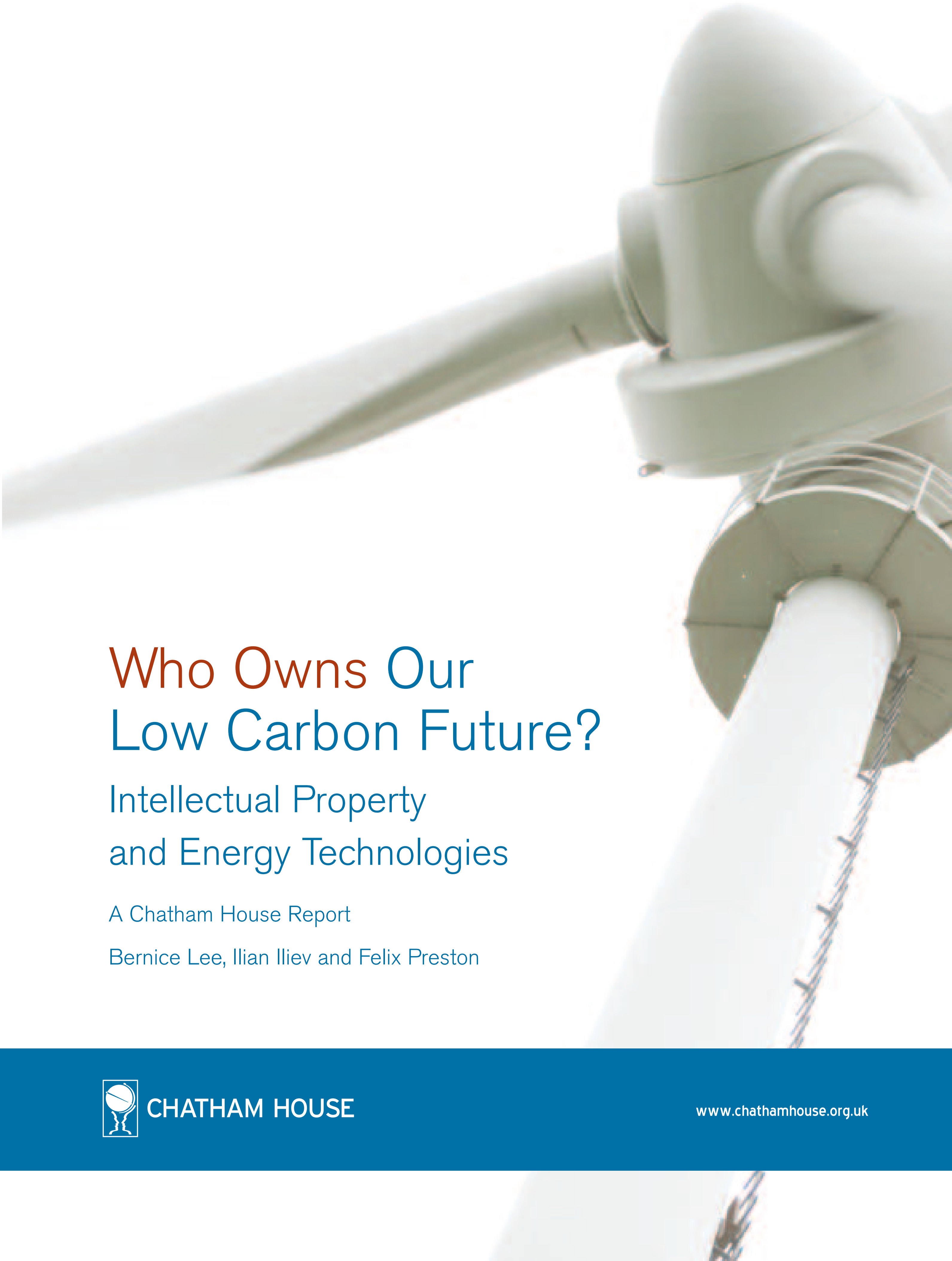

Who Owns Our Low Carbon Future?

Intellectual Property and Energy Technologies

A Chatham House Report

Bernice Lee, Ilian Iliev and Felix Preston

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Chatham House
10 St James's Square
London, SW1Y 4LE
T: +44 (0) 20 7957 5700
F: +44 (0) 20 7957 5710
www.chathamhouse.org.uk

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- Event organized by Climate Change Capital and the Natural Resource Defense Council on ‘Emerging Strategies for International Climate & Investment Policy’ in Washington, DC in January 2009;
- Side event organized by Chatham House and the International Centre for Trade and Sustainable Development at the Standing Committee on Patents of the World Intellectual Property Organization, on ‘Innovation and Diffusion of Climate Technologies: What Role for WIPO?’, in Geneva in March 2009;
- Workshop organized by the Brookings Institution and E3G on ‘Building Transatlantic Consensus on Developing Country Actions to Address Climate Change’, in Washington, DC in June 2009.

Last but not least, this report is dedicated to the memories of Professor John H. Barton and Bernard Schlamadinger. Their wisdom will be sorely missed.

The following outputs from this stream of work are available online

- Background papers and report of a workshop on 'IPRs and the Innovation and Diffusion of Climate Technologies' held in London in November 2007: www.chathamhouse.org.uk/publications/papers/view/-/id/722/.
- William Blyth (2008), 'Linking Carbon Markets and Technology Support Mechanisms: Making Sense of the EU Climate Change Package': www.chathamhouse.org.uk/research/eedp/papers/view/-/id/668/.
- John H. Barton (2008), 'International Diffusion of Climate Change Technologies in the Transport Sector': www.chathamhouse.org.uk/research/eedp/papers/view/-/id/723/.
- Shane Tomlinson, Pelin Zorlu and Claire Langley (2008), 'Innovation and Technology Transfer: Framework for a Global Climate Deal' (co-published with E3G): www.chathamhouse.org.uk/research/eedp/papers/view/-/id/685/.
- John H. Barton (2008), 'Mitigating Climate Change through Technology Transfer: Addressing the Needs of Developing Countries' IPRs': www.chathamhouse.org.uk/research/eedp/papers/view/-/id/671/.
- Jerome Reichman, Arti K. Rai, Richard G. Newell and Jonathan B. Wiener (2009), 'Intellectual Property and Alternatives: Strategies for Green Innovation': www.chathamhouse.org.uk/research/eedp/papers/view/-/id/691/.

Authors

Bernice Lee is Research Director for Energy, Environment and Resource Governance at Chatham House.

Ilian Iliev is co-founder and Chief Executive Officer of CambridgeIP.

Felix Preston is Research Fellow for Energy, Environment and Resource Governance at Chatham House.

Executive Summary and Recommendations

Ensuring access to climate-friendly technologies at affordable prices is a critical issue for international public policy – and one that cuts across economic, legal, security and geopolitical concerns. To keep the rise in average global temperatures below 2°C, global greenhouse gas emissions must peak before 2020 and be reduced to 50–85 per cent below 2000 levels by 2050. Achieving these ambitious targets requires a critical mass of low carbon investment, innovation and deployment that meets mid- and long-term goals. The implications for corporate strategies and business models are profound.

This report examines two issues: patent ownership of climate-friendly technologies, and the rate of technology diffusion. A polarized debate continues between proponents of strengthening intellectual property rights (IPR) regimes to encourage innovation of climate technologies on the one hand, and those calling for more IP-related flexibilities to ensure access to key technologies by developing countries on the other.

In order to bring empirical evidence to these discussions in advance of the Copenhagen Summit in December 2009, Chatham House and CambridgeIP have conducted an extensive analysis of patent ownership and the market adoption rates of six energy technologies: wind, solar photovoltaic (PV), concentrated solar power (CSP), biomass-to-electricity, cleaner coal and carbon capture. The study involved nine months of research across the technologies (and over 30 sub-sectors). A database of close to 57,000 patents over 30 years has been compiled and profiles were developed of selected patent owners. In addition, the team reviewed aspects of corporate strategy and practice, such as collaboration, licensing, litigation and mergers and acquisitions.

Most energy technologies are part of complex global technology systems. Their development does not often follow a linear logic or evolve within the boundaries of individual economic sectors. Many breakthrough innovations occur when different fields interact. For example, innovation in solar PV technologies has benefited from developments in consumer and industrial electronics, and advances in CSP derive from aerospace and satellite technologies.

Findings

Policy-makers managing the transition to a global low carbon economy will struggle when making the critical choices unless they have a clear understanding of the range of technological options available from different sectors within specific time horizons, and they will also require an appreciation of how their technological interactions will affect industrial structures.

Technological innovation and diffusion take too long under business-as-usual practices. Our findings confirm the mismatch between the urgency of climate challenges as set out by the Intergovernmental Panel on Climate Change (IPCC), and the time taken historically for technology systems to evolve and provide a return on investment. Sticking to what we know – and business-as-usual practices – will not bring these much-needed technologies to markets fast enough.

Analysis shows that inventions in the energy sector have generally taken two to three decades to reach the mass market. This time lag is mirrored by the time it takes for any patented technology to become widely used in subsequent inventions. Data on the top 30 most-cited patents from each of the six sectors examined here indicate that it takes between 19 and 30 years with an average of around 24 years. The process of registering a patent can take up to three years. The diffusion time for clean technologies globally will need to be halved by 2025 to have a realistic chance of meeting climate goals.

Targeted policies will be needed if accelerated and wholesale deployment of these technologies is to be achieved. There is encouraging evidence that policy interventions to encourage demonstration and deployment –

learning-by-doing – can be a major accelerator of the innovation process. Patenting rates and deployment in wind, solar PV and CSP (a good indicator of innovative activities) took off from the late 1990s, driven by policy interventions to create market demand in key countries such as Germany and Japan, and at regional level in the United States.

Companies and institutions in OECD countries will determine the speed of diffusion of the most advanced energy technologies in the next decade. Innovation and technological development primarily take place within the OECD countries and companies. This research finds no exceptions among the six selected technologies, including all the sub-sectors. Apart from in carbon capture, where the United States is far ahead of all other countries in terms of patents registered, companies and research institutions from the United States, Japan and Germany are clear leaders in energy innovations. Much has been made of the fast growth in innovation capacities in emerging economies such as Brazil, China and India. But these countries have no companies or organizations in the top 10 positions in any of the sectors and sub-sectors analysed. (A few can be found among the top 20, pointing to these economies' growing innovation capacities.)

Further data analysis shows that large incumbent companies – whether multinationals or national corporations – are the main players today. Small and medium-sized enterprises (SMEs) account for a relatively small part of overall patenting in these sectors, in contrast to biotechnology and information technology. The median age of wind-energy patent owners – the 'youngest' sector – is 54 years. This suggests that the most successful strategy for developing countries wishing to enter these areas may initially be driven by larger firms and be pursued through acquisition of foreign technologies rather than internal growth. It is important that such strategies for technological acquisitions are complemented by investment in indigenous innovation capacities in developing economies.

High-carbon companies control some of the key knowledge assets needed for the low carbon economy. Seven out of the top 20 owners of cleaner-coal patents are from the steel sector. Carbon capture and storage (CCS) technologies originate in a range of applications in the petrochemical, fertilizer and enhanced oil-recovery sectors. The use of advanced alloys is critical for the next generation of wind, PV, CSP and cleaner-coal power generation.

> 'The top four wind-energy patent owners – who collectively own 13 per cent of all wind patents – have a 57 per cent share of the global market for wind turbines, whereas for solar PV, many of the top 10 manufacturers are not patent holders'

The key question is how to identify the assets in high-carbon industries and harness them for low carbon technologies, in developing and developed countries alike. It is also important to ensure that climate policies offer sufficient incentives for innovation among important technology players. The current trend towards excluding heavy industry from climate-change regulations (e.g. by issuing free emission permits) may reduce these incentives, with negative spillover effects on the rest of the economy.

The concentration of patent ownership cannot be assumed to be synonymous with a lack of competition or a monopoly, but it can slow innovation and diffusion in some types of markets depending on companies' business models. Company strategies will vary owing to differences in the composition of industries, the level of competition, stages of development and market structure of specific energy systems. There are also fundamental differences in terms of organizational and capital requirements between (for instance) the manufacture of solar cells and CCS retrofitting of 1GW coal power plants. In practice, companies with smaller patent portfolios can be more influential than is suggested by their patent rankings. But ownership (and maintenance) of a large number of related patents does imply a recognition of the commercial value of the inventions.

This study finds considerable variation in the levels of patent-ownership concentration. For instance, in terms of cleaner coal technology, the top 20 companies own around 42 per cent of total patents, whereas in CSP, the top 20 only have around 12 per cent of total patents. Consolidation is expected across the solar energy sector in the near future – a development that will change the composition of patent ownership. There are wide variations across sectors: the top four wind-energy patent owners – who collectively own 13 per cent of all wind patents – have a 57 per cent share of the global market for wind turbines, whereas for solar PV, many of the top 10 manufacturers are not patent holders.

Intellectual property rights can be a factor affecting the speed of technology diffusion. A patent portfolio is a form of currency that can be used to attract venture capital, facilitate entry into strategic alliances, provide protection against litigation, and create opportunities for mergers and acquisitions. Many of the energy patent owners listed in this report are established industrial giants. Their perception of market conditions and of the level of IP protection in developing economies will do much to determine the rate of roll-out of the next generation of low carbon technologies – whether through investment, licensing, joint ventures or other forms of knowledge-sharing.

One worrying trend is the increase in patent-related litigation in fast-maturing technologies. While it is understandable that patent owners seek to assert their right to protect their inventions and markets, protracted lawsuits can slow the diffusion of key technologies by decades. Litigation poses particular difficulties for smaller companies with only a few key inventions.

Transformative change cannot be achieved by domestic action alone. Cross-border trade and investment in low carbon and energy-efficient goods, services and technologies need to be encouraged and scaled up. Stimulating low carbon trade will create virtuous cycles, creating further investment opportunities and expanding the market for key technologies.

In a global market, the cost of technology can come down quickly as economies of scale are achieved through large-scale deployment. Since the 1970s, with the exception of nuclear power, the costs of energy production and use from all technologies have fallen systematically as innovation and economies of scale have increased in manufacture and use. An ultra-supercritical power plant – using an advanced cleaner-coal technology – can now cost a third less in China than a less efficient coal-fired power station of similar scale in the United States, largely because China is building many identical power plants at the same time.

By adopting advanced technologies – and strengthening their innovation capabilities – developing countries have an opportunity to leapfrog the resource-intensive, highly polluting growth phase experienced by Western countries, but they will need a great deal of help to do so. Among emerging economies, China is in a unique position to bring new, clean energy technologies to maturity because of the size of its domestic market and its position as a supplier of consumer and industrial goods to international markets.

The analysis in this report also demonstrates that as energy technologies mature, advances in design, site selection and operation increasingly depend on innovation in information and communication systems. Many energy technologies are also dependent on innovation in advanced materials, e.g. alloys. This means that developing countries such as India and South Africa with strengths in these sectors are well placed to capitalize on the growth opportunities that will emerge as these technology systems evolve, since they can benefit from shifts in global investment patterns towards low carbon energy and production methods with targeted assistance. There is mutual global benefit in ensuring that climate and technology policies would support such a shift.

Greater international cooperation is needed to double technology diffusion rates. Today, cooperation on innovation is primarily a national, not an international, activity. Across the six sectors, only 1.5 per cent of total patents are co-assigned (i.e. list more than one company or institution as co-owners). No fewer than 87 per cent of co-assigned patents are the results of collaboration between companies and/or institutions from the same country. This internalization of collaboration is especially noticeable in the data for Japan. While there is some collaboration among OECD countries, only two per cent of joint patents are shared between companies and institutions from developed and developing countries. The lack of data means it is impossible to analyse intra-company cooperation across borders.

Technological-system overlaps mean that no one country can provide all the options. Analysis of inventor networks shows a very high level of private-sector cross-fertilization among companies and institutions in the development of new technologies. To speed up diffusion, there is a need to broaden these inventor networks to encourage faster cross-fertilization between inventions from different sectors in different countries.

Government policy that aims to be technology-neutral and support national champions may hinder global innovation in energy systems. To some extent, existing industrial structures, regulatory regimes, research capabilities of private and public institutions as well as other supporting infrastructure are already pre-determining the types of investments or technologies that are most likely to take off in the coming decades. Given the importance of innovation from outside the energy sector to the development of energy technologies, proactive innovation and climate change policy-makers face a complex challenge in both monitoring technological and commercial developments across a wide range of sectors and devising interventions that promote change.

International cooperation is needed to build and strengthen innovation linkages among different industrial sectors, especially those between developed and developing economies. Ultimately, the bulk of the decarbonization needed in fast-industrializing countries will be delivered by their own businesses and institutions. Coordinated action is not just optimal but critical. In designing global solutions it will be necessary to strike a careful balance between private interests and the delivery of global public goods, and to take into account the social and economic needs of developing countries. New incentive systems and collaborative mechanisms at bilateral, regional and international levels will be essential to encourage technological innovation, demonstration and diffusion.

Recommendations

Transforming the marketplace through international cooperation

At the global level, the Copenhagen Summit must send credible and unambiguous signals to the global markets that far-reaching change is imminent and inevitable. Joint-venture companies, cross-training programmes, cross-licensing arrangements, trade tariff exemptions on selected technologies and joint manufacturing programmes are all tried-and-tested methods that could be stepped up at national and local levels. Governments can also help shape the global value chains of clean energy sectors through:

- *Supporting global demonstration programmes.* These are required for large-scale, high-risk technologies such as CCS and CSP. The size and complexity of demonstrating these technologies, which often includes intricate planning and infrastructural support, make it difficult for the private sector to independently finance demonstration. Public funding in the form of grants, loans and risk guarantees is therefore necessary to ensure these technologies can become fully commercial. The joint nuclear-fusion project ITER is an example of a wide-ranging international collaboration project.
- *Maximizing the potential of technology standards bodies.* Technology standards can play an important role in accelerating innovation in an industry, by removing bottlenecks and encouraging economies of scale. This report demonstrates the value of maintaining ongoing maps of potential technology standard hotspots, including the patents that underpin them. There is scope for the formation of industry-level technology standards bodies to set increasingly high standards, bring in the laggards and accelerate diffusion.
- *Supporting open innovation mechanisms.* A range of climate technology prizes should be established to promote innovation in all areas that support climate mitigation and adaptation. Other forms of open innovation platforms should be developed to strengthen incentive structures for innovation and knowledge-sharing.

