique filings in Fast Charging (56,325) and Battery Recycling (44,823).

Notably, Ford Global Tech leads the General EV Battery category with 106,965 filings, reflecting a broad strategic commitment to vehicle electrification.

These findings highlight a multi-faceted technological revolution. Chemistry is shifting from traditional NMC111 toward high-nickel NMC811 and NCA cathodes to boost energy density, while LFP is seeing a resurgence for cost-sensitive applications. In hardware, Cell-to-Pack (CTP) and Cell-to-Body (CTB) architectures are eliminating traditional modules to maximise space. These advancements are supported by 800V architectures and immersion cooling systems, which now enable sub-15-minute ultra-fast charging – a critical milestone for mass-market EV adoption.

Figure 1: LG Energy Solution leads in three major areas of battery innovation

Top 10 innovators in three technical fields, based on patent filings



Source: Anaqua

Battery pack and module design technology

Module design directly influences pack-level performance, safety characteristics and operational lifetime. Modular design architecture provides measurable advantages for battery pack development. Modular configurations reduce disassembly time by 60% and decrease service costs by 40% compared to monolithic pack designs. Additionally, effective module design provides electrical isolation between individual cells, minimising short circuit risks and containing thermal runaway propagation within single modules.

The findings from Anaqua's report show that innovation in battery pack and module design has accelerated significantly, with 309,328 unique patent filings recorded between 2015 and 2025. This sector is led by LG Energy Solution, which holds 13,477 filings focused on module architecture, followed by CATL (7,072) and Samsung SDI (4,459). The industry is currently undergoing a paradigm shift from traditional "Cell-to-Module" designs to more integrated "Cell-to-Pack" (CTP) and "Cell-to-Body" (CTB) architectures. These advancements aim to eliminate redundant structural components, reducing weight and cost while increasing the volumetric energy density of the entire vehicle.

A defining patent in vehicle integration is Toyota Motor's battery mounting structure (US10207573). This filing has demonstrated remarkable "blocking power" having been cited in the rejection of applications from 12 different competitors. By establishing fundamental claims on how batteries are secured within the vehicle frame, Toyota has forced the industry to innovate around its protected designs. Conversely, BYD's Blade Battery architecture (CN111009629) represents the cutting edge of structural efficiency. By utilising long, thin cells that act as structural beams themselves, BYD's CTB approach eliminates the need for separate internal cross-members, significantly improving the vehicle's torsional rigidity and space utilisation.

Battery management systems

A Battery Management System (BMS) is the electronic "brain" of a rechargeable battery pack, monitoring voltage, current, temperature and cell balance to protect the battery, optimise charging and extend lifespan. In EVs, it serves as the critical bridge between chemical energy storage and vehicle performance.

From 2015–2025, the field saw 188,471 patent filings, led by LG Energy Solution (3,260) with advances in SOC/SOH algorithms. Toyota Motor contributed major work in hybrid/EV control, while State Grid China focused on grid battery integration. As battery designs grow more complex, BMS technology has evolved from basic monitoring to advanced predictive modeling for safety and durability.

A major challenge is estimating a battery's internal state without accessing its chemistry. Bosch's patent (US10312699) delivers a breakthrough by estimating open cell voltage and SOC under load using a cost optimisation method that reduces real time measurement errors. The invention improves range prediction, mitigates "range anxiety" and effectively blocks six competitors from similar real time SOC estimation approaches.

While most current BMS technology is optimised for standard lithium-ion, the industry is already preparing for a post-lithium-ion world. Gelion Technologies (US11125827) has established a significant patent for lithium-sulfur batteries, a chemistry that offers much higher energy density but suffers from complex degradation patterns. Gelion's method for determining the health and charge of these cells has been protected in 10 countries, positioning it as a key enabler for future aviation and long-range EV applications. As these new chemistries emerge, the ability of a BMS to adapt its state estimation models – rather than just the hardware – will play a major role in determining the winners of the next decade's energy storage race.

Battery thermal management systems (BTMS)

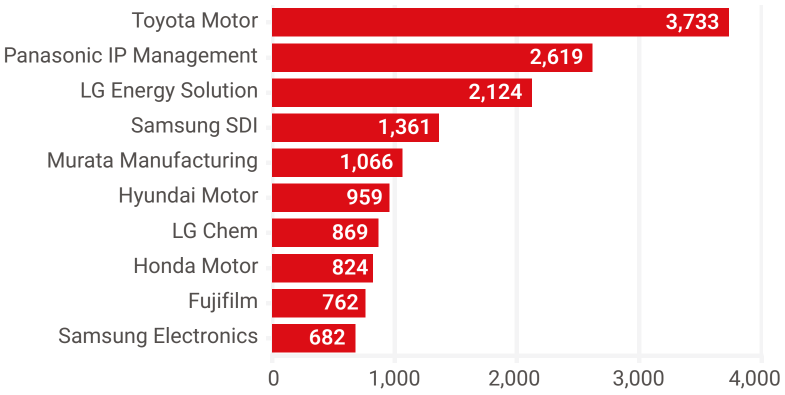
A BTMS keeps batteries within their optimal temperature window (roughly 20–45°C) to maintain performance, safety and lifespan. It prevents overheating that can trigger degradation or thermal runaway and avoids low temperature issues, like reduced power and sluggish charging.Between 2015 and 2025, thermal management became one of the most competitive arenas in EV technology, generating 185,518 patent filings. LG Energy Solution leads with 2,792 filings focused on high-efficiency liquid cooling, followed by CATL (2,518) and Toyota Motor (2,246), which has made major advances in energys aving heat pump systems. As battery densities climb and charging speeds accelerate, cooling has evolved from simple circuits to intelligent, multidomain thermal architectures that manage the battery, cabin and powertrain in unison. Elkem Silicones' widely protected patent (US10501597, covered in 17 countries) on silicone-based thermal interface materials highlights the growing importance of materials technology, which is critical for preventing cell-to-cell heat transfer, avoiding thermal runaway, and enabling high-current fast charging.

One of the sector's defining innovations is Bordrin Motor's MultiLoop Thermal Architecture (US20180178615), with 174 forward citations. It coordinates multiple thermal loops across the vehicle, dynamically shifting between serial and parallel modes. This allows systems to reuse motor waste heat to warm a cold battery or tap the cabin's AC chiller for extra cooling during rapid charging, now a benchmark approach for premium EVs seeking maximum range efficiency.Innovation is also coming from adjacent industries. Joby Aero's foundational patent

(US10960785), originally designed for electric aircraft, confronts extreme thermal constraints where lightweight, highly reliable cooling is essential. With 139 citations and strong blocking power over 11 competitors, the technology, which is focused on eliminating hot spots and ensuring thermal uniformity, is now shaping automotive designs. These principles are crucial for next generation EVs targeting ultrafast charging and longer battery lifespans by 2026 and beyond.

Solid-state batteries

Figure 2: Japanese, Korean companies are investing in solid-state batteries
Leading innovators based on solid-state battery-related patent filings

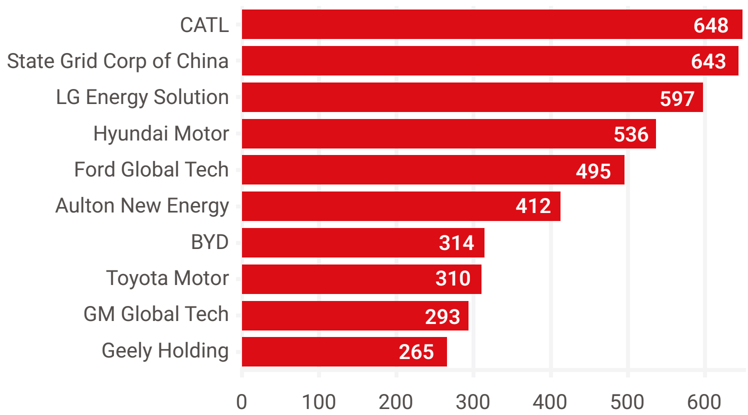


Source: Anaqua

Solid-state batteries replace the flammable liquid electrolyte in conventional lithium-ion cells with a solid ceramic or polymer material. This shift enables higher energy density, faster charging, longer cycle life and dramatically improved safety, paving the way for smaller, lighter and more powerful batteries for EVs and portable electronics. From 2015 to 2025, the field exploded with 74,114 patent filings. Toyota Motor leads with 3,733 filings centered on sulfide electrolytes, followed by Panasonic IP Management (2,619) with oxide ceramics and LG Energy Solution (2,124) developing polymerceramic hybrids. The competitive landscape is defined by a three-way race between sulfides, oxides and polymers, with each targeting breakthroughs in ionic conductivity and scalable manufacturing. A pivotal anchor in this space is QuantumScape's sulfide electrolyte patent (US10116001). With 115 forward citations and over 100 claim rejections issued to 11 rivals, it shapes the development path for sulfide-based SSBs. Meanwhile, Samsung Electronics (US10985407) has secured a strategic edge with its lithium alloy anode design, which suppresses dendrite formation and markedly improves both safety and cycle life. As the industry nears commercialisation, innovation is shifting from chemistry to manufacturing at scale. Mitsubishi Gas Chemical's recent patent (US20240234798) exemplifies this transition, offering a method to mass produce solid electrolyte particles.
With filings across 10 countries, these industrialisation focused advances are crucial for reducing cost barriers and bringing solid state batteries first into premium EVs, and eventually mainstream consumer electronics, by the late 2020s.