Forging more collaborative rules of the game

There are significant opportunities to accelerate bilateral and multilateral collaboration on R&D and technology development. Greater incentives are needed to accelerate collaboration across national boundaries, without relegating national priorities to second place (something that is unlikely to be politically sustainable). Potential avenues include:

- *'Model' R&D cooperation agreements.* Government support for clean energy innovation is more likely to be effective at the early stages of the development of technology systems. There is a need for 'model' technology cooperation agreements that would limit the potential of patent-related conflicts and encourage joint development, especially those between developed and developing economies.
- *Publicly backed energy patent pools and knowledge-sharing platforms.* Through tax, other fiscal or investment incentives, the public sector should support the design and creation of patent pools and cross-licensing schemes to encourage innovation and mass diffusion for relevant technologies. These patent pools can be used to support innovation in SMEs and emerging markets in exchange for a royalty fee. Collaborative initiatives such as the European Commission's European Technology Platform for Zero Emissions Fossil Fuel Power Plants (ZEP) demonstrate the potential of stakeholder advice platforms, and can provide support for knowledge-sharing structures at the regional level (in this case the EU). Such initiatives could be emulated in other regions or used as a starting point for multilateral efforts.
- *A global database on licensing data and best practices.* Very few data on licensing deals, cross-licensing initiatives or patent pools are available in the public domain. The development of a reliable patent-licensing database could assist in setting benchmarks and sharing best practices. As a first step, there is a role for an escrow service, provided by a trusted third party, through which private-sector data are pooled and shared on an anonymous basis on the open market to set benchmarks. There is also a role for institutions such as the World Intellectual Property Organization (WIPO) to set up global databases on licensing and cross-licensing regimes as well as patent pools on climate-friendly technologies. Patent owners could register their licensing deals (and showcase their latest commercial success) within a specified time period (such as 18 months) to protect their latest commercial interests.

Introduction

Decarbonizing global energy use will require the deployment of new and existing technologies to unlock the potential of a wide range of energy sources, user-technologies such as lighting, vehicles, motors as well as infrastructure such as buildings. This report aims to add clarity and empirical research to the crucial yet increasingly polarized debates around intellectual property rights (IPR) and energy technology by using data on the patents registered by researchers to protect their technological inventions.

A patent gives its owner protection over the covered invention from unauthorized use within a given territory for a limited period of time (generally 20 years). The patent owner – known as the assignee – can provide a licence to others to use the technology in return for royalties. This means that patents are not just a tool for protecting property rights but are in fact strategic tools used by their owners for a variety of purposes.

Many assertions have been made by governments, companies and non-governmental organizations about the role of IPR in facilitating or hindering the innovation, commercialization and diffusion of low-carbon technologies. For the proponents of a patents-based innovation system, IPR are the bedrock of societal innovation and the propeller of the diffusion of key technologies. But some developing countries question the basis for the temporary monopolistic rights granted to assignee/owners, especially when the knowledge is essential for promoting public-policy goals such as climate change mitigation and adaptation. Today, there is a polarized debate between advocates for strengthened IPR laws to encourage innovation and diffusion of climate technologies on the one hand, and those calling for more IP-related flexibilities to encourage access to key technologies by developing countries on the other.

Chatham House and Cambridge IP have over the past nine months conducted an extensive patent-landscaping exercise on six energy technologies to analyse concentration in patent ownership by countries and companies. This involved creating a unique collection of patent databases drawn from all the publicly available sources of patent data. The goal of this analysis is to assist stakeholders in moving away from an ideological stance towards evidence-based analysis and set a new standard for debate on issues around IP and climate change.

Patent-landscaping involves creating specific databases for individual sectors or 'technology areas'. It is a tried-and-tested exercise used by the private sector – including venture capital groups and acquisitive corporations – to identify competitors, including as yet unknown or underappreciated ones. It can provide a comprehensive understanding of the new drivers for innovation within a specific sector, and identity opportunities for investments.

So far, most policy-related energy patents analysis have relied on International Patent Classification (IPC) patent codes to define each technology space and have stopped short of sub-sectoral analysis.[1] (IPC patent codes are used by patent authorities to provide for a hierarchical system of language-independent symbols to classify patents according to the different areas of technology to which they pertain.) While a useful first step, the IPC-led approach has many shortcomings as the codes do not account for overlap of technology systems.

This report demonstrates that it is possible to get a handle on the ever more complex international patent landscape, and to extract critically important business intelligence information that can inform private-sector and public policy alike. The micro and macro data that the analysis provides can be used in the development of targeted policies and in interactions with stakeholders.

Six emerging energy technologies are analysed: wind, solar photovoltaic (PV), concentrated solar power (CSP), biomass-to-electricity, carbon capture and cleaner coal. These were selected because of their current and future importance to energy supply around the world.

The first three are examples of **renewable technologies** at different stages on the innovation pathway: wind, solar PV and concentrated solar power. A fourth, biomass-to-electricity, is also sustainable if the fuel source is managed carefully. Each of these technologies has the potential to make a deep and permanent contribution to the decarbonization of our energy systems.

Carbon capture is not a renewable technology but has the potential to make a dramatic impact by capturing emissions from coal and gas plants that would otherwise be vented to the atmosphere. Carbon capture (and storage, which is not covered by this study) is a complicated system of technologies requiring high levels of international cooperation, a dimension which patent rates can shed light on.

Finally, coal technology continues to be installed apace, especially in emerging economies. Ultimately, installing more efficient, **cleaner coal** power production will add to global emissions, not reduce them. But in the short term it can make a contribution by avoiding even greater emissions where the construction of more coal plants – for now – appears inevitable. This will depend on the best technologies being available to emerging economies. The distribution of patents in this mature technology space gives us particular insight into the level of capacity and collaboration in an advanced energy technology.

This report addresses the following set of questions:

1. **Overview of the patent landscape.** What is the comparative rate of technological innovation across the six energy sectors? What is the volume of patents in each energy field and sub-field? Who are the key owners of patents within each sector? What is the geographical distribution of patents by location of assignees and coverage? How does patent ownership differ among technologies when compared by patent filings and patent families?
2. **IP ownership concentration.** What is the concentration of patent ownership in individual sectors? What are the characteristics of patenting strategies in individual sectors? How do firms use their patent portfolios to achieve strategic commercial goals? What is the level of collaboration among assignees? How important is IP for companies in informing their commercial and investment strategies?
3. **Relationship between technology systems.** How do technology systems overlap? What are the implications for policy-makers? How does the role of patents differ between technology systems? Have patents been used by companies to block innovation or diffusion of key climate technologies as part of their commercial development strategies in competing sectors?
4. **Policy implications.** How can the value of public and private investment in low carbon technologies be maximized? How can systems and mechanisms to speed up the diffusion of low carbon technologies be created? What are the implications for climate and other negotiations?

Note on limitations of project methodology

There is a lag of up to 18 months in the publication of patent data by various patent offices. Rapid changes are anticipated for the energy sector in the coming decade.

Only a limited amount of information is available electronically on patents from India. This may have resulted in an underestimate of Indian innovation in many of the focus areas of this report.

The searches were performed in English. These capture the vast majority of commercially relevant patents and patent families – from their point of entry into the Patent Cooperation Treaty (PCT) system. It is likely that owing to language differences a small number of patents still in the national phase have been missed.

Notes

1 Copenhagen Economics A/S and the IPR Company ApS (2009), *Are IPR a Barrier to the Transfer of Climate Change Technology?*, 19 January, http://trade.ec.europa.eu/doclib/docs/2009/february/tradoc_142371.pdf; Johnstone, N., Hascic, I. and Popp, D. (2008), 'Renewable Energy Policies and Technological Innovation: Evidence Based on Patent Counts', NBER Working Paper 13760, January; Antoine Dechezleprêtre, Matthieu Glachant, Ivan Hascic, Nick Johnstone and Yann Ménière (2008), *Final Report on Invention and Transfer of Climate Change Mitigation Technologies on a Global Scale: A Study Drawing on Patent Data*, CERNA, December, http://www.nccr-climate.unibe.ch/conferences/climate_policies/working_papers/Dechezlepretre.pdf.

1. IPR and Climate Change: Friends or Foes?

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) concludes that for the rise in average global temperatures to keep within 2°C above pre-industrial levels, global emissions must peak before 2020 and be reduced to 50–85 per cent below 2000 levels by 2050.[1] Delaying action will require much faster rates of reduction later. If there is a 10-year delay in reducing emissions, the rate of cuts required increases over a five-year period from 14 per cent to 31 per cent.

Delivering these policy outcomes will be difficult at a time of global economic crisis and volatile energy prices unless these forces themselves can be harnessed in support of lower carbon investment. According to the International Energy Agency (IEA), states and markets need to stimulate opportunities in low-carbon and energy-efficient investments across the globe, and generate $44 trillion of investment by 2030 (above business-as-usual projections).[2] This means:

1. Aggressive deployment of existing and near-to-market technologies for global emissions to peak and reduce by 2020, and to avoid carbon lock-in. These include energy efficiency across all sectors, large-scale renewable energy, and cleaner coal with carbon capture and storage (CCS) to cover the residual need for large-scale fossil-fuel-based industrial and power generation;
2. Investment in research and development (R&D) and demonstration of new generations of breakthrough technological solutions to build the capacity to make deep long-term emission cuts by 2050;
3. Deploying technologies simultaneously in developed and developing countries through equitable international collaboration mechanisms to lower the cost and risk of technology investment and to encourage national action in developing countries, and
4. Balancing the search for cost-effective approaches with the need for a strong mix of policy interventions.

As the countdown towards the post-Kyoto negotiations in Copenhagen in December 2009 continues, innovation and technology have become key features of the international debate. Promising signs emerged from the Major Economies Forum (MEF) in July 2009 as developed countries declared their intent to double their current commitments on technology assistance by 2015. Perhaps even more promising is the fact that a pre-Copenhagen deadline of November was set for outlining 'action plans and roadmaps' for how this will be achieved.

Against this background, dealing head-on with the issue of intellectual property rights (IPR) now becomes critical. The United Nations Framework Convention on Climate Change (UNFCCC) negotiating text (released in May 2009) has made explicit reference to different options, including compulsory licensing, patent pools of publicly funded technologies and using the precedent set by multilateral action such as the Doha Declaration on the World Trade Organization's Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS) and Public Health. Perhaps the most radical proposal set out in the draft document is that which calls for least developed countries (LDCs) to be

> exempted from patent protection of climate-related technologies for adaptation and mitigation, as required for capacity-building and development needs. Genetic resources, including germplasms of plant and animal species and varieties that are essential for adaptation in agriculture, shall not be patented by multinational or any other corporations.

Such broad language in the draft text has not only resulted in a heavily bracketed document for negotiations in the run-up to Copenhagen, but also led to a strongly worded resolution passed in the US House of Representatives calling on the president to ensure the protection of IPR in the climate negotiations. This was followed by a number of media interventions by the US Chamber of Commerce's Global Intellectual Property Center, similarly calling for the upholding of existing IPR laws at Copenhagen.

To date, civil society groups have been somewhat divided on exactly what the role of IPR should be in a global climate deal. The NGO Copenhagen Treaty, written by a team of 47 experts from a range of environment and development NGOs, simply calls for a clear framework for reducing and eliminating IPR barriers to the deployment, diffusion and transfer of technology, based on the approach of 'protect and share', with little sense of which mechanism is best suited to achieving this goal.

1.1 Meeting climate challenges through smart technology policies

Despite broad agreement on the importance of clean-energy technology, there has been only slow progress on developing and implementing a practical and effective technological innovation and diffusion system to drive the transition to a global low carbon economy at scale.

While the traditional concept of 'technology transfer' implies a process through which a piece of equipment or a blueprint is transferred to a recipient company or country, this is only half the story. Moving up the technology ladder for a company or country is as much about having access to the hardware as it is about acquiring the know-how to use it effectively.[3] As production processes become more knowledge-intensive, technology transfer increasingly demands 'learning by doing', through use and interaction with experts, rather than solely through physical ownership of a particular technology.[4]

Two complementary forces govern the incentives for innovation: *technology push* – targeted R&D investment by governments and the private sector to move scientific discovery towards commercialization – and *market pull* – incentives to bring products to market that include pricing mechanisms and regulatory standards.

Both push and pull instruments can be used by governments to shape and accelerate the innovation chain. In competitive markets, firms tend to under-spend on R&D relative to the optimal level for society, for fear of being unable to capture adequate returns to justify the upfront investment.[5] Governments have sought to correct this market failure by offering some types of reward to encourage innovation. These 'market pull' efforts include granting innovators (temporary) monopoly rents through, for example, patent protection. This is often complemented by other inducements and subsidies for research in priority areas (e.g. small population diseases, environmental controls). Market 'push' incentives can include research grants, tax credits, and direct or partnership-based research by governmental agencies. Making these incentives accessible to new entrants is critical.[6]

There are many known and studied barriers to technological innovation and diffusion. These include investment conditions and infrastructural constraints as well as absorptive and innovation-generative capacities in developing countries. US academics have led analysis of the technology 'valley of death', in which publicly funded energy innovations languish for decades without being taken forward as commercial developments owing to a combination of failures around 'technology push' and 'demand pull' forces in the energy sector.[7] Uncertainties around both domestic and international regulations and pricing structures can stall investment, discourage collaborative projects and generally dampen investor confidence. Persistent policy uncertainty, for example, has entrenched a pattern of boom and bust in the renewables and energy efficiency sectors.

The incentive structures change along the innovation chain. The appropriateness of measures and incentives may vary according to the technology (including its market structure), the countries to and from which it is to be transferred and deployed, national and regional industrial strengths, and other local considerations. The stage of development of the technology is also important. Pre-commercial power generation technologies such as integrated gasification combined cycle (IGCC), for example, pose different risks and different IPR issues from commercial end-use technologies such as onshore wind energy where the challenge is to achieve wider diffusion.

Despite the urgent need for next generation technologies, it is critical that the substantial gains achievable through better energy efficiency are not overlooked. Achieving them requires the diffusion of incremental technologies (e.g. improved insulation and furnace technologies) as well as of practices (e.g. congestion charges, industrial process optimization training, lean manufacturing/quality management and SCADA systems). These soft practices and incremental improvements also have different barriers to implementation than large-scale capital investment in technologies currently on the horizon. They also involve a wider range of technologies and industries.

For the energy sector, the general assumption is that the development and dissemination of low carbon options suffer from two major market imperfections.[8] First, significant research and development (R&D) is required, but their benefits are not necessarily appropriable to the firm making the investment. Use of patents and other forms of IP protection (such as design rights or trade secrets) is one way in which companies increase their ability to recoup their R&D investments. The second market imperfection is that the social benefit of reducing greenhouse gas emissions is not yet generally reflected in pricing structures. Without regulations and subsidies, it may not be profitable to deploy socially desirable technologies.

Patents are intended to act as incentives for innovation – providing exclusive rights to the use of particular inventions for a fixed period. The expectation is that the exclusivity will enable the firm holding the patent to charge a price above the marginal cost of production and thus to recoup the investment. In return, inventors are required to disclose sufficient information in their patents, so that society can benefit from the increased knowledge about technologies. Traditional economic analyses have frequently taken for granted that patents are liquid and tradable goods, and have not explored inter-sectoral differences in how they are used in practice.[9]

'Compulsory licensing' describes a number of mechanisms for non-voluntary authorization to use patents. While contentious, it is a tool used by many governments to accelerate the diffusion of the latest technologies,[10] and they justify its use as necessary to correct a market failure in the service of a public good. The US Clean Air Act, for example, mandates the compulsory licensing of patented technologies needed to meet agreed standards. In August 2006, a court in the United States granted Toyota a compulsory licence on three Paice patents for hybrid transmissions, for a royalty of $25 per automobile.[11] The most important global norm for the use of compulsory licences is Article 31 of the WTO's TRIPS Agreement, which addresses uses 'of a patent without the authorization of the right holder, including use by the government or third parties authorized by the government.'[12]

Box 1.1: How are disputes over IP settled?

Disputes under World Trade Organization TRIPS: Settling disputes is the responsibility of the Dispute Settlement Body (the General Council in another guise), which consists of all WTO members. The Dispute Settlement Body has the sole authority to establish 'panels' of experts to consider the case, and to accept or reject the panels' findings or the results of an appeal. It monitors the implementation of the rulings and recommendations, and has the power to authorize retaliation when a country does not comply with a ruling.

Disputes at EU level: The European Court of Justice is the dispute mechanism that would be used where disputes arise between European Union member states. The Court has the power to settle legal disputes between member states, EU institutions, businesses and individuals.

Individual company disputes: The World Intellectual Property Organization (WIPO) Arbitration and Mediation Center (established in 1994) offers Alternative Dispute Resolution (ADR) options for the resolution of international commercial disputes between private parties.

Source: UKIPO, www.ipo.gov.uk

1.2 IPR and business strategies

In practice, there are wide differences in the ways IPR are used by companies, both within and among industrial sectors. These range from highly protective practices to active advocacy for open innovation models. The choice of IP-management strategy is dictated by context, the strategic behaviour of individual actors, as well as industrial history. No single IPR usage or practice can be said to be optimal for all companies or industries. This is an important policy lesson. A good understanding of how IPR are used in practice by companies is helpful to policy-makers as they engage with the private sector in developing an optimal IPR management regime for climate technology diffusion in different sectors. The different ways in which companies can use their IP as part of their business practices are outlined below.

1.2.1 Licensing[13]

Licences are frequently used as part of business practice. Patent owners license the use of IP in return for a fee, rather than resorting to litigation or other enforcement actions. Models include:

a. *Pure-play*: This is demonstrated by companies such as ARM (in developing central processing units for mobile phones) and CSR (in Bluetooth technology), which focus on prototyping technologies used by a network of suppliers. The ease of use and utility of the licensed technology is critical to their business models.
b. *Start-up licensing*: The patent owner grants a licence to a newly formed company (such as a corporate spin-off) with the express purpose of commercializing a technology.
c. *Divestiture licensing*: When exiting a business area, the technology owner may seek to recoup past R&D investments.
d. *Controlled licensing*: The owner of a superior technology, also a commercial operator, rations the flow of licences to limit expansion by competitors.

1.2.2 Financing and investment

Patent portfolios can be a strong signal of quality and market potential for technology start-ups in science-intensive industries such as biotech and nanotech, but also increasingly in software.[14] A strong patent portfolio can be seen as a prerequisite for investment by venture capital (VC) companies. Control over the company's core technology is crucial in securing an open space in which a product can be developed and launched. The typical VC funding round will include a budget for expanding the patent portfolio. Patent infringement lawsuits are frequently timed to coincide with the preparations for an IPO (initial public offering) or a trade sale – times at which the investors cannot afford the negative publicity of litigation, and may therefore be forced to settle out of court.[15] In some cases IP can be directly securitized, with some niche German banks also providing company funding to family-owned businesses with strong patent portfolios. In Silicon Valley some of the VC-focused law firms have also used patent rights as collateral or payment in kind in return for early start-up services.

1.2.3 Blockage

Patents can be used to block entry into a market space or the sale of a product that infringes the rights of the patent-holders. Decisions by patent owners to assert their rights (through a patent lawsuit) are mainly informed by strategic and economic considerations – whether such an action supports the company's growth strategy and whether the monetary and strategic benefits justify the litigation costs. Some companies have been found to use patents as a complement to a market dominance strategy.

In the 1980s South Korean companies such as Samsung were gearing up their presence in the US market. In 1988 Samsung was sued by Texas Instruments for violation of patents in a US court. Samsung lost the case and had to pay over US$90 million, incurring huge damage to its brand in the US market. Following the lawsuit, Samsung overhauled its patent management strategy. This resulted in to a vastly increased patent portfolio and increased use of licensing-in of technology. By the 1990s Samsung was suing Texas Instruments on patent-related issues.

In Europe, a case was brought against Tetra Pak – a global leader in packaging – which had pursued an aggressive patenting strategy to block new developments and protect its strong market position.[16] A lawsuit brought by

Zond Energy Systems (subsequently acquired by Enron and then GE) against Enercon blocked the German company from operating in the United States until a joint-licensing agreement was signed with GE in 2004.[17]

1.2.4 Industry cross-licensing

Members of a cross-licensing agreement can use one another's IP. Depending on the terms, outsiders can be prevented from joining an alliance. The terms of licensing and renewals, governance structures and continued innovation around a standard are some of the factors that influence the innovation impact of such alliances. A cross-licensing regime can make it easier for new entrants to avoid infringement and benefit from the technology efforts. Enforcement of a cross-licensing regime can also be achieved through litigation (or the threat of litigation), sometimes used to induce new players to enter the cross-licensing arrangements.

1.2.5 Technology standards bodies

Technology standards bodies are industry associations administering key technology standards on behalf of the market. Typically the entrants will contribute IP for mutual use, which means cross-licensing agreements are often part of these associations. All members can use IP within agreed boundaries and may be required to pay royalties into a common pool. Examples of such technology standards bodies include the European Telecommunications Standards Institute (ETSI), which has had an important role around the management of GSM, GPRS, 3G, WiMax and other related standards, and the Continua Alliance, which develops common inter-compatibility standards for medical diagnostics devices. South Africa's ESKOM co-founded the STS Association, a standards body tasked with administering the standards around pre-paid metering (now a globally accepted standard). Technology standards bodies may also act as a protective umbrella against infringement litigation by non-members.

1.2.6 Licensing for production

Licensing for production sees IP used in ways prescribed by the technology owner: typically to enhance quality of production, and ensure that the quality and design of components are consistent with those of other suppliers, and final assembly requirements. The IP that is licensed may be patented or trade secrets. In sophisticated systems assembly the lead company will play a central role as a design, production and assembly co-ordinator. It will also coordinate business development and deployment with final consumers. Collaborative production however means that the consortium/supplier group as a whole is commercially exposed to weaknesses in IP. For example, each components supplier for the Airbus 380 programme has its own supplier chain. Innovations developed within the A380 programme are patented by the different suppliers, shared under the A380 programme, but also used in other sides of the operation of the respective suppliers.[18]

1.2.7 University-to-industry technology transfer

Universities increasingly license the use of their research or form a spin-off business. A variety of business models is used, including in-house models (primarily used by large, well-resourced universities), pooling resources through a regional partnership or small conglomerate of similar-sized institutions, partnering with a specialist IP organization or a corporatization model which sees a university's technology transfer office turned into a private (and often listed) corporation.

1.2.8 Risk pooling

This involves consortia of major players seeking to pool risks and resources for highly capital-intensive and risky ventures. IP is pooled or shared, but arrangements differ. Again, the A380 programme is one example.

1.2.9 Strategic leadership

Companies may license technology to partners or others in the market to influence the strategic development path of technologies. For example, by opening up the Symbian platform to other industry players, Nokia has achieved market dominance for its operating system. Users of the S60 software platform are licensed under a non-discriminatory, capabilities-based accreditation programme. This strategy was primarily aimed at addressing competition, initially from Microsoft's Windows Mobile platform, and more recently from Google and Apple. The goal of maintaining strategic leadership in an industry was a powerful motive for opening up a proprietary and patented platform. Nokia remains at the centre of a huge and increasingly diverse value chain of suppliers, competitors and application developers.

1.2.10 Enforcement licensing

Here the seller or licensor seeks to enforce patent claims against a licensee that may have overstepped the parameters of the licensing agreement, or an infringer. In most cases enforcement licensing will take place out of court, and will target companies that have already commercialized a technology.

1.2.11 Patent trolls

Patent trolls are a special case of enforcement licensing where 'non-practising' or 'non-manufacturing' entities accumulate patent rights and strategically position themselves to collect licensing revenues. While this practice is legal, patent trolls are often regarded as 'free-riders' in the IP industry.[19]

1.3 Patents and technological innovation in the energy sector

Many have pointed to the differences in incentive structure for technological development in the energy sector as compared to others, such as the pharmaceutical industry within which there has been much debate over the patent-based model of product development. The relative uniformity of the pharmaceutical sector stands in contrast to the emerging diversity of the technological development and business models in the energy sector. The expectation is that there will be competition both within the general product area (e.g. wind turbines) and among different methods of producing electricity or fuel.

According to the World Business Council for Sustainable Development (WBCSD), the royalty cost for energy patents represents a small share of the total investment cost.[20] It argues that the bulk of the cost of bringing a new technology to market relates to the 'soft' aspects, for example operation and maintenance practices, training and organizational procedures, which are not patentable. From their perspective, the real issue for developing countries is not the accessibility of technologies or the price of the patents, but the lack of capital and management. This view is echoed by the Stern Review on the economics of climate change.[21]

Regardless of the actual cost associated with royalty, patents provide powerful financial and strategic incentives for companies that can shape the incentive calculus for innovation and diffusion. In addition to attracting VC, a patent portfolio is also a currency for use in strategic alliances and protection against litigation, as well as in opportunities for mergers and acquisitions. The interplay between financing and access to patents is a critical issue for the new entrants – in developed and developing countries alike.

Previous studies have noted that patents can be used to deter the entry of competitors and shape the industry into an oligopoly able to charge prices above marginal costs and thus to support further research to entrench this position.[22] Others have argued that patents are necessary to attract investment in research and that they do not give an unfair advantage to incumbents.[23] Patented innovations are also likely to provide a basis for developing a differentiated product with features that will help gain larger market share for companies. Clearly, the costs of the innovations are not shared by competitors, unless there is a cross-licence, and prices may be somewhat above marginal costs. The likelihood that the patent system will greatly encourage research, that there will be cross-licences to spread the technology, and whether such cross-licences will encourage innovation and its adoption are all dependent on the competitive conditions of the industry. While IP can incentivize R&D investments, it is not a sufficient condition for diffusion.

Weak IP protection certainly slows diffusion efforts in some developing countries.[24] Leading firms have openly cited weak IP protection in host countries as reasons for withholding their latest technologies from certain markets. Their willingness to license for production or sale may depend on their confidence that they can do so without losing control. Aside from the strength of the host countries' IP systems, these decisions are also a function of IPR management norms, which differ from one industry to another.[25]

Before specific technologies and business models emerge as the successful option, market processes on their own may slow the rate of technology diffusion, locking in to business models that are subsequently revealed as sub-optimal.[26] Early leaders of new technologies may also have disproportionate influence – partly backed by their strong IP position, their participation in the setting of standards, or control of supplier and distributor networks. Their business models often determine the shape of market institutions to come.

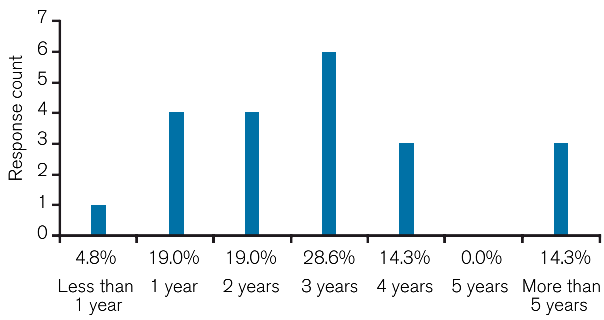
Consider the example of electric versus combustion engine automotive systems in the early 1900s. Electric cars at one point out-sold combustion-engine cars, holding the land speed record until 1899. But the emergence of the mass-produced combustion-engine car (led by Ford), the discovery of oil in the United States, and an underdeveloped electricity network contributed to the rapid adoption of the combustion-engine, supported by the network externalities of an enabling infrastructure of fuel stations and refineries.[27] It has taken more than 100 years for electric vehicles to become a viable alternative again on the back of high gasoline taxes, higher oil prices, climate concerns, changing consumer preferences, new battery technologies and public support for urban recharging networks. But in the absence of these factors, an 'on paper' more efficient technology could be too expensive to adopt owing to the lack of a support infrastructure.

Many prototypes compete for resources (from theoretical and applied R&D to demonstration efforts), especially in the early stages of technological development. While innovators may come to realize that their technologies are unlikely to be commercialized, they often remain reluctant to share proprietary knowledge gained as a result of 'failed' efforts. This can escalate the cost of developing viable technologies considerably by preventing successors from building on the lessons of past efforts.

Innovation and diffusion in some sectors will be driven by technical standards, not just price. To meet prescribed standards, users may need to use patented technologies. In a small number of cases standards and technical regulations may (inadvertently or by design) reduce options for the use of existing and future technologies – whether in the form of technical production methods or product-specific features. At the same time, when designed appropriately, technology standard agreements can accelerate innovation and protect the participants from patent infringement lawsuits from those outside the alliances. The implications of dual 'lock-in' – proprietary/closed standards and patent protection – for the diffusion of existing and horizon climate technologies (from fuel efficiency to low carbon industrial production standards) must be factored into policy and regulations.[28]

Even where market mechanisms function well and the patent owners actively seek buyers, the marketing of patented technology can be lengthy and resource-intensive. Figure 1.1 shows the results of a survey of British universities that suggests the average elapsed time from patent registration to market is three years, and in one in seven cases it is more than five years.

Figure 1.1: Marketing of patented technology – time to market



Source: CambridgeIP/Praxis Survey, February 2009

1.4 Moving beyond business-as-usual

The transition to the low carbon economy will require sustained innovation over a very long period.[29] At this critical juncture, it is important to question if a business-as-usual approach is sufficient to drive technologies fast enough along the innovation chain. Companies emphasize the importance of market and investment conditions in the diffusion of technologies. From their perspectives, the slow diffusion of the latest technologies is a result of weak market incentives and uncertain market conditions. The question is how to enable markets

Table 1.1: Rate of deployment by 2050

	Installed electrical capacity (2006)	Net deployment in 2008 (MW)	Annual capacity installed (MW) under IEA's Climate Protection scenario[a]	Net installed capacity by 2050 (GW) at 2008 rate of deployment
Coal-fired with CCS	0 MW	0	17,500	700
Gas-fired with CCS	0 MW	0	10,000	800
Nuclear	372 GW(e) (2008)	-408[b]	32,000	1,280
Hydro	919 GW	16,000 (2005)	13,424	1,481
Biomass and Waste Plants	45 GW	N/A	5,000	225
Wind – onshore	119 GW (2008)	26,790	56,000	2,520
Wind – offshore	1,461 MW (2008)	240	15,000	6,75
Solar PV	5 GW	2,800	10,000	2,584 TWh
CSP	430 MW (2008)		69,500	2,780

a Based on the scenario put forward in the International Energy Agency's *Energy Technology Perspectives* report of 2008.
b No new reactors were connected to the grid in 2008 and one 440 MW reactor was closed in Slovakia.

to push technologies along the innovation chain at the pace we need.

Estimates vary as to the rate at which low carbon technologies need to be introduced in order to stabilize the global climate. However, in all cases these proposed targets far exceed the current rate of deployment and in most cases they will require a rate far higher than the greatest ever annual deployment of the particular technology. Table 1.1 indicates the scales required in the electricity sector, according to the International Energy Agency.

Many steps are needed to take technologies from theory to market. The speed at which new technologies are developed and diffused will be crucial in meeting objectives in the reduction of emissions and in the security of supply. The following chapters look at the lessons from patent-mapping for the design of more strategic, precise and large-scale technological development policies that have the best chance of fast-tracking these critical technologies to market. They explore the linkages between the micro-dimensions of technological development (individual inventors, company strategies, and organizations) to the macro picture of relative national strengths in specific low-carbon energy sectors and subsectors.

Notes

1 Intergovernmental Panel on Climate Change (2007), *Summary for Policymakers*, in *Climate Change 2007: Fourth Assessment Report, Synthesis Report (AR4)*, Cambridge University Press.

2 International Energy Agency (2008), ***Energy Technology Perspectives 2008***.

3 Cheng, C. (2005), *'Electricity Demand-side Management for an Energy Efficient Future in China: Technology Options and Policy Priorities'.* Doctoral Thesis dissertation. MIT, p. 262.

4 Mytelka, Lynn K. (1999), *Competition, Innovation and Competitiveness: in Developing Countries*, OECD, 1999.

5 Jones, C. I. and Williams, J.C. (1998), 'Measuring the Social Return to R&D' in *Quarterly Journal on Economics*, 113 (4), 1119–35, http://www-econ.stanford.edu/faculty/workp/swp97002.pdf.

6 Ashford, N. (2001), 'Innovation – The Pathway to Threefold Sustainability', in *The Steilmann Report: The Wealth of People: An Intelligent Economy for the 21st Century*, 233–74, http://dspace.mit.edu/bitstream/1721.1/1584/1/3-fold_sustainability.pdf.

7 Holdren, J.P. et al. (1997), *Federal Energy Research and Development for the Challenges of the 21st Century*, President's Committee of Advisors on Science and Technology, Panel of Energy Research and Development, Washington, DC, Office of Science and Technology Policy, Executive Office of the President of the United States, November; Sagar, A. and Holdren, J.P. (2002), 'Assessing the global energy innovation system: some key issues', *Energy Policy*, 30, 465–69.

8 Jaffe, A., Newell, R. and Stavins, R. (2003), Technology Policy for Energy and the Environment, NBER Innovation Policy and the Economy Meeting, 15 April.

9 Dasguptha, Partha and David, P.A. (1994), 'Toward a New Economics of Science', *Research Policy*, 23, 487–521; Arrow, Kenneth J. (1962), 'Economic Welfare and the Allocation of Resources for Invention in the Rate and Direction of Inventive Activity', in Nelson, R., ed.,*The Rate and Direction of Inventive Activity*; Griliches, Z. (1980), *R&D and the Productivity Slowdown,* American Economic Association, 70 (2), 343-48.

10 See, for example, Reichman, Jerome H., with Hasenzahl, Catherine, (2003), *Non-voluntary Licensing of Patented Inventions: Historical Perspective, Legal Framework under TRIPS, and an Overview of the Practice in Canada and the USA,* Issue Paper No. 5, UNCTAD/ICTSD.

11 Paice LLC v. Toyota Motor Corporation, 2006 WL 2385139, (E.D.Tex. Aug 16, 2006) (NO. 2:04CV211DF).

12 See Packard Love, James (2007) 'Recent examples of the use of compulsory licenses on patents', *Knowledge Ecology International Research Note* 2. Other TRIPS provisions that are important are Articles 1, 6, 7, 8, 31 bis, 40 and 44, as well as the provisions of the 2001 Doha Declaration on TRIPS and Public Health.

13 Razgaitis, R. (2003), *Valuation and Pricing of Technology-based Intellectual Property,* John Wiley & Sons.

14 Increasing levels of patenting in the software space (particularly in the United States) mean that non-US startups seeking entry in areas such as search or mobile phone applications increasingly need to acquire US patent protection to enable a US market entry strategy, and to increase their attractiveness to potential corporate buyers.

15 Wessing and Go4Venture (2009), Back to Basics: Creating Value Through IP During a Recession, Workshop, 25 June.

16 'In the Tetra Pak 1 case, the Commission found that Tetra Pak had abused its dominant position by acquiring an exclusive license when it took over a smaller competitor. The license was formally covered by the patent licensing block exemption then in effect, Regulation 2349/84, but a block exemption regulation, unlike an individual exemption, does not imply a positive evaluation of the individual case.' in Ritter, L. and Braun, D. (2005), *European Competition Law: A Practitioner's Guide*, Kluwer Law International, Alphen aan den Rijn, Netherlands.

17 Fortnightly (2006), Wind Turbines Take Off, June, http://www.fortnightly.com/pubs/06012006_MAINSTREAM.pdf.

18 Morgan Stanley Research (2006), EADS – The A380 Debate, 5 September.

19 Law.com (2006), Meet the Original Patent Troll, 20 July, http://www.law.com/jsp/article.jsp?id=1153299926232.

20 WBCSD (2009), *Towards a Low Carbon Economy: A Business Contribution to the International Energy & Climate Debate.*

21 HM Treasury (2006), *Stern Review: Economics of Climate Change.*

22 Barton, J. (2001), 'Antitrust treatment of oligopolies with mutually blocking patent portfolios'., *Antitrust Law Journal* 69: 851–82.