Fast charging technology

Figure 3: Auto, battery titans are charging ahead on rapid charging
Top filers of fast charging-related patents



Source: Anaqua

Fast charging battery technology uses higher power (voltage/current) and intelligent BMS to rapidly charge batteries. This reduces charging time from hours to minutes, often by employing advanced materials, optimised charging algorithms and robust thermal management to safely handle increased power and prevent damage like lithium plating.

The pursuit of rapid energy replenishment has become a cornerstone of electric vehicle adoption, with 56,325 unique patent filings recorded between 2015 and 2025. CATL leads the sector with 648 filings focused on ultra-fast cells, followed closely by State Grid China (643 filings) and LG Energy Solution (597 filings). The innovation landscape is currently divided between two major philosophies: ultra-high voltage charging, such as the 800V platforms championed by Hyundai Motor, and battery swapping technologies led by companies like Aulton New Energy. As of 2026, the trend has shifted heavily toward "megawatt-level" charging, with manufacturers aiming for charging times that match those of traditional refueling.

While cell chemistry is vital, the strategic placement of charging stations is equally critical for long-distance travel. A foundational breakthrough in this area is the charging station planning method (US10360519) developed by Tianjin University of Technology. This patent, which has earned 52 forward citations, provides a mathematical framework for optimising the location of fast-charging hubs along expressway corridors. By analysing traffic flow and battery depletion rates, this innovation ensures that charging networks are both economically viable and geographically accessible, serving as a blueprint for the national highway charging networks now being completed across North America, Europe and Asia.

An important trend to keep an eye on in fast-charging intellectual property is the prevalence of domestic-only filings, particularly within the Chinese market. Companies like Aulton New Energy and BYD have filed extensively to protect battery swapping and "Blade" fast-charging architectures, respectively. However, many of these innovations are initially filed only in their home jurisdictions.

This suggests a strategic regional focus where companies prioritise dominating their local infrastructure before expanding internationally. As 2026 unfolds, the industry is closely watching whether these domestic breakthroughs will successfully bridge the gap to global patent protection and international standardisation.

The 2015–2025 automotive battery patent landscape, characterised by over 300,000 unique filings in pack design alone, signals a decisive shift toward highly integrated, safe and circular energy ecosystems. Innovation is currently defined by a "chemistry convergence" where high-nickel NMC leads the performance tier and LFP dominates the mass market, supported by foundational silicon anode breakthroughs from Wacker Chemie that address long-standing stability issues.

Conclusion: patents are levers of market power

The automotive battery technology landscape underscores a critical truth: patents are not just markers of innovation; they are also levers of market power. Beyond sheer filing volume, the ability to secure IP positions that define technical standards or unlock new applications can reshape entire sectors, as seen in Toyota's battery mounting structure or QuantumScape's sulfide electrolyte.

Geographic filing patterns tell their own story: domestic-first strategies often foreshadow global ambitions, while PCT filings signal competitive intent long before it surfaces commercially. And disruption rarely stays in its lane. For example, technologies born in aviation, grid infrastructure, or consumer electronics routinely cross boundaries, creating both freedom-to-operate risks and partnership opportunities.

In fast-evolving industries, IP teams should view patent analytics as a predictive intelligence tool, not just a historical record. Those who harness it to anticipate industry shifts will lead; those who ignore it will be blindsided. IAM

Matt Troyer, Senior Director of Patent Analytics at Anaqua.

THE COST OF INACTION AS STANDARDISATION COMES FOR THE EV AND BATTERY INDUSTRIES

As standard adoption accelerates and charging ecosystems harden, essential intellectual property around is becoming more valuable, write experts from Fish & Richardson.

Technical standards and standard essential patents are playing increasingly important roles in the electric vehicle (EV) and battery industries. As standardised technologies underpin more features, the costs of inaction continue to rise for automakers, suppliers and other industry stakeholders.

This article examines recent standardisation trends, evaluates the SEP enforcement landscape and outlines strategies for licensing, acquiring or building an SEP portfolio in the EV and battery industries.

Costs of inaction rise as new technologies take centre stage

History teaches us a lesson about SEPs: if you are not prepared, you may face heavy royalties down the road. Companies controlling SEPs behind core technologies can flip this dynamic by leveraging their portfolios for cross-licences. This playbook comes from the smartphone industry, where key players built proprietary SEP portfolios for the sole purpose of cross-licensing. The EV and battery industries are approaching a similar inflection point.

First, original equipment manufacturers are converging around charging standards. SAE International (formerly the Society of Automotive Engineers) has been leading standardisation for NACS (the North American Charging Standard, or the SAE J3400 standard) and CCS2 (Combined Charging System Combo 2, or the SAE J1772 standard) EV charging standards.

NACS adoption is accelerating in North America since Tesla made the protocol available to other OEMs in 2022. For example, nearly every major automaker in North America adopted or pledged to adopt the NACS standard by 2025.

Automakers in Europe, India, and Southeast Asia are shipping more CCS2-compliant vehicles. Other markets, such as Japan and China, are also converging towards CHAdeMO (IEEE Standard 2030.1.1TM-2015) and GB/T (Guobiao/Tuijian) charging standards, respectively. As standard adoption accelerates and charging ecosystems harden, essential intellectual property around these charging stacks is becoming more valuable, and this trend is expected to continue.

Second, features previously deemed peripheral in automobiles are becoming integral to connectivity and modern user experiences. OEMs and suppliers face a growing need to patent or license SEP-dense technologies as vehicles incorporate advanced telematics.

Wireless communication patents directed to standardised protocols (eg, cellular communications, C-V2X, Bluetooth and Wi-Fi) have been proactively enforced against consumer electronics companies in federal district courts and the International Trade Commission. Automakers should expect the same. OEMs and suppliers should bolster their SEP holdings, proactively license key SEPs, and consider joining patent pools as licensors.

Virtually every major automaker is a licensee to Avanci's 5G Vehicle patent pool, with JLR, Volvo Group, Honda Motor and Nissan Motor joining the pool in 2025 alone. OEMs and suppliers have also licensed SEPs directed to information compression (eg, Mercedes-Benz's licence to Access Advance's HEVC Advance video codec pool), infotainment (eg, Panasonic Automotive Systems' licence to Sisvel's Wi-Fi 6 pool), and in-vehicle wireless charging technologies in 2025.

Third, EV and battery industry stakeholders face growing patent litigation risk. Electrification has coincided with increased patent litigation over battery technologies. Battery suits have clustered around popular patent venues, including the Eastern District of Texas and the ITC. As an example, battery manufacturers and component suppliers have been embroiled in litigation over the past few years on patents covering everything from core cell design all the way down to the materials used in electrodes, electrolytes and separators.

Relatedly, in November 2025, Bunker Hill Technologies – an affiliate of IP firm Dominion Harbor – initiated litigation campaigns against Ford Motor and Toyota Motor in the Eastern District of Texas, asserting patents directed to EV/plug-in hybrid EV (PHEV) on-board power and charging architectures.

At the same time, autonomous driving technology will also see an uptick in litigation as its adoption continues to expand to major automakers, particularly in EVs. For example, software company Perrone Robotics asserted automated driving system patents against Hyundai Motor, Kia, Mazda Motor, Nissan Motor, Tesla, Toyota Motor and Volkswagen Group in November 2025 in the Eastern District of Texas and the Eastern District of Virginia.

Current SEP landscape trends towards stronger enforcement

Trendlines across major forums point to a stronger SEP enforcement climate in 2026. Implementers may face heightened injunction risk and compressed negotiation timelines. SEP holders and licensing agents may find themselves well-positioned for coordinated multi-forum enforcement campaigns. These changes matter for automakers, suppliers and other industry stakeholders.

The past year brought notable developments in the United States and Europe.

In the US, the new administration signaled a patentholder-friendly turn in SEP policy. On 24 June 2025, the Department of Justice and the United States Patent and Trademark Office jointly filed a Statement of Interest in Radian Memory Sys. LLC v Samsung Elecs. Co., Ltd., No. 2:24-cv-01073 (E.D. Tex.). In their statement, the government argued against the categorical unavailability of preliminary injunctions for non-practitioners. On 25 November 2025, the DOJ and USPTO filed a Joint Public Interest Comment in Certain Dynamic Random Access Memory (DRAM) Devices, ITC Inv. No. 337-TA-3854, stating that "the public interest overwhelmingly favors the enforcement of valid patent rights through exclusion orders at the [ITC]".

More recently, the USPTO announced the launch of a Standard-Essential Patent Working Group on 29 December 2025. The Working Group reports directly to Director John Squires and is tasked with "ensuring that all patent holders … are treated fairly and that their rights receive strong and predictable enforcement wherever standards incorporate patented technologies".

In Europe, the Unified Patent Court remains central to SEP litigation and appears prepared to defend its jurisdiction. The UPC Mannheim Local Division granted the world's first anti-interim licence injunction in InterDigital v Amazon, LD Mannheim, decision of 30-09-2025 – UPC_CFI_936/2025. The Mannheim Local Division rejected the England and Wales High Court's interim licence, which would have permitted temporary sales pending final fair, reasonable, and non-discriminatory licensing determinations. In the UK, the Court of Appeal reaffirmed its willingness to set global FRAND rates by replacing a lower first-instance award with a global lump sum. Also in 2025, the European Commission withdrew plans to regulate SEPs – directed to technologies for telecom equipment, consumer electronics, and connected vehicle – which sought to rein in costly and lengthy litigation.

SEP licensing in the EV and battery industries

In 2025-26, SEP licensing in the EV charging and battery space continued to develop rapidly. Patent pools grew, licensing outreach expanded and some programmes moved into active enforcement. One important example is the battery patent licensing programme launched in May 2024 and administered by Tulip Innovation, which aggregates core and essential lithium-ion battery technology patents from LG Energy Solution and Panasonic Energy. In May and July 2025, Tulip Innovation secured multiple injunctions in Germany against Sunwoda Group entities.

Also in May 2025, SAE International published SAE J3400/2 as part of the J3400 family of standards covering EV connector and inlet architecture. That publication reflects continued momentum toward North American charging standardisation – exactly the kind of environment in which SEP licensing demands tend to grow over time. Separately, licensing programmes tied to EV charging standards continued to market portfolio licences in 2025.

Two other 2025 developments also shaped the landscape. First, In April 2025, Zhejiang Geely Holding Group announced it would open access to a battery safety patent pool (reported as more than 1,500 patents) to the broader auto industry. Second, and as mentioned above, the European Commission withdrew its proposed EU SEP regulation in February, leaving the existing EU framework in place for industries that include connected cars and, increasingly, EV platforms.

Building an SEP portfolio in the EV charging and battery industries

In 2025, companies building patent portfolios in the EV charging and battery fields were influenced by two trends: high-profile battery patent enforcement in Europe and growing standardisation activity.

A common strategic question for developers and automakers is whether to develop SEPs in-house or acquire them externally. In-house SEP development usually aligns more closely with a company's R&D work and the direction of the relevant standard, but it requires early and sustained investment. In practical terms, it means focusing R&D on likely standard features, harvesting inventions on the standards timeline (not just the product timeline), and prosecuting patents in a way that preserves claim scope as drafts of the standard evolve. By contrast, acquiring SEPs through portfolio purchases or company acquisitions can speed up coverage and fill gaps across patent families, jurisdictions, and standard generations. But it requires careful diligence, including confirming chain of title, identifying any SSO-related obligations, evaluating essentiality support, and checking whether the standard is likely to become widely adopted.

Because SEPs are closely tied to SSOs, active participation in SSO work is important. Attending working group meetings and tracking draft standards can help companies understand which technical features are likely to remain in the final standard, make informed technical contributions, and target patent filings toward the most relevant developments.

The USPTO's SEP Working Group, mentioned above, is also worth monitoring because it might signal a more active – and potentially more patent holder-friendly – federal posture on SEP policy, with downstream effects on enforcement expectations, portfolio valuation and licensing leverage. Practically speaking, the Working Group's priorities may shape how the USPTO and other bodies, including the ITC and district courts, evaluate SEP/FRAND licensing positions, negotiation conduct and enforcement remedies. Shifts in USPTO SEP policy can meaningfully affect deal economics and litigation risk, so stakeholders should monitor developments as guidance and enforcement expectations evolve.

Finally, companies should weigh the risks and rewards of an SEP strategy when considering whether to declare their patents as SEPs. On the risk side, there is no guarantee a patent will be adopted into a standard or that the standard will become commercially dominant. Essentiality disputes can be expensive, while FRAND commitments can limit royalty outcomes and restrict certain enforcement strategies. On the reward side, if a patent becomes essential to a widely adopted standard, licensing opportunities can be global and repeatable, and the economic value of a portfolio can grow over time – especially as EV charging and battery technologies converge around fewer interoperability standards and structured licensing programmes (including pool-style programmes) become more common.

In short, as EV and battery standards crystallise and licensing programmes mature, the decision to declare SEPs should be made deliberately and early by balancing FRAND constraints against the long-term leverage and scalable returns SEPs offer. IAM

Principal Daniel Tishman and Associates Eli Svetlov and Tae Hong at Fish & Richardson.

ROUNDTABLE: HOW IP IS PROPELLING BATTERY RACE FRONTRUNNERS

Top strategists at CATL, Panasonic Energy and EVE Energy on the balance between fierce IP protection and healthy collaboration as the battery market evolves

With global demand for batteries expected to shoot up through the 2030s, the pressure is on for manufacturers to compete on cost and outpace rivals on battery chemistry innovation.

Cheaper, longer-lasting, faster-charging and safer batteries are sought after as electric vehicles take over roads across the world, pushing R&D centres to improve the market favourites – lithium-ion chemistries nickel-cobalt-manganese (NCM) and lithium-iron phosphate (LFP) – and develop new contenders such as solid-state and sodium-ion batteries.

As competition intensifies the stakes are higher than ever to guard the intellectual property around these chemistries. Patent and trade secret litigation has proliferated as companies seek to push rivals out of the market. At the same time a licensing regime appears to be taking shape, led by the likes of LG Energy Solution and Panasonic Energy, which have a joint licensing venture, and Chinese carmaker Geely, which intends to share its battery safety patents to the auto industry.

Against this backdrop, IAM sought the opinions of top strategists at three major battery companies on the state of the sector, the role of IP as the market evolves, and the balance between assertive protection and healthy collaboration among industry players.

We spoke with the following in-house counsel:

John Kwon: Global general counsel at CATL, Kwon is steering legal strategy for the world's biggest manufacturer of EV and ESS batteries amidst intense competition and through rocky geopolitical terrain. The battery giant has factories in China, Germany and Hungary. In the US, it operates on a licence-royalty-service model for clients Ford and Tesla. The company is a global leader in battery research, investing not only in lithium-ion batteries but also in next-generation solid-state and sodium-ion chemistries. Kwon held C-level positions at companies such as SF International and Otis Sigma before stepping into the global general counsel role at CATL in 2022.

Kazuki Kawakami: Head of IP at Panasonic Energy. Having developed batteries since the 1920s and rechargeable lithium-ion ones since the '90s, Panasonic is an industry veteran – but one

> "Opportunities lie in product upgrading driven by core technological breakthroughs and diversified expansion of downstream scenarios such as new energy vehicles and energy storage"

that is now facing growing competition from Chinese and Korean companies. Panasonic Energy was formed in 2022 in a consolidation of Panasonic's battery businesses. Under Kawakami's lead, Panasonic Energy has adopted an assertive IP strategy aimed at bringing industry latecomers using its patented technologies under licence. Together with Korea's LG Energy Solution, Panasonic Energy tasked Tulip Innovation with licensing 5,000 of their combined lithium-ion battery patents – a venture that has proven sucessful thus far, inspiring Kawakami and his team to broaden their licensing efforts through various channels.

Nancy Zhang: Head of IP at EVE Energy, China's fifth-largest EV battery manufacturer. Zhang brings EVE extensive experience in overseas patent/SEP litigation and licensing negotiations from her time at Coolpad, which was followed by a stint at Midea Group. At EVE, Zhang leads a Huizhou- and Hubei-based IP team responsible for some 8,500 granted patents (out of over 15,000 patent applications) focusing on battery structures, thermal management, solid-/semi-solid-state and large cylindrical battery technologies. She steers a "3-in-1" IP strategy of patent leadership, trade secret protection and global risk control, with support from EVE's top management, whom she says recognises the importance of IP strategy to the company's global business.

IAM asked these strategists the same set of questions in separate interviews. Below we present their answers, which have been edited for clarity, brevity and IAM style.

What are the biggest challenges and most promising opportunities for companies in the battery sector today?

Kazuki Kawakami, Panasonic Energy (KK): The greatest challenge is that the business environment can change dramatically in a short period. Market demand can shift significantly, and volatility in raw material prices and updates of regulations across countries often require us to respond flexibly, with region-specific adaptations as well. Companies that closely monitor the environment and have the resilience to respond flexibly to such drastic shifts stand to find significant opportunities.