23 See, for example, Johnson, Daniel K.N. and Lybecker, Kristina M. (2009), 'Innovating for an Uncertain Market: A Literature Review of the Constraints on Environmental Innovation'. Colorado College Working Paper 2009-06.

24 See, for example, Center for American Progress and Global Climate Network (2009), Breaking Through on Technology: Overcoming the Barriers to the Development and Wide Deployment of Low-carbon Technology, July 2009: http://www.americanprogress.org/issues/2009/07/pdf/gcn_report.pdf

25 Barton, John H. (2007), 'IP and Climate Technology', Background Paper, Chatham House, http//www.chathamhouse.org.uk/research/eedp/papers/view/-/id/724/.

26 Arthur, W. (1989), 'Competing technologies, increasing returns and lock-in by historical events', *The Economic Journal* 99; Dosi, Giovanni (1982), 'Technological Paradigms and Technological Trajectories: A Suggested Interpretation of the Determinants and Directions of Technical Change', *Research Policy* 11.

27 Kirsh, D. (1997), 'The Electric Car and the Burden of History: Studies in Automotive Systems Rivalry in America, 1890-1996', *Business and Economic History*, 26 (2).

28 There are examples of badly managed and better managed technology standards agreements or institutes. Within the mobile telephony industry, participants generally consider the ETSI (European Telecommunications Standards Institute) as a relative success story, as it has been able to assist the diffusion of the GSM and other standards globally, while also opening up the market for developing economy players. See www.etsi.org.

29 Delay, T. (2007), *The Low Carbon Economy*, The Carbon Trust, www.carbontrust.co.uk/climatechange/policy/lce.htm.

2. Innovation in Energy Technologies: The State of Play

This chapter discusses the patenting trends for the six energy technologies analysed in this report. It provides a global picture in terms of leading geographical regions and organizations in terms of patent ownership and concentration.

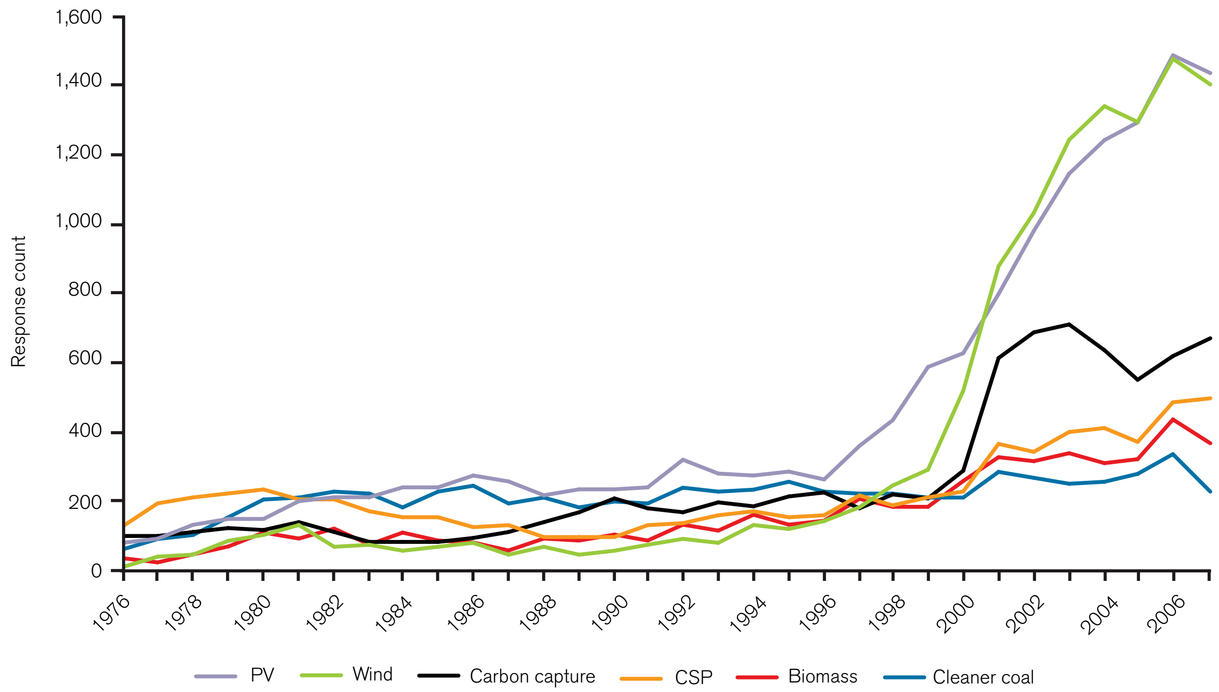
2.1 Patenting trends since the 1970s

The patenting rate of the six energy technologies has been surprisingly sluggish in the past 30 years. Many of the innovations that began in the 1970s and 1980s are only now coming onto the market. But following the introduction of stronger policies in key markets, private and public investments in R&D have accelerated. Patenting rates duly surged in the mid-1990s, with a rapid increase in deployment coming a few years later.

Figure 2.1 outlines the year-by-year patenting rate across the six energy technologies selected for this study. From the mid-1990s, steep increases are recorded for wind and solar photovoltaic (PV), with carbon capture and concentrated solar power (CSP) rising around the turn of the century. For cleaner coal, there have been around 200 to 300 patents per year for the past three decades.

Growth in patenting activities is not merely a result of R&D investments; it is also a response to shifts in market conditions, for example when the perceived commercial value of inventions grows and where emerging technologies create opportunities for new entrants to access profitable energy markets. Both of these factors are likely contributors to the dramatic rise in patenting levels for both solar PV and wind. The 10 years after 1996 saw a nine-fold increase in wind patents and a five-fold increase for solar PV. The timing of their take-off may also reflect the impact of policy incentives such as feed-in tariffs in key wind markets such as the United States (1992), Germany (1991) and Denmark

Figure 2.1: Patenting trends for six sectors (1976–2007)

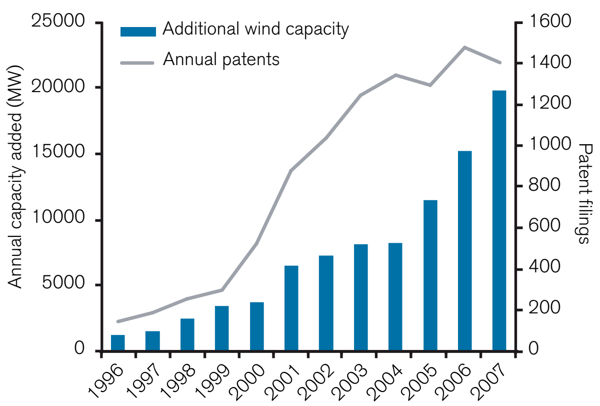


(1993). It is also consistent with the EU renewable energy target introduced in 1997 (12 per cent of energy consumption by 2010, equivalent to a doubling of the contribution over the period). In the United States, the first state-level renewable portfolio standards were introduced in Nevada in 1997, Ohio in 1998 and Texas in 1999.

2.1.1 Patenting and deployment rate

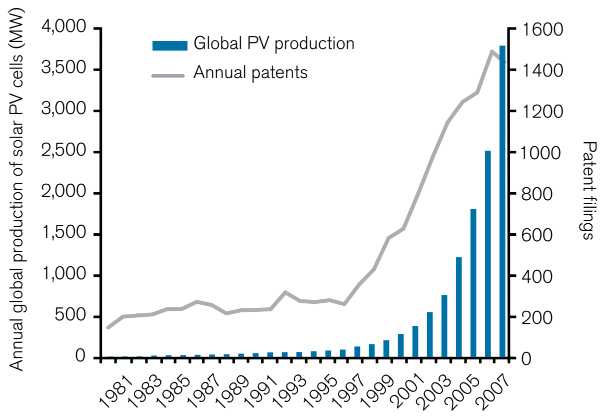
For wind power, as Figure 2.2 demonstrates, the rate of deployment closely correlates with patenting growth – particularly if we consider that several years can be expected before a patent finds its way into the technology. Figure 2.3 shows a similar correlation between rate of patenting and production of solar cells.

Figure 2.2: Wind – patenting level and deployment



Source: Data on installed capacity are from Global Wind Energy Council.

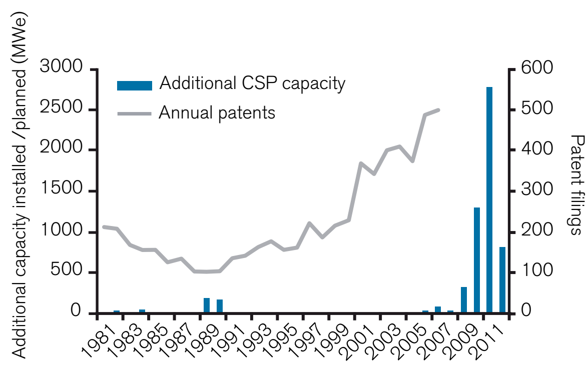
Figure 2.3: Solar PV - patenting level and deployment



Source: Data on global production of PV cells are from *Vital Signs*, Worldwatch Institute, May 2008

Deployment of concentrated solar power (CSP) installations is far lower than that of wind and solar PV and project data are incomplete, as shown in Figure 2.4. However, using recently compiled figures we can see that a steep increase in the rate of patenting again predates the take-off of deployment by a few years.[1] In this case, projects under construction and in planning have been included, where the target completion date is available. It is unlikely that all of these will come to fruition, but a large amount of CSP will come online in the next few years.

Figure 2.4: CSP – patenting level and deployment



Source: Greenpeace, *Concentrating Solar Power Global Outlook* 2009

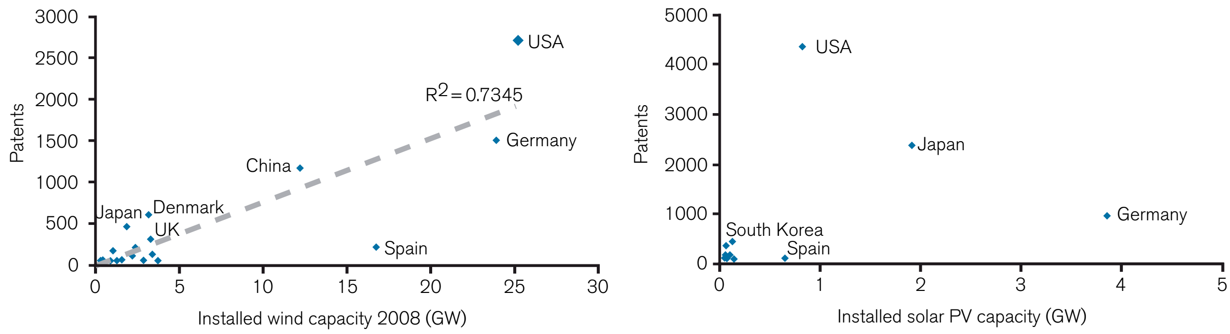
Figure 2.5 shows the relationship between patenting and deployment at the national level. In wind, innovation has often gone hand-in-hand with local deployment – roughly one patent for every gigawatt (GW) of power installed. In solar PV, although the three major patent-holding countries are also the top three in terms of deployment, the relationship is much less clear overall. This reflects the more complex history of PV innovation and the ease of transporting and exporting the technology (to where incentives for installation are strongest).

Some countries have been more successful than others in building local innovation capacity on the back of deployment. For example, Spain is the third highest in terms of deployment, but is significantly below the trend in terms of patents hosted (see dotted line). The United States punches above its weight in both wind and PV.

2.1.2 Comparison with other sectors

While the growth in wind and PV patents looks impressive when compared with the other four energy technologies,

Figure 2.5: Wind and solar PV – location of assignees, patenting level, installed capacity



it is important to put this in context by comparing these numbers with those in other growth industries.

As shown in Figure 2.6, patenting in one component of mobile telecoms accelerated dramatically in the late 1990s. A diverse range of companies entered the market, especially small and medium-sized enterprises (SMEs) and from emerging markets. These trends are underpinned by an industry-wide cross-licensing agreement around mobile-telecoms standards.[2] In contrast, one typical medical diagnostic device is characterized by a highly proprietary IP regime, dominated by several big players. In total, there have been only around 2,000 patents for the device (Table 2.1).

Table 2.1: Total number of patents

Technology areas	Total number of patents identified	Technology areas	Total number of patents identified
Solar PV	15,989	Biomass	5,305
Cleaner coal	7,059	Carbon capture	9,160
Wind	12,264	Mobile telephony	11,363
Concentrated solar power	7,193	Medical diagnostic device	1,984

2.2 Geographical and organizational distribution of patent ownership

The location of the patent assignee provides a broad indication of where innovative activities are taking place. But patents are not necessarily filed where the inventor is based and not only filed in the home country of the assignee. They are also registered in potential markets, where the patent owner intends to sell, license or manufacture products containing the patented innovation.

2.2.1 Where are the innovation hubs?

Across the six sectors, the top 10 reported locations of patents assignees or owners are primarily OECD economies. As shown in Figure 2.7, the United States leads and is followed by Germany, Japan, Denmark and South Korea. The exception is China, which is fourth across the six technologies by this measure and has a significant share in all except carbon capture. The location of patent assignees indicates the extent of local technological and innovation capacities.

The ultimate ownership of these capacities may have a quite different geographical distribution, however, because some patents are registered by the local subsidiaries of parent companies in another country. For example, a number of patents with US assignees may refer to the US subsidiary of European or Japanese global enterprises.

Figure 2.6: Comparing patenting rates in energy with other sectors

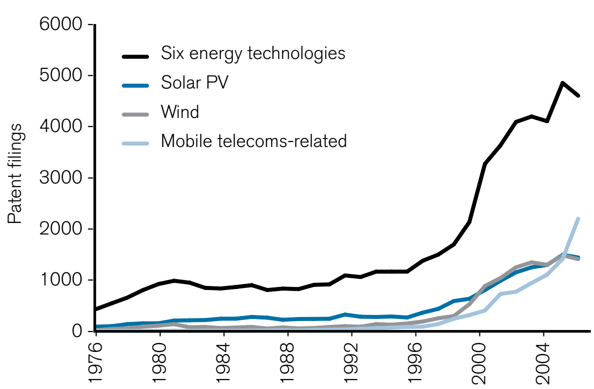


Figure 2.7: Share of patents by geographical origin – top 10 countries

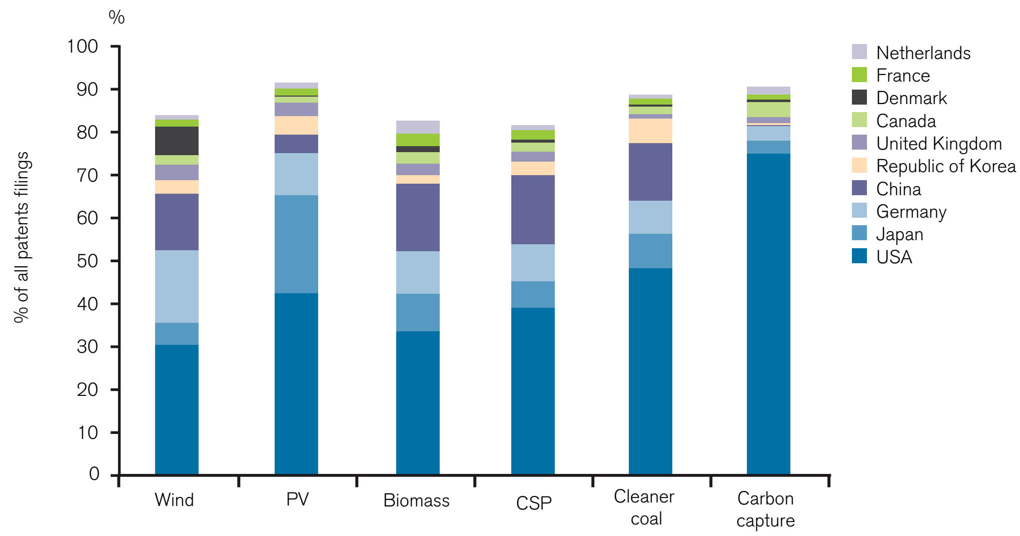
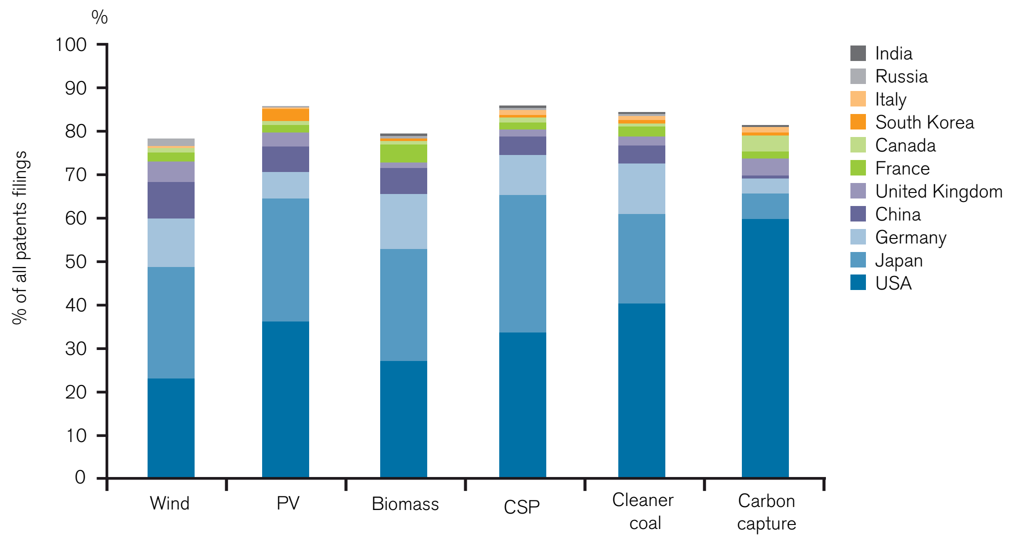


Figure 2.8: Geographical origins of parent companies of patent assignees (with more than four patents)



Similarly, patent filings in China may be conducted by the Chinese subsidiaries of global enterprises.

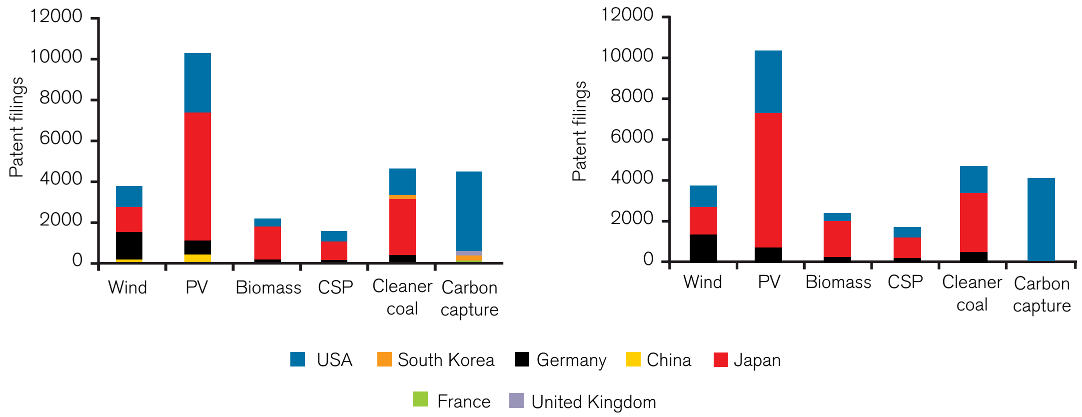
Figure 2.8 shows the geographical location of the *parent companies* of patent owners that have more than four patents at the time of filing. Analysis of assignees with more than four patents reveals a clear geographical pattern in patent ownership. By this measure, Japanese organizations have a strong presence in five fields, while the United States is far ahead on carbon capture technology and second strongest in four technologies. Germany pushes the United States into third place in the wind sector – largely owing to two companies, Enercon and Siemens. The low share for China suggests that most patents 'originating' from the country are in most cases filed by foreign subsidiaries.

Figures 2.9 and 2.10 show the geographical distribution when only patent owners with more than three per cent and five per cent of patents are counted. This underscores the strong position of Japan, the United States and Germany.

Mergers and acquisition activities are also an important factor. If we took into account acquisitions of OECD-based companies by Indian wind companies, the proportion that could be allocated to India would be much higher.

Figure 2.9: Geographical origins of assignees with more than three per cent of total patents

Figure 2.10: Origins of assignees with more than five per cent of patents



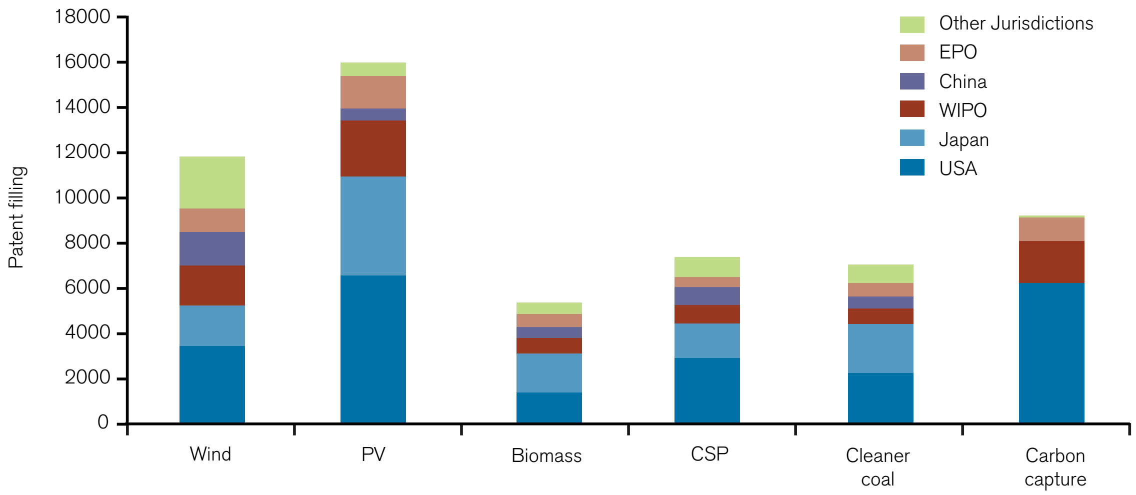
2.2.2 Where are the potential markets?

As noted earlier, companies also file their patents in potential markets, where they intend to invest, license or sell, and where they anticipate future competition. The composition of patent-filing destinations provides a strong indication of commercially attractive markets for foreign companies and investors. Despite the growth of emerging economies as market destinations, most investment, licensing and sales are likely to concentrate in a few developed-country markets, as the data in Figure 2.11 suggest, with China on the rise as a patenting destination, most clearly seen in wind technology.

Patent-filing destination is also an indicator of innovation hubs, as inventors typically have their first patent-filing in their country of origin. As in other fields, the United States and Japan are leading locations of filing.

The European Patent Office (EPO) is also a key filing location, especially since the implementation of the community-wide patent-filing rules, which typically provides filers with protection across the EU. In the wind sector, for example, the EPO filings in combination with Germany, the United Kingdom and France confirm Europe as a major wind energy market and location of inventive activity. But more patents have been filed in

Figure 2.11: Patent-filing locations



China than at the EPO – an indication of the rapidly growing importance of China as a market and a manufacturing location for both Chinese and multinational corporations (MNCs).

Several macro factors can account for the increasing levels of activity seen in China – both in terms of patent filings and assignees. First, China has been used as an outsourced manufacturing location by multinationals. Second, there has been a rapid growth in the deployment of renewables in recent years, responding to China's current target of 15 per cent renewable energy by 2020 and the range of supporting measures that have been put in place. China's ambitions for wind deployment have been raised dramatically, from 20GW by 2020 to 120GW.[3] The combination of a growing domestic market (on the back of increasing government support), large export markets and the increasing global ambitions of Chinese companies is resulting in greater domestic capability for innovation. This, in turn, translates into more patent filings in China and internationally.

The rise in patent-filings in China can also be attributed to a backlog of patentable innovations and products of Chinese or OECD-based companies waiting to enter the Chinese market. As the Chinese patent system strengthens and IP practices mature, companies' willingness to use its national patent system will further increase. Some observers have expressed concern about the quality of patents currently being granted in China, specifically around the distinction between design and utility patents. Something to watch for over the next few years is whether the boom in China patents will be translated into PCT patents (patents filed under the Patent Cooperation Treaty) and national-stage filings in the United States, EU and Japan.

2.2.3 Organization mix

Patents can be held by a wide range of organizational types. Figures 2.12 and 2.13 (which consider only assignees with more than four patents) show that multinationals own the majority of patents across the six sectors covered here. These are major international companies featuring in the *Forbes Global 2000* list. The second largest share is owned by 'national corporations'; these are defined as national firms with more than 250 employees but are typically much larger. In wind, national corporations have a larger share than multinationals. SMEs (companies with fewer than 250 employees) own about 5–10 per cent of the patents in each technology.

The share of patents owned by public institutions is similar to that owned by universities in each technology space, though they have a larger share in concentrated solar technologies. These institutions are almost all non-university, publicly funded research organizations such as national laboratories. The few cases where countries or regions own the patents have also been included.

Figure 2.12: Share of patents by organization type

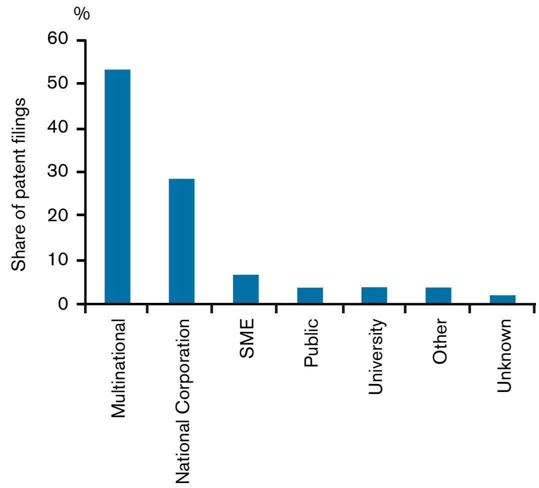


Figure 2.13: Type of patent holder by technology

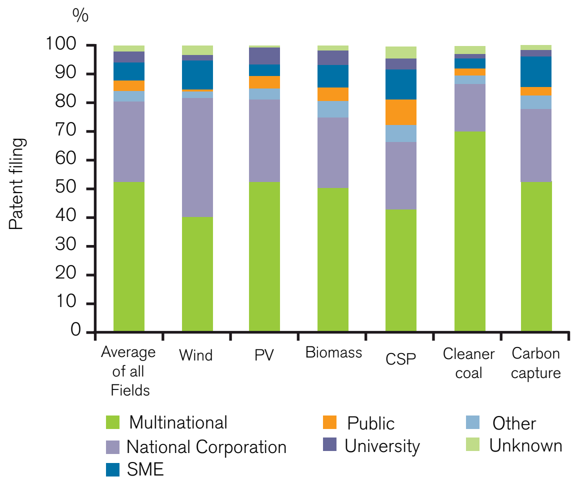
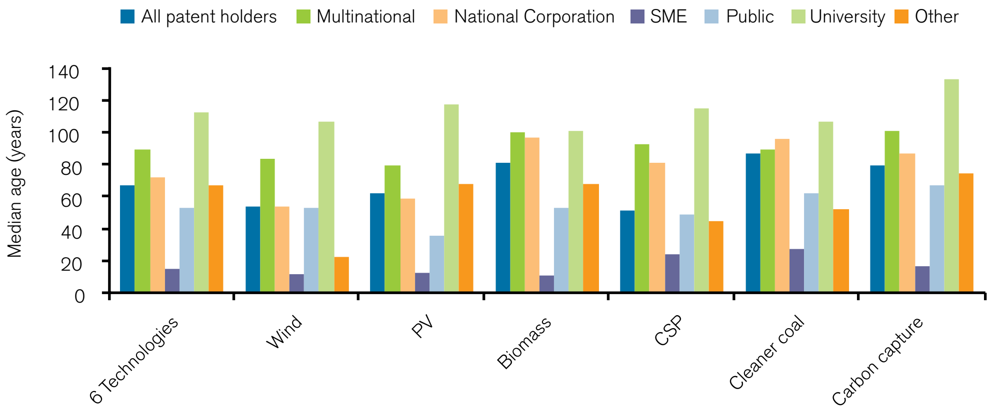


Figure 2.14: Age of patent owners by organization type



2.3 Patent ownership concentration, patent families and patent volumes

2.3.1 Corporate age and the role of incumbents

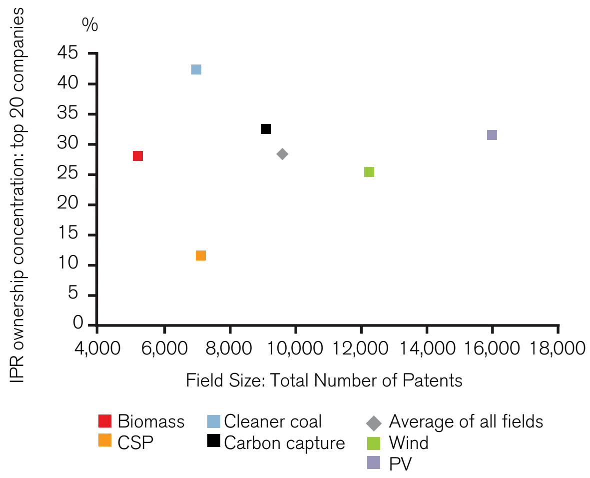
Regardless of their institutional background, older institutions and incumbents continue to have a strong influence over innovation in energy sectors, having accumulated patents over time (see Figure 2.14). The median age of assignees in biomass, cleaner coal and carbon capture is between 80 and 90 years, and between 50 and 60 years for wind, solar PV and CSP. A typical SME in the wind, biomass and solar PV fields would have been established in about 1995 – but while these are much younger organizations, they own a relatively small share of patents.

It is important to note the natural bias towards higher age in MNCs and national corporations, many of which can trace their origins back decades and sometimes even a century. When a corporation acquires a smaller company, the brand adopted is typically that of the purchasing company, so only the age of the acquiring corporations is shown here.

2.3.2 Concentration of patent ownership

In principle, the concentration of patent ownership in a sector could affect the overall level of innovation – either positively because the large players have strong innovative capacities, or negatively owing to a combination of weak incentives and potential use of blocking strategies (where patents are used to block entry into a market space).

Figure 2.15: IPR concentration – top 20 companies

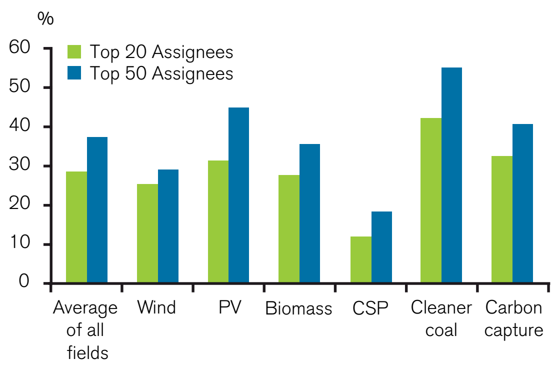


In four out of the six technology areas, the top 20 assignees own between 25 and 35 per cent of the total patents (see Figures 2.15 and 2.16). These include the two most patented technologies (wind and solar PV) but also the least patented – biomass-to-electricity. Moreover the technology with the highest concentration, cleaner coal, has a similar number of patents to the technology with the least concentration, CSP. There is no simple correlation between concentration of patent ownership and the overall number of patents (taken as a proxy for the level of innovation activities). The absence of a clear pattern suggests that concentration of patent ownership does not imply monopolistic behaviour or a lack of competition.

In cleaner coal, the top 10 assignees hold over 30 per cent of all patents, with a few companies having considerable influence. This reflects a high degree of consolidation and market concentration in fossil-fuel and power markets compared to renewable technology sectors. It could also be related to the high cost of R&D as well as high levels of vertical integration of the operations. The more established companies feature strongly here – the average corporate age of assignees in cleaner coal is over 80 years – perhaps reflecting the longer history of coal energy development.

Analysis of patent families – explained in the next section – may reveal an even higher concentration of patent ownership. This has implications for the design of new tools to promote technological cooperation, which may be need to be markedly different when a small number of actors in any given sphere achieve a particular importance.

Figure 2.16: Patent-ownership concentration: Top 20 and top 50 assignees

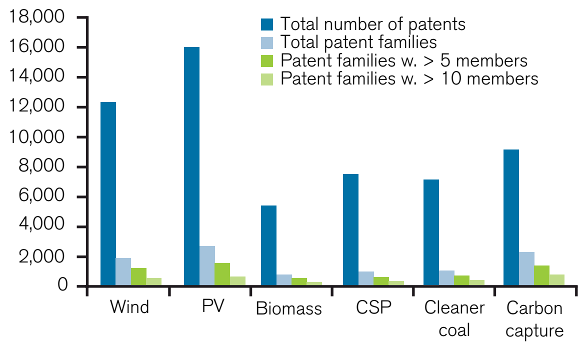


2.3.3 Understanding patent families: concentration of commercial value

A patent family comprises all the patents and patent applications resulting from one initial patent application. As discussed earlier, a patent application for an invention is originally filed in one country, typically the home country of the assignee or inventor. Where the invention proves commercially valuable, the original patent application will form the basis for patent-filing applications in other countries. Each of these new patent applications can become the basis for the filing of subsequent patent applications. Thus a single patent occasionally results in many patents throughout the world.

There is a relatively high concentration of patent ownership across the six energy sectors, especially cleaner coal (Figure 2.17). In each technology space there are between 250 and 600 patent families with more than 10 patents. Between 60 and 85 per cent of all patents from the six sectors belong to patent families.

Figure 2.17: Patent families across six technology areas



The number of patent families in each sub-sector can indicate where commercial value is concentrated within a sector. The larger the patent family, the more likely it is that the underlying technology or invention is valuable or has been commercialized. It is much more expensive to maintain a large patent family than a single one, as patent owners must pay a fee periodically to extend the term of protection of each patent in each jurisdiction. Patent owners would only maintain large patent families if the value outweighed the cost. The value of maintaining a patent family may come from licensing revenue, the ability to protect market leadership (as in the case of blockbuster drugs), or as a means to determine a preferred technological pathway in a field. Patent owners may also use their portfolio to protect their commercial position in key export markets, to prevent 'copycat' products from entering the market. Where inward trade or parallel imports may be a concern, they will seek to minimize the likelihood of reverse engineering in certain markets.

In practice, only companies with substantial resources (and successful products) are likely to invest in increasingly complex patenting strategies. Hence patent ownership concentration rates are likely to be even higher than is suggested by total patent data.

In rapidly growing fields key technologies may not have been patented or may be awaiting approval, or patent families may still be maturing. It may take up to three to five years for one patent family generation to be rolled out across the world. For example, while over 9,000 patents are associated with carbon capture technology as a whole, there are only around 1,000 patent families with more than five members. This may be an indication of its relatively early stage of development for power-sector use, and reflect the perception that market conditions for deploying carbon capture technologies at scale are yet to be put in place.

Notes

1 Project and project planning data sourced from Greenpeace (2009), *Concentrating Solar Power Global Outlook 2009*. Where a range of dates is provided, the later date has been included.

2 Bekkers, R. et al. (2002), 'Intellectual property rights and standardization: the case of GSM', *Telecommunications Policy*, 26 (3-4), 171–88.

3 www.chinadaily.com.cn/bizchina/2009-07/06/content_8380826.htm and www.chinadaily.com.cn/bizchina/2009-06/30/content_8335789.htm.