Nancy Zhang, EVE Energy (NZ): Global battery companies face four core challenges: irrational industry competition with falling prices squeezing profits and R&D; rapid technological iteration with large R&D investment and difficult route selection; prominent overseas IP compliance risks; and constraints from supply chains and environmental policies. Opportunities lie in product upgrading driven by core technological breakthroughs and diversified expansion of downstream scenarios such as new energy vehicles and energy storage.

John Kwon, CATL (JK): The fact that the EV industry has taken off is because of a lot of government subsidies in many countries. Lately, with those EVs rebates being withdrawn, there has been a slight drop in EV demand, so OEMs are readjusting EV car production targets in certain areas. But when you see the EV market as a whole, we see it growing. Overall, the trend is that EVs are outselling petrol cars, and in certain countries like China, the EV car is cheaper than the petrol car. So, the trend for EV cars globally is fairly optimistic and growing.

The other area seeing a boom is energy storage systems (ESS). This is energy producers realising that they can store energy from wind or solar and then harness that energy to address supply chain peak hours instead of building new facilities. That sector is going to grow and probably overtake the EV energy sector soon in terms of the proportion that they occupy.

As for battery manufacturers, they choose between LFP and NCM chemistries. The trend is that LFP is a lot more cost-effective, safer, and therefore the growth area. The companies that are doing well are the ones that have the ability to make those batteries right now. It's the same with energy storage systems.

> "The most promising next-generation battery technologies are large cylindrical batteries, large lithium-iron phosphate batteries, solid-state batteries and sodium-ion batteries"

How can companies use IP to differentiate themselves from others and sharpen their competitive edge?

KK: The important point is to identify the areas where we should differentiate and those that can be broadly used, and to determine the patents associated with each area. In the field of lithium-ion battery cells, I think we are no longer in a position to secure our technology advantage solely through patents. At the same time, we believe that even if we license our patents, we can still maintain a competitive advantage through manufacturing technology, product quality and safety grounded in know-how and various other factors. Accordingly, we chose to obtain royalties through licensing via Tulip Innovation. In other fields, we may not license our patents, and there are areas in which we exercise our patents as an exclusive right. We also believe that business partnerships leveraging IP will become increasingly important.

JK: It is in the battery chemistry itself. Batteries have been around for over a hundred years, but the battery chemistry has gone through exponential growth only in the last five years. It really depends on who comes with better chemistry. Companies can develop aggressive IP strategies to ensure that that a particular chemistry is well protected. The other chemistry is with the battery pack efficiency, or how we can store energy, charging times, and so on. But the area that's developing very fast is how data from battery usage can be optimised, hence the growth of AI in this field: how AI could benefit battery usage, tracking battery degradation trends, and how that data can be used to further optimise battery operation. We are investing in all three.

NZ: Companies can achieve differentiated competition through three IP measures: first, focus on cutting-edge technologies to build high-value patent clusters and promote patent standardisation; second, strengthen trade secret protection to create technological differentiation advantages; third, integrate resources through IP licensing and patent pools, standardise management to enhance brand strength, and convert IP advantages into market competitiveness.

What do you see more of in the industry: aggressive IP protection and enforcement, or open innovation or collaboration? What does that mean for long-term industry health?

KK: While it varies on a case-by-case basis, we sense a shift toward open innovation and collaboration. We also regard the activities of Tulip Innovation as a form of collaboration not only with LG Energy Solution but all industrial players, in the sense that we are broadly licensing patents to the industry. The more the industry grows, the less realistic it becomes for any single company to do everything on its own and, even for technologies we initiate in-house, there are cases where other companies can manufacture them more effectively. What is important is to establish an environment where those who make technological contributions are appropriately rewarded and this environment will contribute to the healthy development of the industry.

NZ: In the lithium battery industry, the protection of core technologies and open collaborative innovation are not opposing but co-existing forces. On one hand, we proactively build IP layouts and conduct forward-looking risk defence for core technologies such as cell design and cathode/anode materials to solidify our technological barriers. On the other hand, we adhere to the concept of win-win industrial collaboration and promote open cooperation across the upstream and downstream of the industrial chain. This is highly consistent with the cooperation, licensing and service (CLS) model practiced by EVE Energy in its global manufacturing and operations. We have always carried out external technological collaboration centered on CLS and are committed to empowering healthy and rapid industrial development with our own technological accumulation.

JK: For CATL, it's open innovation and collaboration through our licensing model. That is because we feel that, beyond battery sales, the adoption of renewable energy is a bigger goal than immediate sales. That would actually transform the industry. There are always ways to aggressively protect IP, but that would be in the area of developing battery chemistry. What is actually not there right now? For example, we are entering into third-generation sodium batteries – sodium batteries you can make out of salt. Because no one is doing it, the IP around that is highly protected. We ensure that everything is patentable and everything is protected. For technologies that are available and commoditsed, that is something we can share.

On litigation: Against international competitors, CATL has no litigation. Against domestic competitors, we do. Why? Because most of them are former employees who took our trade secrets to set up those companies.

What lessons in patent and trade secrets enforcement have you learned from your litigation?

JK: We believe in the rule of law surrounding trade secrets and patents, and we play by the rules. If anyone wants to challenge that, we're not scared to go after patent infringement. In our case, patent infringement occurs because our trade secrets are being taken.

Panasonic Energy took a proactive approach to licensing by working with Tulip Innovation in 2024. When you last spoke with IAM, you said you will not hesitate to sue industry latecomers who refuse to be licensed. In what ways have you refined your strategy since then?

KK: Our overarching policy remains unchanged. We prioritise amicable resolutions, but litigation is sometimes necessary to make clear the legal risks counterparties face. We continue to refine our enforcement strategy, including the selection of the most effective jurisdictions and respondents in litigation. While we believe battery manufacturers should obtain a licence from us, effective enforcement may, in some cases, require involving their downstream customers.

As new battery chemistries emerge, how do you strike a balance between developing and protecting proprietary technologies and engaging in joint ventures or cross-licensing?

NZ: As a global lithium battery leader, EVE Energy adheres to the coexistence of core technology protection and open innovation, consistent with its CLS model in global operations. It maintains high-intensity R&D with RMB 2.942 billion invested in 2024 (over 6% of annual revenue); 6,068 R&D personnel; and 14,238 total patent applications (8,125 authorised as of Jun 2025). It focuses on frontier technologies like solid-state batteries, while conducting global cooperation industry-university-research collaboration and providing technology licensing/services in non-core fields to contribute to the industry.

KK: We are developing next-generation batteries in collaboration with a variety of suppliers, universities, and research institutions. Creating entirely new materials on our own is challenging, and we therefore explore promising new chemistries and jointly refine them into materials suitable for battery applications.

JK: We don't license the latest technology we are researching. But as to technologies that have become commoditised, we are open to licensing that without much restriction.

What do you think is the most promising next-generation battery technology? How should companies endeavour to get ahead?

NZ: In our view, the most promising next-generation battery technologies are large cylindrical batteries, large lithium-iron phosphate (LFP) batteries, solid-state batteries and sodium-ion batteries – each with unique advantages to meet diverse market demands. Large cylindrical batteries excel in reliability and scalability (our 46-series products are mass-produced and will equip BMW's new models), large LFP batteries stand out for safety and long-life cycle, and sodium-ion batteries offer excellent low-temperature performance and cost benefits. For solid-state batteries, EVE Energy has adopted sulfide and halide solid electrolyte technical routes, focusing on breaking core bottlenecks such as sulfide electrolyte stability and interface impedance. We have built an R&D team of over 200 people to tackle key technologies including sulfide ceramic electrolytes and metallic lithium anodes. To lead competitors in these technologies, EVE continuously increases R&D investment and strengthens IP, forming a comprehensive layout to accelerate technological iteration and industrialisation.

KK: A variety of next-generation battery materials are being explored, each with distinct characteristics. Since battery requirements vary widely by market and application, I don't believe we can definitively say which one is the most promising. To deliver optimal products that meet market needs, we believe a battery manufacturer must pursue multiple options. Recognising that conventional liquid electrolyte lithium-ion batteries still have room to evolve, we are developing a diverse set of material technologies in parallel.

JK: NCM is a high-density battery, allowing longer range and quick charging times, while LFP was low-density, with low range and long charging time. So NCM was the battery of choice until we saw all those fires. In the meantime, none of the international players touched LFP. So the Chinese players invested in LFP, worked on the chemistry, innovated it so that there is just about a 10% difference between NCM and LFP. But the cost is a lot less, it's a lot more competitive, and LFP is not combustible, so it is now becoming the preferred choice.

Where do you see the battery industry heading in five to 10 years' time? How should IP teams prepare for that future now?

JK: In five to 10 years, we will see batteries in commercial airlines and vessels and AI-based robots. There will be a boom in battery usage for various functions. IP teams could prepare to adapt basic energy technology into new uses, whether that be flight, shipping, robotics, and the many areas that will utilise portable battery packs that are durable and fast-charging.