3. Patent Landscapes of Individual Energy Sectors

Most energy technologies are part of complex technology systems. Individual companies may specialize in manufacturing one or several components, or in their assembly and operation, while companies from other industries may try to adapt existing technologies to novel applications.

Disaggregating the patent mapping of energy technologies into the constituent components of individual value chains allows policy-makers and stakeholders to identify core areas of innovation. It also brings to light the leading players in key parts of the value chain that may go unnoticed in a macro-level analysis.

The level of granularity in the picture that emerges also enables easier identification of the different origins of system components. For example, recent patenting in the area of wind turbine blades has focused on the use of improved materials and sensors that can allow longer product life-cycles and decreased system costs, while enzyme-based carbon separation methods can be traced to advances in the biotech industry. Box 1 below describes some of the innovation hotspots identified in this analysis.

This chapter describes the patent landscape for six energy technologies, including their sub-sectors, that were selected because of their current and future importance to energy supply around the world. The first three are examples of renewable technologies at different stages on the innovation pathway: wind, solar PV and concentrated solar power. A fourth, biomass-to-electricity, is also sustainable if the fuel source is managed carefully. Each of these technologies has the potential to make a deep and permanent contribution to the decarbonization of our energy systems.

Table 3.1 Innovation hotspots

Wind	▪ Composite materials: cheaper and lighter, also allowing larger wingspan (especially for offshore) ▪ Sensors related to extreme environments (e.g. icing, stalling) ▪ Advanced blade coatings for offshore applications ▪ Pitch-rotation/optimization of lift
Cleaner coal	▪ Advanced alloys to allow lower costs of supercritical boilers ▪ Innovations related to adaptation of technologies to CCS (see CCS section) ▪ Increasing operating temperature of PCC and PCFBC boilers
Carbon capture	▪ Novel carbon separation processes, such as enzymes ▪ Incremental innovation around existing technologies, such as absorbents, adsorbents, membranes ▪ New power plant design: 'all-in-one'
Biomass	▪ Gasification field: scalability ▪ improved biomass quality and yields
Solar PV	▪ Nano-related innovations ▪ High temperature tolerance ▪ Solar concentrators ▪ Integration with buildings, fabrics and other materials
CSP	▪ High Temperature Collectors ▪ Convergence between CSP & Concentrated Photovoltaic: improved economies ▪ Heat transfer liquids (air, hydrogen, molten salt) ▪ Heat storage (molten salt), batteries, plus hydrogen as a by-product

The fifth technology space, coal, continues to be installed apace, especially in emerging economies. Ultimately, installing more efficient, 'cleaner' coal will add to global emissions, not reduce them. But in the short term it can make a contribution by avoiding even greater emissions where the construction of more coal plants – for now – appears inevitable. This will depend on the best technologies being available to emerging economies. The distribution of patents in this mature technology space gives us particular insight into the level of capacity and collaboration in an advanced energy technology.

The last technology is carbon capture. This is not a renewable technology, but has the potential to make a dramatic impact by capturing emissions from coal and gas plants that would otherwise be vented to the atmosphere. Carbon capture (and storage, which is not covered by this study) is a complicated system of technologies requiring high levels of international cooperation, a dimension which patent rates can shed light on.

For each of the six technologies an initial list of up to 10 technology sub-spaces was compiled. For each subsystem sets of technology descriptors were developed and fed through CambridgeIP's patent ranking tool to generate patent datasets representative of a given technology subsystem. The list of systems and components described in this chapter is not exhaustive, but it demonstrates differences and commonalities between the most important systems components. It is also a scalable method that can be extended to a more complete definition of the technology systems. The datasets were then manually cross-checked to identify duplications and false positives.

3.1 Wind

In the last 20 years, the wind energy sector has evolved from a source of energy only used in niche applications into a mainstream and multi-billion-dollar market. The sector saw the emergence of new players that specialize in wind technology, such as Vestas, a Danish company, and German wind turbine manufacturer Enercon. As seen in Table 3.2, leading companies also include global equipment manufacturers General Electric (GE), Siemens and Mitsubishi. Component suppliers such as Hansen International (gear-transmission systems) and ABB (electrical-distribution equipment) also feature.

Table 3.2: Wind – top patent holders

	Assignee	No. of patents
	Total	12,264
1	Enercon	612
2	General Electric Co	525
3	Vestas Wind Systems A/S	316
4	Mitsubishi	239
5	LM Glasfiber A/S	171
6	Hitachi Ltd	146
7	Siemens	140
8	United Technologies Corp	122
9	ABB AB	116
10	RePower Systems AG	111
11	Gamesa Innovation & Technology Sl	89
12	Nordex Energy GmbH	86
13	NTN Corp	77
14	Aerodyn Engineering Gmbh	68
15	Hansen Transmissions International	60
16	Neg Micon A/S [Vestas: 2003]	59
17	Matsushita Electric Ind Co Ltd	56
18	Shinko Electric Co Ltd	55
19	Fuji Jukogyo KK	34
20	Ebara Corp	30
20	Toshiba	30

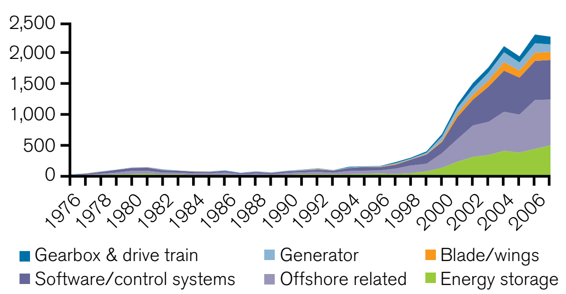
In 2008 global installed wind capacity reached 93,864 MW. The installed capacity is forecast to triple at least in the next decade.[1] As wind-energy operations grow worldwide, so has the level of patenting, as described in Chapter 2. Recent patents include innovations in new niche applications. They also attempt to address technical and social issues arising from the wind operators' learning from running wind farms and their interaction with the energy system and local communities.[2] Areas of interest include short-term energy storage, a shift from gearboxes to direct-drive generators and software systems for optimizing wind energy operations. The fast growth of offshore-related wind turbine patents also reflects increased attention given to offshore deployment.

As an industry expands, its knowledge assets become more valuable to market players. Companies become more mindful of protecting their innovations and patents, sometimes adopting more aggressive and complex IP-related business strategies as a result. In the wind sector the numbers of both patent-related litigations and cross-licensing deals have gone up in the past decade as the technology matures. One of the best-known patent disputes in the wind sector concerns Enercon, which lost a patent lawsuit to Zond Energy Systems in the 1990s. Meanwhile, GE acquired wind assets in the early 2000s from Enron (which had acquired Zond in 1997). Enercon could not sell a range of turbines in the US market until a cross-licensing deal was reached with GE in 2004.[3]

3.1.1 Areas of innovation within wind sub-spaces

Patent landscaping can reveal the changing focus of technological innovation and relative growth of sub-sectors of particular energy systems – as in the example of wind, shown in Figure 3.1.

Figure 3.1: Wind – patenting rates by subsector since 1976



The early focus of innovation in wind was in blades (harnessing mechanical energy from the air), the generator (efficient conversion of mechanical energy into electricity) and the gearbox, a frequent cause of breakdowns. These three sub-spaces continued to dominate patent trends after the rapid growth in patenting in the late 1990s. In recent years, wind has become a conventional energy source – placing a greater premium on effective integration with the grid, accurately modelling wind patterns and building in more difficult locations with high wind speeds. Investment in innovation has spread to software and control systems, short-term energy storage and offshore technologies.

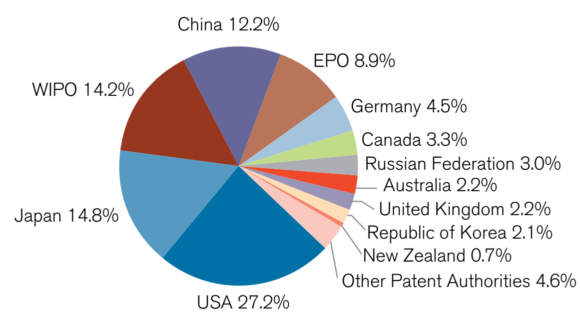
Across the whole technology space there has also been a trend towards larger-scale turbines.[4] For instance, RePower has 5 MW turbines with a 125m rotor diameter (larger than the wingspan of an Airbus 380) under way off Scotland, and it is expected that future offshore wind farms may have even larger unit sizes.

3.1.2 Key trends: geographical distribution and IP ownership concentration

Patent ownership and key markets

The United States and Japan are the leading locations of patent filing for wind energy (Figure 3.2), together with EU countries including the European Patent Office (EPO). As discussed in Chapter 2, Europe is both a major market and a location of inventive activity for this sector. The rapid rise of patent filings in China reflects its rising significance as a potential market and a manufacturing location for both Chinese and multinational corporations. Market developments in both China and India are also attracting significant investments by key technology owners in the space.

Figure 3.2: Wind – patent filing locations



The majority of assignees are based in OECD countries, led by the United States, Germany, Denmark and Japan (Figure 3.3). However, the rate of patenting by China-based assignees is accelerating and China is now third overall. Patents with Russia-based assignees are also growing in number. Reported assignee location may reflect local subsidiaries, rather than the parent company, and thus provide a misleading guide to ultimate patent

Box 3.1: Wind sub-sectors in detail

Table 3.3: Top five patent owners of wind sub-space

Assignees		No. of patents
GENERATOR		
	Total	5,834
1	Enercon	227
2	General Electric Co	213
3	Mitsubishi	125
4	Hitachi Ltd	90
5	Vestas Wind Systems A/S	80
GEARBOX & DRIVE TRAIN		
	Total	3778
1	General Electric Co	116
2	Vestas Wind Systems A/S	95
3	Enercon	81
4	NTN Corp	76
5	Hansen Transmissions International	53
OFFSHORE WIND ENERGY		
	Total	1,170
1	Enercon	43
2	Aerodyn Engineering Gmbh	36
3	General Electric Co	29
4	Norsk Hydro As	19
4	ABB AB	19
ENERGY STORAGE		
	Total	936
1	General Electric Co	41
2	ABB AB	22
3	Vrb Power Systems Inc	19
4	Hitachi Ltd	18
5	Canon KK	8
5	Matsushita Electric Ind Co Ltd	8
5	Proton Energy Systems Inc	8
BLADES/WINGS		
	Total	5,547
1	Enercon	318
2	General Electric Co	283
3	Vestas Wind Systems A/S	208
4	LM Glasfiber A/S	159
5	Mitsubishi	83
SOFTWARE/CONTROL SYSTEMS		
	Total	950
1	General Electric Co	52
2	ABB AB	47
3	Vestas Wind Systems A/S	17
4	Siemens	16
5	RePower Systems AG	10

Generators ensure the efficient conversion of mechanical (wind) power into energy. They account for the largest share of the wind-related patents. As this technology is adapted from electric machinery and turbines in other fields, established companies such as GE, Siemens, Mitsubishi and ABB enjoy a head-start over their competitors. However, Enercon, a relatively new entrant to the industry, currently owns the most patents, ahead of several multi-nationals.

Transmission systems: Gearboxes and drive trains led to bottlenecks owing to their frequent breakages and operational limitations, which increased costs and limited the efficiency of early wind deployment. Several big players in gearboxes and drive trains come from the manufacturing and automotive sectors. One current trend is towards direct drive systems, which remove the need for a gearbox.

Offshore wind energy offers the possibility of larger turbines located in areas with higher and more constant wind – but with operational and maintenance challenges. Servicing of some offshore turbines is only possible by helicopter. All leading wind players are active in offshore innovation, demonstrating their adaptive R&D capacities. Others include the Engineering Business (an IHC Merwede subsidiary), from the oil and gas industry, with expertise in pipe-laying equipment, sub-sea trenching machines and other specialist systems.

Energy storage systems are critical in enabling further penetration of wind and solar energy owing to the intermittent nature of renewable energy sources. A cheap and reliable storage solution would allow the integration of wind energy into base load power of the grid. Over 400 patents related to energy storage are identified within the wind dataset. Crossovers from other industries include advanced battery storage systems and hydrogen production.[a] Patent owners include electronics companies (Canon, Hitachi) and energy storage specialists (Proton Energy) as well as GE.

Wings/blades of wind energy systems owe much to the aviation industry, not only in terms of mechanical design but also through the use of composite materials that are lighter, cheaper and more durable for wing manufacture. Among the top 10 companies in this sub-sector is United Technology Companies, which is more closely associated with aviation than wind.

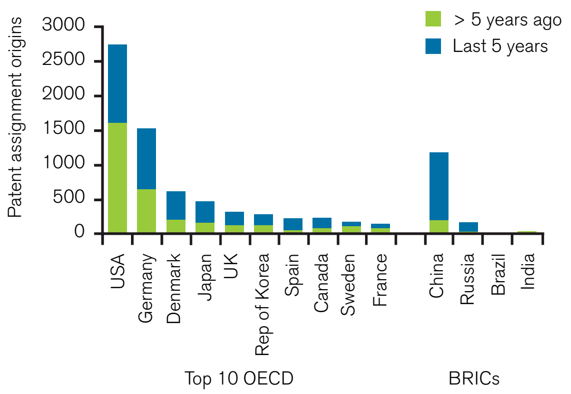
Software and control systems only became commercially attractive after wind-energy use increased. Examples of innovations include intelligent grid-management systems, predictive modelling of wind 'stock' for a farm or at the turbine level and advanced sensor or control systems.

a There is a much broader field of energy storage systems that was not explicitly researched, but the importance of which is apparent as a link-up of different renewable sources of energy, for instance, the use of hydro-systems to store surplus power or larger-scale hydrogen and battery systems.

control (see Chapter 2). If acquisitions by Indian companies of OECD-based players in the wind industry are considered (such as Hansen International), the proportion of patents controlled by India would be much higher than that shown by the raw data.

Even though the top tier of the field appears dominated by OECD-based companies, non-OECD-based companies are climbing up the ranks, sometimes through mergers and acquisitions (M&A). Suzlon is an Indian wind turbine manufacturer group founded in the 1990s. A key part of its strategy has been to acquire European technology companies. In addition to Hansen International, these purchases include rotor-blade designer AE-Rotor Techniek in 2000, and Suzlon is currently involved in a takeover bid for RePower, another leading European wind turbine manufacturer.[5]

Figure 3.3: Wind – top patent assignee origins



As Table 3.3 shows, the top 20 players in wind own about 25 per cent of all patents, less than in solar PV or biomass-to-electricity. There are a number of specialized niche players in each of the sub-systems, who are competing with the major players who are present in all sub-spaces.

Table 3.4: Wind – concentration of IPR

Field/sub-field	Top 20 assignees patents as % of all patents in field
Average of all 6 technologies	28.5
Wind – overall	25.4
Gearbox & drive train	20.2
Generator	21.3
Blade/wings	28.8
Software/control systems	23.3
Offshore wind energy	22.3
Energy storage	20.9

In this sector, the major patent holders are the leading manufacturers. The top four wind patent owners – who collectively own 13 per cent of all wind patents – have a 48 per cent share of the global wind turbine market.[6]

With significant level of M&A in this industry, patent concentration levels should increase over time. In the more novel areas of the industry (software, offshore), more M&A activity can be anticipated, with the leading industry players seeking to capture a higher market -share of the technology. However, it is in the nature of crossover industries that exposure to other fields may increase their independence and inventiveness. This may reduce the prospect of a small group of players consolidating control over IPRs in this space.

3.2 Solar photovoltaic (PV)

Since the 1980s, improved efficiency and lower production costs – including the introduction of feed-in tariffs in key markets – have propelled solar photovoltaic (PV) technology into the mainstream of power generation, both off-grid and on-grid. Global installed capacity of solar PV grew from 1.3 GW in 2001 to 15.2 GW by 2008.

Table 3.5: Solar PV – top patent holders

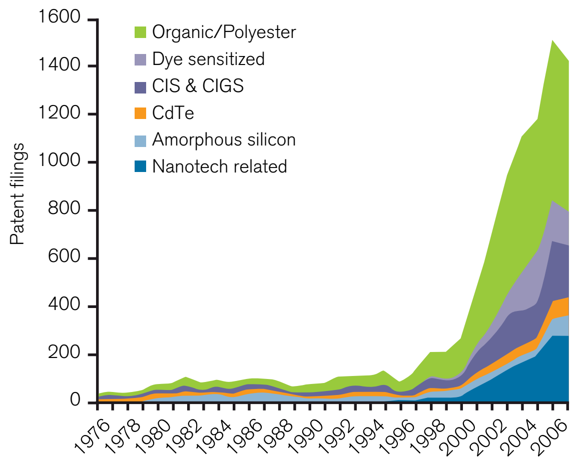
	Assignee	No. of patents
	Total	15,989
1	Sharp	608
2	Canon	561
3	Sanyo	483
4	Asahi Glass Co Ltd	478
5	Matsushita Electric	359
6	Fuji Electric Co Ltd	258
7	Hitachi	223
8	Merck Patent Gmbh	198
9	Kyocera Corporation	190
10	Kanegafuchi Kagaku Kogyo KK	184
11	Samsung Electronics Co Ltd	178
12	DuPont	172
13	General Electric Co	164
14	Shin Etsu Handotai Co Ltd	160
15	Sumitomo	159
16	Sony Corp	157
17	Honda Motor Co Ltd	155
18	Seiko Epson Corp	144
19	Atlantic Richfield Company	129
19	Siemens	129

As the levels of PV deployment capacity have grown, annual patent filings have increased rapidly. As in the wind sector, increased maturity and value of technology has been accompanied by increasing levels of patent portfolio complexity, litigation and cross-licensing. However, in the PV space the crossover between different fields is significantly higher: there is a battle going on between competing approaches to next generation PV (discussed in the section below).

3.2.1. Areas of innovation within PV sub-spaces

Advances in this sector centre on the next generation of PV technologies. Second and third generation technologies are focused on using materials that improve thin film efficiency. Emerging non-silicon technologies have significant advantages in terms of efficiency, ability to absorb higher levels of radiation, or lower material and manufacturing costs. However, they have an entry barrier owing to the high fixed investment costs in manufacturing facilities and technological requirements. Silicon-based approaches benefit from the computer industry infrastructure and a decade of experience of PV panel production. Microcrystalline PV allows higher conductivity, while protocrystalline PV allows the stacking or tandem operation of cells.