NZ: Over the next five to 10 years, the battery industry will move towards diversified technology routes, safer performance and global integration, with solid-state and sodium-ion batteries gradually industrialised. IP teams can help companies prepare by building a global patent network covering core technologies, identifying potential patent risks in overseas markets, and promoting the integration of patents into industry standards to maintain competitive advantages.

KK: While the EV market is currently growing more slowly than initially expected, the market for energy storage systems for data centres is rapidly taking off, driven by the sharp growth of the AI server sector. Although fluctuations by application are to be expected, we believe the battery industry as a whole will continue to develop. As industry advances, collaboration with other companies becomes indispensable, with IP serving as a key component whose importance will further increase. While IP activities such as prosecution and licensing are, of course, essential in collaborations with suppliers and research institutions, we believe IP teams can help create a collaboration framework with partners or to bring new partners onboard. Indeed, we are seeing more and more opportunities to work together with the business divisions to engage with partners. IAM

Nicole-Anne Lagrimas, Senior Reporter, IAM.

SHINING A LIGHT ON SOLAR

Solar has seen a meteoric rise in popularity as the world increasingly turns to alternative, renewable energy sources. With this rapid growth comes fierce industry competition resulting in plummeting solar module prices and a complex web of patent disputes as global solar giants seek to outmaneuver rivals in a crowded market.

This chapter explores the multifaceted world of solar energy, tracing the evolution of solar cell technologies and patenting hotspots and breaking down enforcement strategies by some of the most important players on the field.

The first article, from the IAM archives, shines a light on solar photovoltaic patenting, showing China's unparalleled dominance in patent volume and its popularity as an enforcement venue, even while the US remains the most desirable jurisdiction for protecting the strongest of solar inventions.

In the second article, Yingchun Liu, Nongfan Zhu and Zhiming Zhou of King & Wood Mallesons review significant patent battles among solar industry giants, revealing a development in the market's taste for patent cross-licensing as a way to minimise losses and maximise benefits to individual companies and to the sector more broadly.

Finally, Karthik Kumar and Abhinav Garg of Finnegan discuss the technological race underpinning the trajectory of the sector: the competition between TOPCon and back-contact solar cell architectures, which has the potential to reshape the future of the industry, further raising the stakes for sophisticated IP portfolio management and strategic enforcement. IAM

CHINA SHINES BRIGHTEST IN SOLAR PHOTOVOLTAIC PATENT RACE

The mainland is also the focus of erupting disputes while the US sees a large share of "high-strength" patent filings, an exclusive Clarivate analysis from IAM's archives shows.

China is dominating the solar photovoltaic innovation landscape on multiple fronts, according to an exclusive analysis by data provider Clarivate for IAM. Not only is it the biggest overall source of solar PV inventions globally – it is also the origin of the highest volume of "high-strength" patents and the home of half of the top 40 innovators in the field.

Furthermore, 80% of solar PV patent infringement cases are playing out in China, most likely the result of white-hot competition among the country's solar giants and of a domestic patent explosion at a rate not seen anywhere else in the world.

Nonetheless, the US remains the most desirable location for protecting high-strength inventions and the venue of half of all solar PV-related patent actions, indicating that the US remains an important field for innovators even as China wins the volume game, the analysis has found.

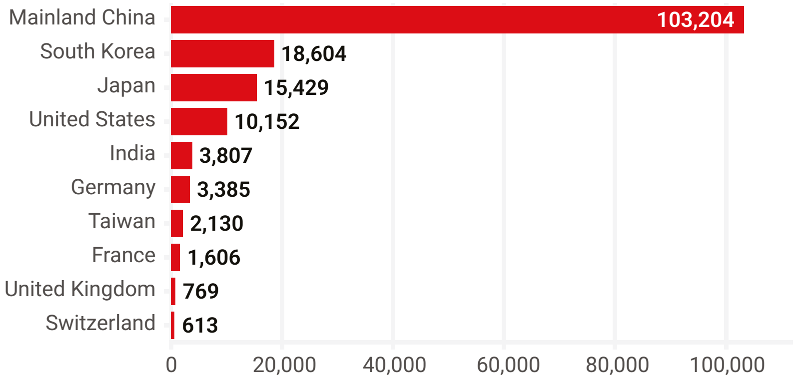
At the request of IAM, Clarivate investigated innovation in solar PV, the technology that converts sunlight directly into electricity, at a time when more nations are setting renewable energy targets and companies are fighting fiercely to secure or maintain their foothold in an increasingly hot market.

Clarivate searched for patents (excluding utility models) published from 2015 to 2024 and looked at both inventor and filing locations. Importantly, it also examined patent strength – particularly which patents sit within the global top 0.5% of inventions – using the Derwent Strength Index, which scores inventions based on influence, the breadth of filing locations, the size of the granted footprint of protection, and rarity. The data provider analysed patents filed in at least two jurisdictions as an indicator of strength.

Over the last decade, mainland China-based innovators filed 103,204 solar PV patents around the world. This is nearly six times the filing volume of inventors located in South Korea, the second-biggest source of solar PV patents (18,604 inventions in the same period). Japan comes in at third place with more than 15,000 inventions, while the US ranks fourth with 10,152 patents. India rounds out the top five, with 3,807 inventions.

Figure 1: China is the biggest source of solar innovators

Top sources of solar PV patenting by inventor location, 2015-2024



Source: Clarivate

Even when measuring by patent strength, the top five ranking of patent sources remains largely the same. China comes out on top: 466 solar PV patents filed by China-located inventors sit within the top 0.5% of inventions worldwide (therefore considered "high-strength"). Inventors in Korea, Japan and the US have also produced hundreds of high-strength patents. Instead of India, however, Germany takes the fifth spot with 128 high-strength inventions. India falls to the 13th spot by this metric, behind countries such as Taiwan, the UK and Canada.

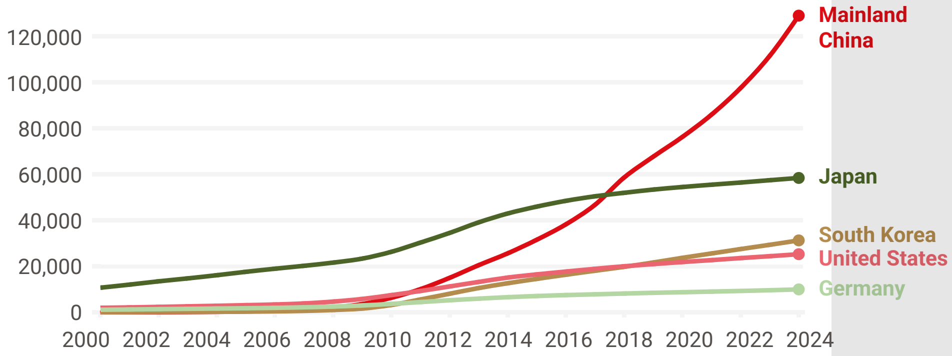
Indeed, solar PV innovation in China has increased significantly over the years, outpacing patent filing growth by innovators from Japan, South Korea, the US and Germany by a wide margin. China overtook Japan as the world's biggest source of solar PV patents in 2018 and has held on to the top spot ever since. The chart below displays the astonishing leap in Chinese solar inventive activity versus more moderate increases in other leading innovation hubs.

In terms of filing locations, China is also the global leader, with nearly 109,000 solar PV patents published from 2015 to 2024. The US is at a distant third place with about 20,800 filings.

This is where the analysis becomes more nuanced: Clarivate has found that the US has seen the largest share of high-strength patent filings based on the Derwent Strength Index over the last decade. Close to 1,000 patents filed in the US during this time fall under the top 0.5% of solar PV inventions, although China is not far behind with about 900 high-strength inventions filed within its borders.

Figure 2: Chinese solar innovation has grown exponentially

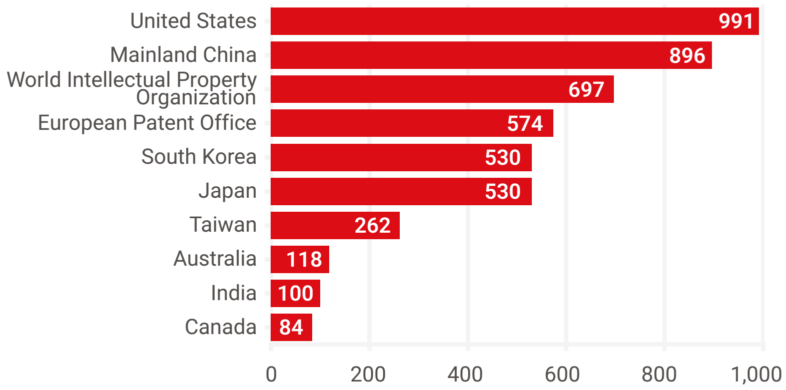
Patenting activity in solar PV innovation hotspots, 2000-2024