Figure 3.4: Solar PV – patenting rates by subsector since 1976



In the 20 years after 1976 PV patent rates were low and focused on four sub-fields, each with its own crossovers with other manufacturing applications, as shown in Figure 3.4. Amorphous silicon is a key ingredient in LCD displays. It can be used over larger areas than traditional crystalline silicon and can be printed onto plastic as well as glass to make large solar cells. CIS and CIGS are copper alloys used in thin-film PV. Thin-film PV requires less light-absorbing material (reducing manufacturing costs) and is also easier to integrate with other materials. Cadmium telluride-based PV is suitable for high-temperature conditions and has been developed from the use of advanced alloys in solar panels on satellites and lasers. Organic PV is related to developments in light-emitting diodes. These involve mounting plastic onto glass – a less efficient but cheaper approach that could in future be found on the surface of mobile phones, for example.

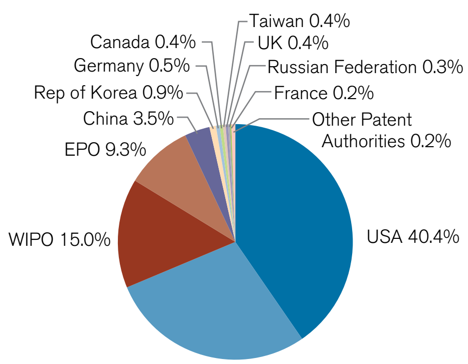
When PV patent rates took off in the late 1990s each of these four categories expanded. Organic PV and CIS/CIGS combined still make up over half of all patenting activity. At the same time, however, advances in materials science opened new avenues for PV technology development, with nanotech and dye-sensitized approaches (which can be painted on to surfaces) emerging strongly.

3.2.2 Key trends: geographical distribution and IP ownership concentration

Filing destinations

The United States and Japan are leading locations for patent filing in solar PV energy, followed by WIPO and the EPO. While the trend broadly reflects current markets and R&D capacity, emerging markets such as China are also seeing increasing patenting rates. PV patent-filings in China are lower than those of wind despite the fact that a significant proportion of world PV production is based in China. This is partly because first generation PV (where much of past Chinese PV production is focused) has not been patented as heavily as the emerging thin-film PV technologies.

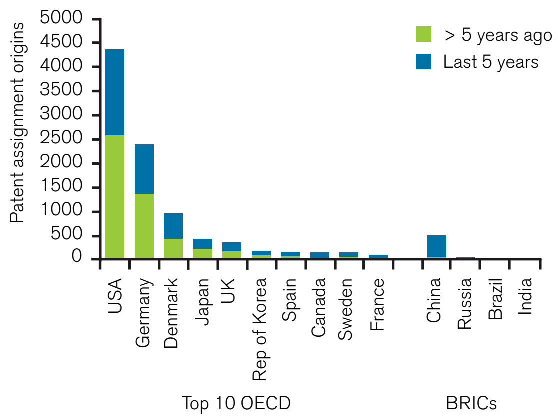
Figure 3.5: Solar PV – patent filing locations



Location of assignees

While the United States and Japan are leaders, Germany, South Korea, the United Kingdom, France and Switzerland all have a significant presence. Our sub-sectoral research showed that particular country strengths are also reflected. The United Kingdom owes its presence to strength in nanotechnology and advanced alloys, while Switzerland is home to both dye-sensitized method inventors and nanotech PV manufacturers.

Figure 3.6: Solar PV – top patent assignee origins



IPR concentration

Today, there are different and competing technology approaches to next generation PV, and none has gained dominance or full market acceptance. While some of these technology approaches may end up dominating the next phase in PV deployment, as yet the key players in these subsectors do not appear in the overall top 20 patent ranking. In addition, different dynamics are going on in each of these subsectors: as demonstrated by significant differences in their patent ownership concentration rates – ranging from 23 to 46 per cent. In clear contrast to wind, only two of the top 10 manufacturers of PV modules[7] (Sharp and Kyocera) are among the top 20 patent holders. The probable explanation for this is a high degree of cross-licensing.

The maturation of the PV industry is accompanied by an increase in the number of patent-related litigations. For instance, Nanosys is a US producer of nanotech quantum dots, which are used in lighting,

Box 3.2: Solar PV subsectors in detail

Table 3.5: Top 5 patent owners in solar PV sub-spaces

	Top Assignees	No. of patents
AMORPHOUS SILICON		
	Total	993
1	Sanyo	57
2	Canon	49
3	Kanegafuchi Kagaku Kogyo Kk	36
4	Atlantic Richfield Company	33
4	Fuji Electric Co Ltd	33
5	Asahi Glass Co Ltd	29
NANOTECH RELATED		
	Total	1,667
1	University California	42
2	Nanosolar Inc	41
3	Konarka Technologies Inc	40
4	General Electric Co	34
5	Samsung Electronics Co Ltd	30
CcTe-BASED		
	Total	730
1	Matsushita Electric	27
2	Atlantic Richfield Company	19
3	Energy Conversion Devices Inc	15
4	Nanosolar Inc	14
5	First Solar Inc	13
5	University California	13
DYE SENSITIZED		
	Total	987
1	Sharp	49
2	Ngk Spark Plug Co Ltd	43
3	Dupont	40
3	Fujikura Ltd	40
5	Samsung Electronics Co Ltd	37
CIS & CIGS		
	Total	1,810
1	General Electric Co	50
2	Shell Oil Company	42
3	Boeing	37
4	Energy Conversion Devices Inc	29
4	Nanosolar Inc	29
ORGANIC PV/ OLEDS		
	Total	4,991
1	Merck Patent Gmbh	182
2	General Electric Co	99
3	DuPont	96
4	Canon	78
5	Konarka Technologies Inc	67

Amorphous silicon production offers a step-change in the use of traditional crystalline silicon-based PV panels. One of the main advantages is that amorphous silicon is much more uniform over large areas. It can be deposited on plastic as well as glass.[a] Key players include glass manufacturers such as Asahi Glass, a specialist in high-spec glass material for the buildings and other areas, who provides high-resistance glass covers for silicon PV cells.

Nanotechnology is related to about 31 per cent of all PV patents, including some 50 per cent of all organic PV patents. Large corporations and universities are active in this space, as well as younger companies such as Konarka Technologies and Nanosolar. The latter received nearly $500m in investment in 2008 from venture capital and utility companies to finance production plant expansion aimed at 1GW p.a. production capacity[b] in what has been termed a race to expand production to capture increasing market demand.[c]

Cadmium Telluride-based PV (Cd Te) owes its advances to uses of advanced alloys in solar panels on satellites and lasers. Resistant to high radiation and solar intensity in space conditions (or under a laser), they are suitable for use with concentrator technology in CSP applications. Improvements in crystal-growth methods have also led to their increased use in security- and medical-related applications (e.g. 3D X-ray machines). These developments have created a global market for the underlying base metals, and for crystal growth facilities. Several oil and gas companies also feature in this space, very likely through their capabilities around materials processing

Dye-sensitized cells (also known as Grätzel cells, after their Swiss inventor) use photo-sensitive dyes as a thin film, allowing the PV cells to be painted onto surfaces. The materials are very low-cost, and the panels are robust to scratches or hail but they have relatively low efficiency rates. Potentially they can be used in automobile and building coatings.

Copper Indium Diselenide (CIS) and Copper Indium Gallium Selenide (CIGS) are alloys used in polycrystal-line thin-films, with reported laboratory-level efficiencies of up to 19.9 per cent.[d] While having lower efficiency levels than Crystalline Silicon cells, CIGS and CIS-based PV are expected to be cheaper because the photovoltaic material can be deposited directly onto glass.

Organic PV/OLEDs is one of the fastest moving sub-sectors of solar PV energy. Key players include GE, DuPont, Merck and Japanese electronics companies. Less well known is Konarka Technologies, which has attracted a lot of investments from venture capital as well as Total in the past few years. It develops printable nano-enabled polymer PV materials, which could theoretically enable for everyday devices, systems or structures to have embedded sources of renewable power. Konarka has developed strategic partnerships with many companies and institutions, including Air Products, 24 Innovations, Kurz, SkyShades, Chevron, Merck, Toppan Forms, Dupont and Siemens as well as the US Air Force.[e]

a Amorphous Semiconductors Research Group, Amorphous Silicon, http://www.ayil.hacettepe.edu.tr/pages/Amorphous/Amorphous%20silicon.html.
b Nanosolar Blog (2008), Nanosolar Ups Funding to $0.5B; Partners Strategically for Solar Utility Power, 27 August, http://www.nanosolar.com/blog3/?p=138.
c Greenbeat (2008), Nanosolar outshines the competition with $300 million financing, 27 August 2008, http://green.venturebeat.com/2008/08/27/nanosolar-outshines-the-competition-with-a-300m-financing/.
d Repins, I., Contreras, M. A., Egaas, B., DeHart, C., Scharf, J., Perkins, C. L., To, B. and Noufi, R. (2008),19.9%-efficient ZnO/CdS/CuInGaSe2 solar cell with 81.2% fill factor, *Progress in Photovoltaics: Research and Applications,* 16, 235.
e See www.konarka.com/index.php/company/our-partners/.

solar power and electronic display systems. In July 2009 it settled a patent infringement lawsuit against Nanoco Technologies Ltd of the United Kingdom. The lawsuit claimed that the British firm's quantum dot technology infringes upon five seminal quantum dot patents held by Nanosys.[8]

Table 3.6: Solar PV – concentration of IPR ownership

Top 20 Assignee patents as % of all patents in field	
Average all 6 fields	28.5
PV: overall	31.8
Nanotech-related	25.4
Amorphous-silicon	46.1
CdTe-based	31.1
CIS & CIGS	24.6
Dye sensitized	49.9
Organic and polymers	22.8

Australia has historically held a strong technology position in solar power – both PV and CSP. Yet many of its solar entrepreneurs moved to California where they had access to capital and a rapidly growing solar market. Another example is the technology used in Russia's PV industry, which has its origins in space technology. Alongside the United States, Russia was a pioneer in the use of solar power in military and civilian space applications, as demonstrated by Soviet-era patents in the field. Yet that capability has waned and has remained unexplored.

3.3 Biomass-to-electricity

As with other energy technologies, investments of R&D in biomass-to-electricity systems are sensitive to changing market conditions. Patenting rates peaked after the twin oil shocks of the 1970s and early 1980s but then subsided in the mid-1990s. There has been a steady growth since 1995, but annual registrations still fall short of those in wind or PV. Current patenting rates are similar to those seen in the wind sector in the late 1990s.

As Table 3.7 shows, adaptation of technologies from coal-based electricity generation puts traditional players, such as the major Japanese corporations, at the forefront of biomass-to-electricity patenting activity. The significant presence of research institutions may reflect public-sector investments in coal-related R&D. Outside the top 20, there is an emerging group of companies in biomass use/production or waste management.

Table 3.7: Biomass-to-electricity – top patent holders

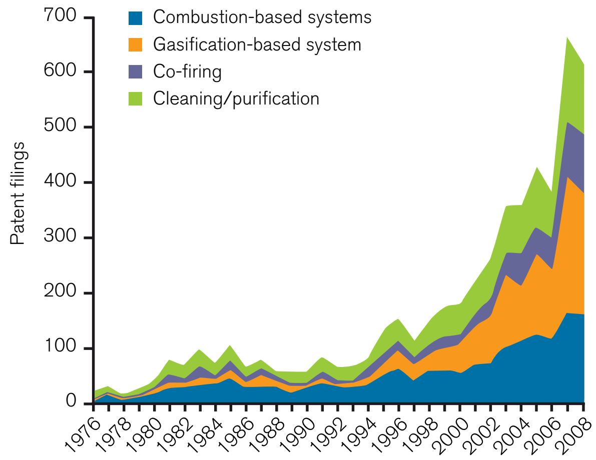
	Assignee	No. of Patents
	Total	5,305
1	Hitachi	334
2	Mitsubishi Heavy Industries	265
3	Kawasaki Heavy Ind Ltd	116
4	Ishikawajima-Harima Heavy Industries	97
5	Nippon Steel Corp	94
6	Ebara Corp	87
6	Sumitomo	87
8	NKK Corp	69
9	Mitsui	62
10	Toshiba Corp	36
11	Fuji Electric Co Ltd	27
11	Nippon Kokan KK	27
13	General Electric Co	25
14	Kubota Ltd	24
14	Ube Industries Ltd	24
16	Chugai Ro Co	22
16	Takuma Co Ltd	22
18	Chinese Academy of Sciences (and Affiliates)	21
19	Kobe Steel Ltd	20
19	Union Carbide Corporation	20
19	University of California	20

3.3.1 Areas of innovation within biomass-to-electricity sub-spaces

The various biomass-to-electricity technologies have emerged via different pathways. Combustion-based applications are relatively mature, with patenting rates steadily growing since the late 1970s. By contrast, approaches based on gasifying biomass prior to combustion are only maturing today, with accelerating patenting rates since 2000, as seen in Figure 3.7.

There are overlaps between biomass and coal technologies, such as in combustion and gasification. However, biomass technologies involve a range of fuels (see Table 3.9) and fuel quality, consistency and emissions control are major issues. Cleaning or purification-related patents

Figure 3.7: Biomass-to-electricity: patenting rates by subsector since 1976



have been important since the beginning, and have grown in line with the overall rise in patenting.

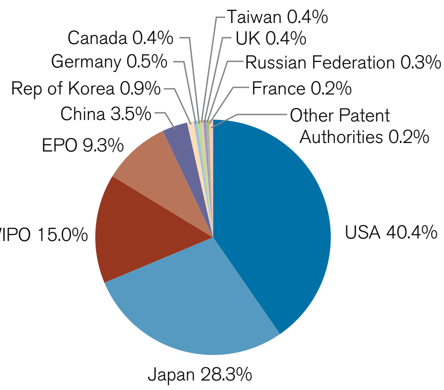
Patents related to biomass co-firing with coal have become prominent only in the last 10 years, reflecting the perceived commercial prospects.

3.3.2 Key trends: geographical distribution and IP ownership concentration

Filing destinations

The leading location for biomass-to-electricity patents is Japan, followed by the United States (Figure 3.7). This reflects the leading role of Japanese companies in this space, but it may also be linked to behavioural differences – Japanese companies, for example, are perceived as profligate patent filers. The low number of patents in Germany should be interpreted in the context of the EPO being an alternative option for patenting within the EU. China comes fourth after Japan, the United States and the EU. There are more patents filed in Russia than South Korea.

Figure 3.8: Biomass – filing by patent authority



Box 3.3: Biomass sub-sectors in detail

Table 3.8: Top five patent owners in biomass-to-electricity sub-spaces

	Top assignees	No. of patents
	COMBUSTION-BASED SYSTEMS	
	Total	1,715
1	Hitachi	109
2	Mitsubishi Heavy Industries	89
3	Ebara Corp	34
3	Kawasaki Heavy Ind Ltd	34
5	Ishikawajima-Harima Heavy Industries	30
	GASIFICATION-BASED SYSTEMS	
	Total	1,511
1	Mitsubishi Heavy Industries	68
2	Hitachi	45
3	Kawasaki Heavy Ind Ltd	38
4	Ebara Corp	37
5	Nkk Corp	35
	CO-FIRING	
	Total	693
1	Hitachi	46
2	Mitsubishi Heavy Industries	27
3	General Electric Co	14
3	Sumitomo	14
5	Kawasaki Heavy Ind Ltd	11
	CLEANING/PURIFICATION RELATED TECHNOLOGIES	
	Total	1,455
1	Hitachi	55
2	Mitsubishi Heavy Industries	41
2	Sumitomo	41
4	Nippon Steel Corp	40
5	Kawasaki Heavy Ind Ltd	31

Combustion-based systems are the oldest technology in this field, with most market-leading technologies incubated in the 1980s. There are significant overlaps with coal combustion technologies, including adaptation of fluidized bed systems for use in biomass, and co-firing of coal with biomass mixes. Key areas of innovation include efficiency gains, the quality of feedstock and utilizing non-steam working fluids. At small scale, innovation focuses on the organic Rankine Cycle, an approach that is more efficient at lower working pressures and temperatures.

Gasification-based systems avoid some problems associated with combustion, but are more recent developments.[a] While there are commonalities between coal and biomass combustion technologies, there are few overlaps between biomass-gasification and integrated gasification combined cycle (IGCC), except post-gasification technologies for carbon capture. Research institutes feature strongly in the top 15 patent assignees. The Chinese Academy of Sciences (including CAS affiliates) has more patents than GE and other industrial leaders.

Co-firing systems, such as mixing low-grade coal powder with biomass fuel, are used to increase the output from the burn cycle. Much of the effort has focused on retrofitting coal fluidized bed combustion systems for use with biomass.

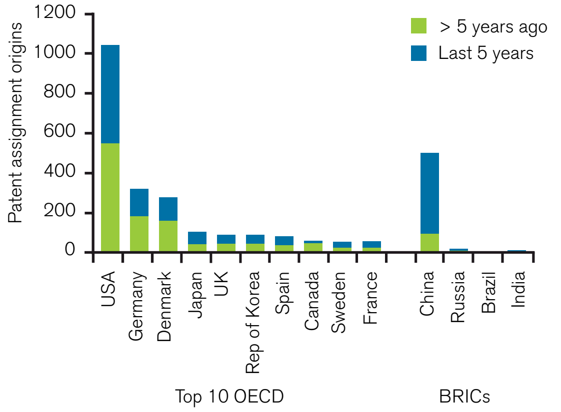
Cleaning/purification: A key consideration for all biomass-to-electricity systems is the quality of biomass. This is a function of consistency of the feed, storage requirements, by-products or residues, as well as ensuring greater compatability between the energy conversion processes and multiple biomass types. Each combination of fuel source and energy generation type may have its own cleaning/purification requirements. Therefore a key area of innovation lies in purification and quality control as well as the cleaning of equipment. While among the top 10 the largest patent portfolio holders are Japanese, there is a wider composition of patent owners in the top 20, with companies from Germany, the Netherlands, Finland and other EU countries.

a A key barrier is related to the drying of biomass: it usually comes with 50 per cent water content, which needs to be reduced to 15 per cent. Gasification-based systems operators have found a use for waste heat from the process as a cheap way of drying biomass.