Source: Clarivate

Figure 3: US is top location for high-strength solar patenting

Top filing locations for solar PV patents in the global top 0.5%



Source: Clarivate

Leading innovators

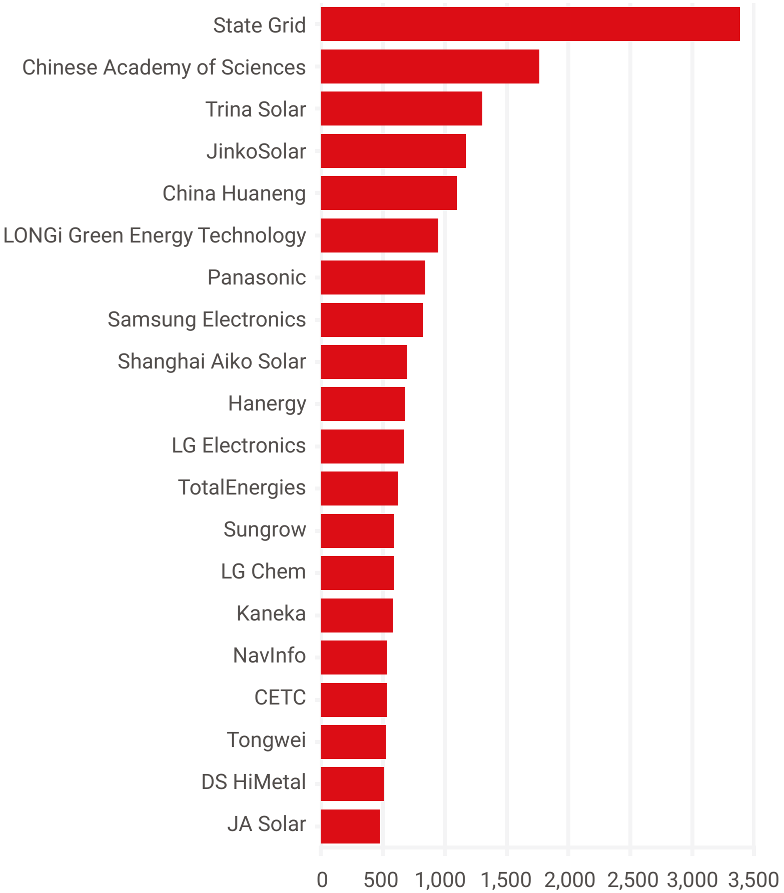
The State Grid Corp of China, one of the world's biggest patent owners, unsurprisingly claimed the top spot in the solar PV patent volume leaderboard, having filed 3,385 patents from 2015 to 2024. It is followed by the Chinese Academy of Sciences, which has nearly 1,800 patent applications to its name from the same period. However, these two entities are by no means specialists in the field – only 1% of their respective portfolios relate to solar PV.

A specialist, according to this Clarivate analysis, is a company whose solar PV inventions represent more than 10% of its patent portfolio. Of the top 40 filers, Clarivate identified 12 specialists, including many of China's biggest solar industry players: Trina Solar, JinkoSolar, LONGi Green Energy Technology, Aiko, Tongwei and JA Solar.

The table below shows the top 40 patentees ranked by the absolute number of solar PV inventions from 2015 to 2024.

Figure 4: Chinese organisations dominate in solar patenting

Leading solar PV patent filers, 2015-2024



Source: Clarivate

interestingly, the analysis has found that the companies that own the most high-strength patents do not manufacture solar PVs themselves. Samsung Electronics (which, like State Grid, owns one of the world's biggest overall patent portfolios), owns the highest volume of high-strength solar PV patents (57), even though only 1% of its portfolio relates to the field.

Merck, the German science and technology company, and DS HiMetal, a Korean materials manufacturer, each own 50 and 48 high-strength solar patents, respectively.

This indicates that strong innovation is happening at the materials level and thus lends a supply chain element to the analysis, as Merck and DS HiMetal are likely suppliers to key solar PV players, Clarivate notes.

Of the solar PV specialists, JinkoSolar has the biggest number of high-strength patents – 31 of its 1,171 solar PV inventions from 2015 to 2024 are considered in this category, according to the data. Meanwhile, LONGi has 12 high-strength inventions out of its solar PV portfolio of 947 patents. Aiko, JA Solar, Tongwei and Trina Solar have relatively fewer patents that sit within the high-strength subset.

Litigation hotspots

These major Chinese PV players have turned to patent enforcement in recent years and months, likely as a way to protect and expand their market share in an increasingly competitive industry.

JinkoSolar and LONGi, for example, engaged in a months-long patent dispute that had prongs in China, Europe, the US, Australia and Japan, over tunnel oxide passive contact (TOPCon) and back contact (BC) patents before striking a cross-licensing agreement in September. TrinaSolar, Canadian Solar, Singapore's Maxeon and Korea's Hanwha Solutions have also been involved in litigation over patents relating to TOPCon and BC, the two major competing solar cell technologies.

Other deals have emerged in recent months, too: TrinaSolar has licensed its TOPCon patents to French company Holosolis, and has itself taken a licence to perovskite-based PV technologies owned by Oxford PV. Elsewhere, First Solar has granted a licence to Talon PV, and Maxeon has signed a cross-licensing agreement with Tongwei Solar.

However, while litigation may appear to have picked up only recently, the Clarivate analysis reveals that close to 400 solar PV patent cases have been initiated over the last five years.

Using its tool Darts IP, Clarivate has identified 920 solar PV-related patent cases initiated between 2020 and 2025 around the world. Of this number, 393 are infringement cases. A greater number, 527, are patent validity challenges, including oppositions, inter partes reviews, and invalidity petitions.

The US is the venue of about 50% of all types of solar PV patent actions. Notably, though, China is the venue for 80% of infringement lawsuits while the US and Europe are playing host to significantly smaller percentages (8% and 6%, respectively) of the action. More validity challenges are also taking place in China than anywhere else, Clarivate reports.

Most interestingly, however, none of the most active parties in infringement cases are Chinese companies. US-based KT Imaging is the most frequent plaintiff, having filed 18 cases from 2020 to 2025, while Samsung has been the most targeted. Samsung's US unit and the Korean parent company have collectively been named defendants in 17 and 16 infringement cases, respectively. Against this backdrop it makes sense that Samsung has filed the most challenges to the validity of its opponents' patents during this period. IAM

Nicole-Anne Lagrimas, Senior Reporter, IAM

"China overtook Japan as the world's biggest source of solar PV patents in 2018 and has held on to the top spot ever since"

RENEWED RESHUFFLE IN THE PV INDUSTRY DRIVEN BY IP ENFORCEMENT

Weak market demand, rising raw material costs and geopolitical factors have all intensified the battle for market share among global PV companies, write experts from King & Wood Mallesons.

There was once a time when the photovoltaic (PV) industry was emerging as a standout in the energy sector. Since then, its substantial development has spanned just over seven decades, and global competition has become intensely fierce!

Particularly in the past two years, a wave of bankruptcies has swept through the global PV industry, notably in Europe, the United States and China. Amid this downturn, the global PV sector is once again engulfed in conflict and facing a profound reshuffle.

Weak market demand, rising raw material costs and geopolitical factors have all intensified the battle for market share among global PV companies. In recent years, patent litigation in the industry has gradually increased, with many of the world's top 20 PV manufacturers becoming entangled in patent infringement disputes.

On an international scale, for example, Hanwha Group and its affiliates filed patent infringement lawsuits with the US International Trade Commission, the US District Court for the District of Delaware, the Federal Court of Australia and the Regional Court of Düsseldorf in Germany in March and April 2019. They alleged that some products sold by LONGi Green Energy Technology, Jinko Solar, Trina Solar and their subsidiaries in these regions infringed upon Hanwha's patents.

In December 2024, Jinko Solar initiated a patent infringement lawsuit in the US District Court for the Northern District of California, accusing the Japanese PV company VSUN Solar and related entities of infringing its N-type TOPCon technology patents and, in June 2023, Germany's Maxeon sued China's Tongwei in Düsseldorf for patent infringement concerning shingled module technology.

Domestically in China, more than 10 leading PV module manufacturers have been drawn into the patent battle. On 13 February 2025, Jinko Solar sued LONGi Green Energy Technology for patent infringement; on 10 February 2025, Trina Solar sued Canadian Solar for patent infringement; and on 19 July 2024, JA Solar Technology sued Chint New Energy for patent infringement.

Chinese companies are involved in over 80% of these global cases, both in terms of the number of cases and the amount in dispute. This is primarily attributed to the unique position of Chinese PV firms globally.

Regarding the market share, the Chinese PV industry holds an absolutely dominant position worldwide, steadily maintaining more than 80% of the global market share. According to data in 2023, China accounted for 83.4% of the global photovoltaic module production capacity and 84.6% of the global output. In key segments, such as silicon wafers and cells, China's global share exceeded 75%. Among the world's top 20 PV companies in 2025, 19 were Chinese companies, with all top 10 spots occupied by Chinese enterprises. In terms of technological advancement, China has achieved full supply chain control, from polysilicon to modules, with 100% self-sufficiency. Chinese PV companies have achieved mass production TOPCon cell with efficiencies of 25.5%, HJT cell exceeding 26%, and perovskite tandem module lab efficiencies reaching a world-leading 34.85%.

In terms of cost competitiveness, the cost of PV power generation in China has dropped by 90% over the past decade. It is 20% lower than that in the US and 35% lower than that in Europe, making its levelized cost of electricity the lowest globally. Consequently, the vast majority of global patent disputes involve Chinese companies.

Despite the continuous and intensifying patent disputes, information disclosed by relevant companies and judgments published by courts indicate that most global infringement lawsuits involving photovoltaic giants ultimately result in settlements and cross-licensing agreements—either globally or in specific regions.

In March and April 2019, Hanwha filed lawsuits in the United States, Germany, Australia, and other countries against Chinese companies Longi Green Energy, Jinko Solar, and Trina Solar for patent infringement related to PERC cells. These cases were eventually resolved through global settlements and patent cross-licensing agreements between February and August 2023. In September 2025, Longi and Jinko jointly announced the termination of ongoing global patent disputes and reached a cross-licensing arrangement for certain core patents.

In November 2025, JA Solar and Chint New Energy announced a settlement and cross-licensing agreement for their global patent lawsuits. In January 2025, China's Tongwei and Germany's Maxeon reached a global settlement and a worldwide patent cross-licensing agreement, resolving their series of patent infringement and invalidation lawsuits. Many other photovoltaic patent litigation cases have also ended in settlements.

The surge in patent disputes stems from the competition for market share. Many leading photovoltaic companies have expanded from a single segment of the PV industry chain to covering the entire chain. Having moved from a nearly saturated domestic market in China to a global stage, they now dominate the worldwide market.

Despite rising raw material costs, these companies continue to lower product prices, leading to shrinking profit margins and even losses across the entire chain. As a result, they resort to sending warning letters and filing lawsuits to secure their market positions.

However, unlike in earlier years when they were more vulnerable, these giants now possess independent intellectual property rights, well-structured patent portfolios, and specialised legal teams during the litigations.

This has quickly triggered a wave of global mutual infringement lawsuits and patent invalidation disputes, consuming substantial human and material resources and turning what might have been quick legal battles into protracted wars. During these lengthy proceedings, some products have already become outdated – for instance, Perc cells are being replaced by TOPCon and others – diminishing the rationale for continuing the fights.

“Unlike in earlier years when they were more vulnerable, PV giants now possess independent intellectual property rights, well-structured patent portfolios and specialised legal teams ”

Meanwhile, the exchange of warning letters has led to customer hesitation and attrition. In this scenario, like the mantis stalking the cicada unaware of the oriole behind, none of the involved parties have succeeded in retaining their clients.

As many giants have expanded from specialised segments, such as silicon materials, wafers, cells, or modules to full-chain operations, the relentless pursuit of scale and comprehensiveness has reduced cooperation and intensified competition among enterprises.

Interestingly, the parties in these disputes have often collaborated for years in certain aspects of the PV value chain, achieving mutual benefits in the past.

Considering potential prospects for future collaboration and complementary business opportunities, they recognise that seeking long-term reconciliation, delineating respective markets, and shifting from confrontation to cooperation is the sustainable path forward. Moreover, the independent intellectual property portfolios of these giants encompass various technological routes. Cell technologies such as Perc, TOPCon, and BC each have their advantages.

In some cases, the patents asserted in lawsuits were technologies previously undervalued by earlier companies. Through patent transfers and subsequent technical transformation, cross-licensing agreements regarding patents via settlements enable continued R&D and utiliation in term of this, further optimising existing technologies. This also serves as a pathway for these giants to develop higher-value technological products further.

On 9 January 2026, the Ministry of Finance and the State Taxation Administration jointly announced the cancellation of export value-added tax (VAT) rebates for PV and battery products. Specifically, for PV products, the export VAT rebate will drop directly from the current 9% to zero starting 1 April 2026.

For battery products, the reduction will be phased in two stages: from 9% to 6% on 1 April 2026, and completely cancelled on 1 January 2027. This marks the end of the era where the PV industry could rely on policy incentives for easy gains.

This change undoubtedly poses additional challenges to Chinese PV giants with significant export exposure. Even though on 13 January 2026, China's Ministry of Commerce decided to continue imposing anti-dumping duties on polysilicon from the United States and South Korea for another five years, providing some policy buffer for the domestic PV industry, factors such as raw material prices and cell conversion efficiency will still filter out less competitive players. After this industry shake-up, only the strongest will remain.

To conclude, PV giants involved in patent wars often opt for cross-licensing and structured negotiations as more rational choices, considering factors such as litigation costs, time, market dynamics, and policy or political uncertainties. This approach aims to minimise losses and maximise benefits.

As a strategic emerging industry in China, the PV sector must ultimately rely on enhanced production capacity, strengthened intellectual property portfolios, rational market pricing, and cooperative models that foster mutual success to achieve sustainable development. IAM

Yingchun Liu, Nongfan Zhu, Partners, and Zhiming Zhou, Patent Attorney at King & Wood Mallesons.

TOPCON V BACK-CONTACT SOLAR CELLS: THE TECHNOLOGY RACE FUELLED BY PATENT STRATEGY, ENFORCEMENT AND LICENSING

A trend of increased efficiency and lower pricing shows no signs of stopping as markets consolidate and the importance of IP ownership increases, write experts from Finnegan.

As global demand for solar energy accelerates, competition among manufacturers has increasingly shifted from purely technological innovation to a complex interplay of efficiency gains, cost pressures and intellectual property positioning. Against this backdrop, TOPCon and back-contact architectures have emerged as the leading contenders for dominance in next-generation crystalline-silicon photovoltaics.

The solar photovoltaics (PV) market has continued to surge globally, with 2024 seeing a 37% increase in installed PV capacity over 2023. By Q3 of 2025, global PV output was a third higher than by the same time in 2024 with pricing falling to just $0.08/W by the end of 2024.

In an environment of reduced pricing and incrementally increasing efficiency numbers, global competition is intense. The United States has seen a similar boom in PV through 2025 due in part to extensive tax incentives and loans under the 2022 Inflation Reduction Act. However, US PV activity is expected to decline significantly due to clean energy incentives being reduced in 2025 and increased uncertainty due to tariffs.

Some industry analysts are optimistic that, despite the Trump administration's actions relative to US clean energy, the solar industry will not collapse, as the cost of solar energy is rivalling or beating the cost of energy by burning fossil fuels, even without incentives.

The market has also arrived at a consensus on crystalline silicon as the dominant cell architecture, making up 98% of the market in 2024. In terms of cell structure, in 2025, passivated emitter rear cell (PERC) panels were largely phased out in favor of Tunnel Oxide Passivated Contact (TOPCon) panels, which have about 80% market share.

Back-contact (BC) panels are expected to gain significant popularity in the coming decade. PV efficiencies have also continued to rise, with top performers ranging between 21-25+% efficiency and with BC panels edging past TOPCon panels.

Rising patent disputes and license agreements reflect the highly competitive nature of the industry, with TOPCon being a major area of IP activity.

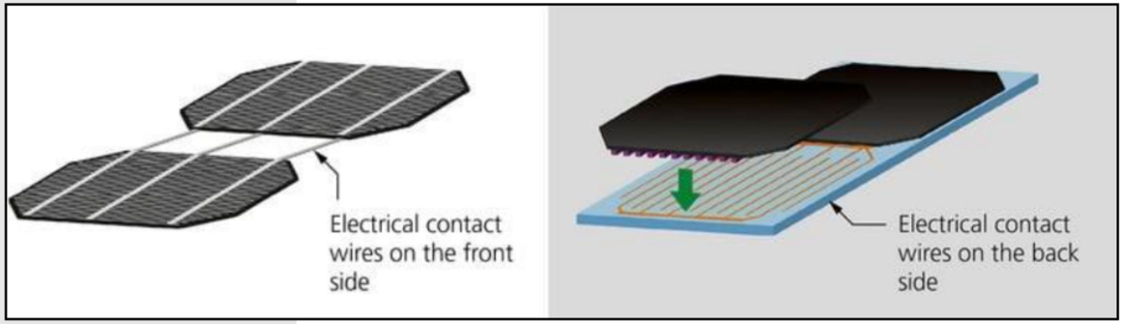
Historical development and modern TOPCon and BC technologies

From early selenium cells and thermopiles to Bell Labs' silicon p–n junction, each wave lifted efficiency while cutting cost. The in most modern solar panels comes from surface passivation (reducing surface defects in the silicon) and current collection (routing charge away from the solar cell via carefully placed metal contacts), each of which affects efficiency, manufacturing complexity, and reliability. A popular option over the past decade has been PERC, which introduced passivation on the rear-side of the solar cell.

In the early 2020s, TOPCon technology began gaining market share, displacing PERC and becoming the market leader of today. TOPCon panels use a tunnel oxide passivated contact to enable strong charge carrier selectivity and high efficiency. TOPCon panels are able to achieve efficiencies on the order of 25+%.

Now, BC designs are being developed that promise higher efficiencies. BC panels are defined by placing the metal contacts or "busbars" on the rear side, which reduces front-side shading and enabling efficiencies surpassing 26%. Manufacturers are aggressively seeking to remedy the increased process complexity that comes with the rear-side busbar arrangement.

Industry experts expect BC to achieve cost parity with TOPCon by the end of the decade, which will likely bring increased market share, potentially surpassing TOPCon. Looking toward 2030, the next wave of efficiency gains is expected by combining crystalline silicon with a hotly researched material, perovskite.



Conventional PV cells with front-side busbars **Back-contact PV cells with back-side busbars**

The business landscape and the main layers

The solar panel market has been characterised by "[a]ggressive pricing, intense competition, and continued capital investment", an analysis by Wood Mackenzie noted.

"China continues to dominate the solar module manufacturing landscape in terms of scale", with India, South Korea, and Vietnam trailing behind. The next few years are predicted to be defined by "industry consolidation, deeper vertical integration", "regionalisation of manufacturing" and efficiency gains, it said.

As of 2024, the top companies in terms of module shipments were Jinko, LONGi/JA Solar, Trina, Tongwei, Astronergy, Canadian Solar, GCL, DAS Solar, and Yingli. In terms of efficiency numbers, as of Q3 of 2025, there were about 33 companies producing 50 modules that hit or overcome 21.5% efficiency. The following companies top the efficiency charts:

- AIKO (24.4% efficiency);
- LONGi (24.2% efficiency); and
- Maxeon (24.1% efficiency).

Patent positioning of key players

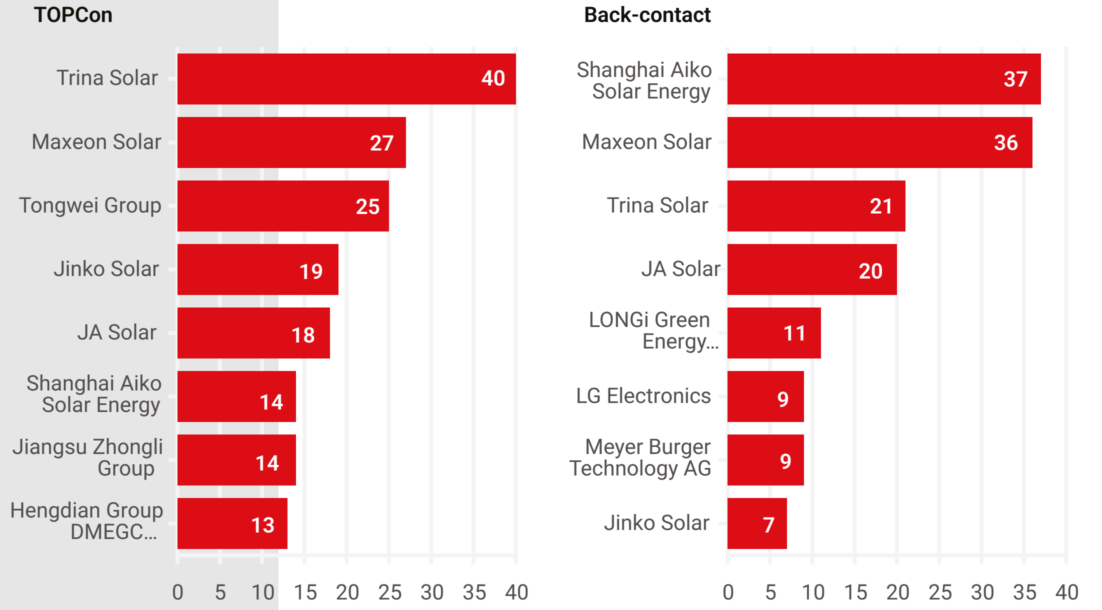
Solar panel development has largely been a story of stacking innovation. In other words, some efficiency gains are achieved by adding a physical layer or a processing step. This means that some patents covering aspects of TOPCon's predecessor (PERC) may also be relevant to TOPCon developers. And some patents covering aspects of TOPCon may prove relevant to BC developers.

For TOPCon, patent claim scope appears to concentrate on the passivated contact structure, deposition and dopant control, metallisation, and integration choices. For BC, claim scope more often centers on rear side architecture: contact layout, patterning and electrical isolation, and scalable fabrication sequences.

The TOPCon and BC patent counts (global, pending and granted) of top solar manufacturers are provided below.

"Solar panel development has largely been a story of stacking innovation"

Figure 1: Innovation in the market favourite – and in next-gen solar cells
Active TOPCon and back-contact patent families by organisation



Source: Finnegan

Leveraging IP through litigation and licensing

Active IP litigation is likely to arrive with the industry's aggressive competition, rapid pace of technological development, and financial pressures. Solar technology can sometimes be additive in nature, so IP covering the current generation of solar cells may be asserted against future generations of solar cells. And even patents that cover aspects that are unique to the current generation of solar cell technology may be valuable as negotiation leverage.

Acquiring patents from earlier market entrants can be an effective strategy to clear the path for marketing products, stopping competitors, and obtaining favorable settlements or licensing agreements.

Leaders in the industry agree. For example, First Solar acquired a patent portfolio from California-based startup TetraSun that covered TOPCon technologies back in 2013, when the technology was still quite early. First Solar has used its acquired IP two-fold: initially to develop its own "transformative, disruptive solar technology", and later to assert against its competitor JinkoSolar.

Similarly, Solar panel giant JingAo Solar had acquired patents from LG Electronics in 2014 as LG was exiting the solar panel business.

2024 brought several other TOPCon-related IP lawsuits around the world:

- Singapore-based Maxeon asserted its patent brought suit in the US against Qcells, Canadian Solar, and REC.
- JA Solar brought two cases in Europe.
- US-based First Solar files suit, asserting US patent No. 9,130,074 against its competitor JinkoSolar in the US. First Solar also reached a licensing agreement with Talon PV, a SU.S.based solar cell manufacturer.
- Trina Solar filed a lawsuit in the US against Runergy and Canadian Solar and reached a licensing agreement with Qcells.
- JingAo Solar asserted two of its TOPCon patents at the Unified Patent Court against competitors Astronergy and Chint. After challenges to the asserted patents' validity at the European Patent Office, the UPC handed the win to JingAo. As a result, JingAo was entitled to the powerful remedy of enjoining its competitor from participating the German, French, Dutch and Italian markets.

2025 saw BC-related patent lawsuits. On 10 December 2025, Maxeon Solar filed suit against Aiko Solar and four of Aiko's distributors in Munich, Germany, asserting its EP2297789B1 patent.

Maxeon had also asserted its EP2297788 patent against Aiko Solar in 2023 in Germany and the Netherlands and its EP3065184 at the UPC in 2024. These actions signal the importance of actively monitoring the competitive landscape and the associated distribution network.

These examples of global IP enforcement underscore the critical importance of (1) IP asset ownership for offensive action and defensive leverage; and (2) obtaining freedom to operate opinions before entering new markets.

For fast-developing industries, where to bring suit is also critical. For example, the US International Trade Commission and the UPC each examine infringement allegations quickly and efficiently, with hearings within about nine months, and routinely grant permanent injunctions. Some US District Courts are similarly known for their quick time to trial and frequent seven-to-nine figure damages verdicts. The speed of these venues allows IP owners to assert their

IP before the market shifts to the next generation of technology and strengthens negotiation positions against the alleged infringers facing potentially crippling injunctions or damages figures.

Looking forward, the expected industry consolidation may increase incentives to litigate as the set of high value targets becomes smaller and damages stakes grow with scale. At the same time, consolidation can increase incentives to settle or cross-license IP rights because repeat player dynamics and mutual exposure make protracted legal fights more expensive.

How these marketplace dynamics and IP litigation and licensing strategies play out remains to be seen.

Conclusion

For decades, solar panel technology has steadily increased efficiencies and lowered pricing. That trend shows no signs of stopping with TOPCon and BC technologies as markets consolidate and the importance of IP ownership increases.

Karthik Kumar, Partner and Abhinav Garg, Associate, Finnegan.

> "Even patents that cover aspects that are unique to the current generation of solar cell technology may be valuable as negotiation leverage"

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Contact us

London
Holborn Gate
330 High Holborn
London WC1V 7QT
United Kingdom
T +44 20 7234 0606
info@iam-media.com

Hong Kong
2301, 23/F, Jubilee Centre
18 Fenwick Street
Wan Chai
Hong Kong SAR
info@iam-media.com

Washington DC
2122 P Street NW
Suite 201
Washington DC 20037
United States
T +1 202 831 4654
info@iam-media.com

Austin, TX
3000 Polar Lane
Suite 1001, Cedar Park
Texas 78613
United States

New York, NY
575 Fifth Ave, 14th floor
NY 10017
United States