Location of assignees

As Figure 3.9 shows, OECD leaders include the United States, Germany and Japan lead, but China appears as the second most important assignee location – it also has the third highest growth rate in this space. India, Russia and Brazil are less active but they are likely to become important in this sector owing to their endowment of natural resources. Less obvious in these numbers is the relative specialization of European countries in biomass-to-electricity technology related to the type of biomass available locally: e.g. wood in the Nordic countries.

Figure 3.9: Biomass – top patent assignee origins



IPR ownership concentration

The IPR ownership rates in the biomass field are similar to the average for the six fields researched. Within the biomass-to-electricity space, one driver towards greater concentration is the relationship between some of the sub-fields and cleaner coal (which was found to have the highest IPR ownership concentration rate). M&A have played a significant role in consolidating IP ownership in the biomass-to-electricity sector. For instance, in 2002 GE acquired the Austrian gas turbine manufacturer Jenbacher, which has been investing in technologies for co-generation, synthetic gas (Syngas) and waste gas areas. Jenbacher is now GE's Global Center of Excellence For Gas Engine Products.[9]

Table 3.9: Biomass-to-electricity – concentration of IPR (%)

Average all 6 fields	28.5
Biomass: overall	28.0
Combustion-based systems	28.0
Gasification-based systems	27.8
Co-firing	29.4
Cleaning/purification	32.6

In markets served by smaller-scale turbines, ownership of IP is more dispersed. There is a greater diversity of players among those focused on specific types of biomass or waste. As the use of biomass for electricity generation (and transport fuel) spreads globally, it is likely that a lot of activity will be located in land-rich developing economies. It remains an open question whether they will be able to leverage such activities to develop indigenous innovation activities and specializations.

3.4 Concentrated solar power

Concentrated solar power (CSP) holds the promise of cheaper, more scalable electricity generation in regions with good levels of sunlight. The opportunity to store heat means that power can be delivered at peak times. In terms of maturity of designs and deployed capacity, however, CSP technology lags behind solar PV, despite its invention over 100 years ago when a series of solar power generators using parabolic troughs were developed in France.

Recent developments have seen major industrial initiatives around the large-scale deployment of CSP from the EU and the United States.[10] CSP is on the cusp of becoming part of the core mix of low carbon energy technologies.

Several aerospace giants, including Boeing, UTC and NASA, are active in this area, developing technologies such as advanced tracking systems, high-temperature-resistant materials, and concentrator technologies as used in satellites.

In this rapidly growing area, the profile of leading patent owners is set to change dramatically in the next few years. The patent portfolios of emerging players (particularly those based in California) are likely to grow significantly on the back of a large number of venture capital (VC) investments between 2006 and 2009, and as CSP farms enter into operation.

At this early stage of technology development the relative patent portfolio size of even the leading players in the field is fairly small. Components suppliers that work with other industries are important since relevant technologies may be in use in other industries, whereas, to date, technology integrators or genuinely innovative companies have relatively small patent portfolios protecting the core of their technological innovation.

As technology deployment increases, the new leaders in a technology space are likely to increases the size of their patent portfolios, as they protect higher parts of their value chain and the number of patentable inventions increases. In the wind sector, for example, the leading players each have hundreds of patents protecting their overall technology systems.

Table 3.10: CSP – top patent holders

	Assignee	No. of patents
	Total	7,193
1	Matsushita Electric	95
2	Mitsubishi Heavy Industries	94
3	Sanyo	73
4	Toshiba Corp	69
5	Hitachi	62
6	Agency of Industrial Science & Technology	56
7	Boeing/Rockwell Intl.	45
8	United Technologies Corp/ Pratt & Whitney	41
9	Sharp	35
10	Sumitomo	34
11	Deutsches Zentrum für Luft-und Raumfahrt EV	32
11	US Department of Energy	32
13	Canon	30
14	Yeda Research and Development (Weizmann Institute)	29
15	NEC Corporation	27
16	General Electric Co	26
17	Siemens	24
18	Fraunhofer-Gesellschaft zur Förderung der Angewandten Forschung EV	21
18	3M	21
18	NASA	21

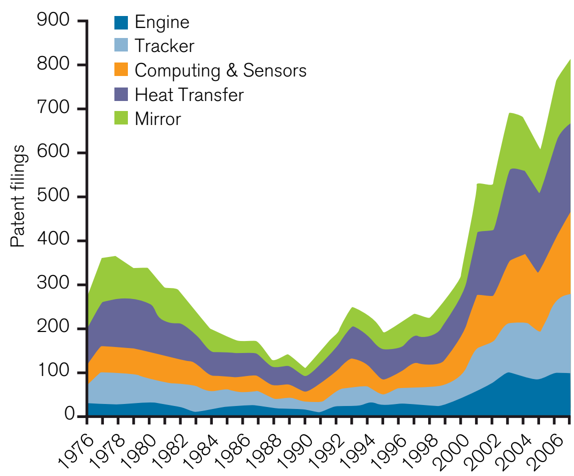
3.4.1. Areas of innovation within CSP sub-spaces

It took until 2000 for patenting in CSP to return to the level of late 1970s, but the number doubled again in the following six years (see Figure 3.10). This acceleration reflects the renewed interest in the technology around the world.

Which of the competing technologies in CSP will emerge most strongly is still unclear, and may vary according to local conditions. Owing to historical investments in the area, trough-based systems are expected to be prevalent until 2012 or 2013, after which these could be displaced by heliostat/power towers systems, compact linear Fresnel reflectors (CLFR) and dish-engine developers if that technology advances more quickly (see Box 3.4).

Sub-fields such as trackers and sensors (both developed from space applications) apply across these competing CSP technology options, and their even contribution in patenting trends suggest that advances in a range of areas are still ongoing – in other words, there is no single key to CSP technology development.

Figure 3.10: CSP – patenting rates by subsector since 1976



3.4.2 Key trends: geographical distribution and IP ownership concentration

Filing destinations

Key filing destinations are the United States, Japan and China. However when EPO filings are considered jointly with those in country authorities, the European total is higher than that of China. The large number of US filings is probably due to a combination of component-level patents that precede the take-off in CSP (such as in aerospace), in addition to recent increased interest in the space. However, as most of the deployed CSP capacity is likely to be in developing economies, it is likely that we will see increased patenting into such markets (such as South Africa).

Location of assignees

The origins of several world leaders in CSP technology, such as California-based Ausra, can be traced to Australian

Box 3.4: Four competing technology approaches in concentrated solar power

Parabolic trough

Sunlight is reflected by a long parabolic mirror onto a tube running alongside the mirror at the focal point. The tube is filled with heat-transfer fluid (usually oil), which is then used to heat steam in a standard turbine generator. Thermal efficiency ranges from 60 per cent to 80 per cent when heating the pipe. Many designs rotate to track the sun as the earth rotates. The overall efficiency from collector to grid is about 15 per cent, similar to PV cells but less than Stirling dish concentrators. Israel's Solel Solar Systems plans to develop a 553 MW solar power plant in California using this technology.

Linear Fresnel reflector

A Fresnel reflector system uses flat plate mirrors to concentrate the sun's rays directly on water pipes, boiling the water to run steam turbines. The components can be made from plastic, significantly decreasing systems costs. In 2007 Ausra (originally from Australia but now headquartered are in California) signed a power purchase agreement with San Francisco's Pacific Gas & Electrical for a 177 MW thermal plant. Other players include Sharp and Boeing.

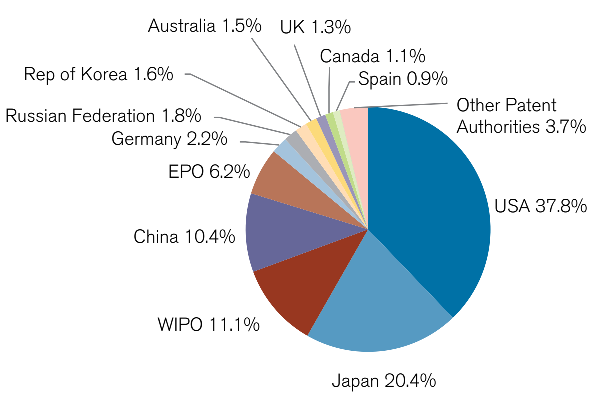
Heliostat solar

In a heliostat system an array of solar reflectors (heliostats) can be combined to concentrate the sun's energy on a solar tower where the heat is converted into energy. A large number of motor-controlled mirrors track the sun and reflect the solar energy onto a tower receiver, which in turn heats a liquid that can be used to make steam. A steam turbine then produces electricity. Such systems are being tested in the United States and Spain.

Parabolic dish

A dish system uses a large, reflective, parabolic dish (similar in shape to a satellite television dish). It focuses all the sunlight that strikes the dish up onto a single point above the dish, where a receiver captures the heat and transforms it into a useful form. Typically the dish is coupled with a Stirling engine, but also sometimes a steam engine is used. These create rotational kinetic energy that can be converted to electricity using an electric generator.

Figure 3.11: CSP – patent filing locations



research from the 1980s and 1990s. However, increased investment by other countries has eroded Australia's early lead. Today, several leading providers of CSP technology are either located in Israel or have strong Israeli links. Since many Israeli high-tech enterprises pursue commercialization through US-registered subsidiaries, it is likely that many of the Israeli-originated technologies are picked up under the US assignees and US-filed patents. Patents filed by Russia-based assignees trail behind OECD-based ones, yet the inclusion of Soviet Union-era patents brings the total to just behind South Korean levels. Soviet-era technology is likely to come from aerospace and defence industry applications.

IP ownership concentration

The concentration of patent ownership in CSP is lower than the average for the other five energy technologies, with the top 20 per cent of assignees owning around 15 per cent of all patents. This is not surprising given the low number of patents and the fragmented nature of the sector. A period of consolidation can be expected in the near future as the technology is scaled up; this will in turn alter the patent landscape.

Box 3.5: CSP subsectors in detail

Table 3.12: Top patent holders of CSP sub-spaces

Top Assignees		No. of patents
CONCENTRATOR SYSTEMS		
	Total	2,291
1	Boeing	22
2	US Department of Energy	21
3	Agency of Industrial Science & Technology	20
4	Sanyo	18
5	Yeda Research and Development (Weizmann)	16
HEAT TRANSFER		
	Total	3,221
1	Mitsubishi Heavy Industries	42
2	Matsushita Electric	29
3	Toshiba Corp	28
4	Hitachi	21
5	Agency of Industrial Science & Technology	20
5	Siemens	20
5	US Department of Energy	20
ENGINES		
Total		1,308
1	United Technologies Corp/ Pratt&Whitney	31
2	Matsushita Electric	17
3	General Electric Co	16
4	Aisin Seiki Co Ltd	14
5	Daikin Ind Ltd	12
TRACKER SYSTEMS		
	Total	2,069
1	Sanyo	37
2	Toshiba Corp	23
3	Matsushita Electric	20
4	Yeda R&D (Weizmann Institute)	18
5	Boeing	15
COMPUTER/SENSOR SYSTEMS		
Total		2,268
1	Matsushita Electric	28
1	Sanyo	28
3	Mitsubishi Heavy Industries	22
4	Toshiba Corp	19
5	Boeing	15
5	Hitachi	15
5	Yeda R&D (Weizmann Institute)	15

Reflective/concentrator systems in use include parabolic trough, linear Fresnel reflectors, heliostat systems and parabolic disc (see above). The concentrator system is the determining factor of the types of technology platform, while other components (such as engines) can cut across CSP systems. Each has had some success in commercial operations.

Heat transfer systems include patents on various types of materials. It is usually a fluid but can be a solid used in storing systems. The use of molten salt as a heat transfer fluid allows the longer storage of energy (potentially overnight), while the use of air as a heat transfer unit allows higher temperature levels than the use of water/steam.

Engines of three family types are used with different concentrator systems: Stirling, Brayton and Rankine engines. Suppliers of engines may be from other fields: for instance Organic Rankine Cycle engines were developed for the biomass field by Italian company Turboden (bought by UTC's Pratt & Whitney in 2009).

The tracker system is a key CSP component. Each concentrator system entails specific technology challenges. For heliostats, for example, dozens or more mirrors are used to track the sun and to ensure that reflected rays centre on a single point in the solar tower. Components are closely related to software and control systems.

Sensor systems, computing systems and software are critical for optimizing the tracking system, adaptation to the environment (such as high wind), and the control of engine uses. There is a large overlap between the players in this segment and those in 'tracking systems'.

CSP developments attracting most public attention today are desert applications of CSP at scale, requiring the transportation of energy to the point of consumption and thus raising the prospect of a need for high-voltage long-distance transmission lines. The lesson from wind deployment is that the growing deployment of CSP could create niches of applications where new entrants can develop relevant technologies. Emerging markets such as

South Africa and Mexico may become key users of the technology. While their presence in the space as patent owners or patent-filing destinations is as yet minimal, the number of patents – albeit low – indicates the presence of some level of technology-absorptive capacity.

Figure 3.12: CSP – top patent assignee origins

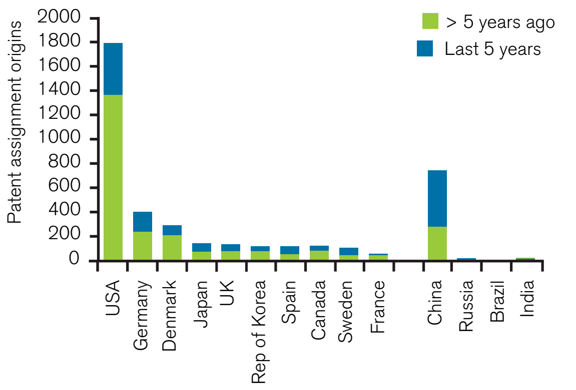


Table 3.12: CSP – concentration of IPR

Top 20 assignee patents as % of all patents in field	
Average all 6 fields	28.5
CSP: overall	14.9
Engines	14.9
Tracker systems	12.3
Computer/sensor systems	11.2
Heat transfer	10.2
Concentrator systems	9.8

3.5 Cleaner coal

Coal power makes a significant contribution to power generation in most developed and developing economies. A large number of coal power plants built in the recent past have been in emerging markets, with many more planned.[11]

China on its own accounted for 42 per cent of global coal consumption in 2008 (compared to 16 per cent for Europe and Eurasia). But some developed economies are also an important market for cleaner coal applications; in 2008 the US economy relied on coal for up to 40 per cent of its generation capacity, and coal accounted for 17 per cent of global coal consumption.[12]

Given the prevalence of coal use across the world, the deployment of cleaner coal technologies is of critical importance. Yet in terms of growth in patenting rates, they are among the 'laggards', especially considering the proportionately larger role that coal has played historically in energy systems. Most companies patenting in this space are from OECD economies. They come from diverse industries: steel, turbine equipment, oil and gas, and air-supply equipment.

Table 3.13: Cleaner coal – top patent holders

	Assignee	No. of patents
	Total	7,059
1	Babcock Hitachi Kk	557
2	Mitsubishi Heavy Ind Ltd	404
3	Hitachi Ltd	265
4	Nippon Steel Corp	227
5	Kawasaki Heavy Ind Ltd	210
6	Ishikawajima-Harima Heavy Industries Co Ltd	190
7	Posco	141
8	Sumitomo Metal Industries Ltd	137
9	NKK Corp	126
10	ExxonMobil	111
11	Combustion Engineering	108
12	General Electric Co	96
13	Air Products and Chemicals Inc	68
14	Voest-Alpine Industrieanlagenbau GmbH & Co	67
15	Babcock & Wilcox Co	65
16	Ebara Corp	63
17	Kobe Steel Ltd	57
18	Siemens Power Generation Inc	52
18	Chevron Texaco	52
20	Foster Wheeler Energy Corp	50

3.5.1 Areas of innovation within cleaner coal combustion sub-spaces

Three types of cleaner coal applications are explored in this research: pulverized coal combustion (PCC), pulverized coal fluidized bed combustion (PCFBC)[13] and integrated gasification combined cycle (IGCC) technologies (see Box 3.6).

In PCC and PCFBC systems the coal is ground into powder to improve efficiency. These technologies are already globally deployed. In contrast, only five IGCC power plants have been launched globally, each with a capacity of around 300 MW. In IGCC, the coal is gasified prior to combustion. While the technology is proven, innovative steps are needed to scale it up cost-effectively.

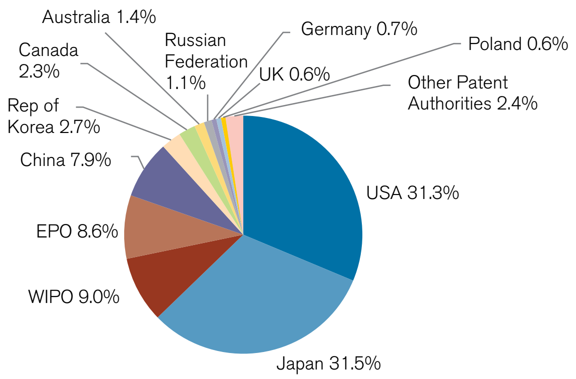
Part of the early wave of environmentally focused innovation in coal power generation was focused on the reduction of sulphur oxide and nitrous oxide emissions in response to acidification of the environment. Some of the technologies developed for flue gas cleaning (especially amine-based systems for SO_2 control) are now being adapted for absorbent-based carbon capture (see section 3.6).

3.5.2 Key trends: geographical distribution and IP ownership concentration

Filing destinations

While the United States and Japan dominate the patent filings space, Chinese patent filings now represent 7.9 per cent of all patents – a significant rise from a very low base only five years ago. The low level of filings in Germany can be accounted for partially by filings through the EPO. South Korea also emerges as an important patent filing jurisdiction, on the back of local industrial capabilities in this space.

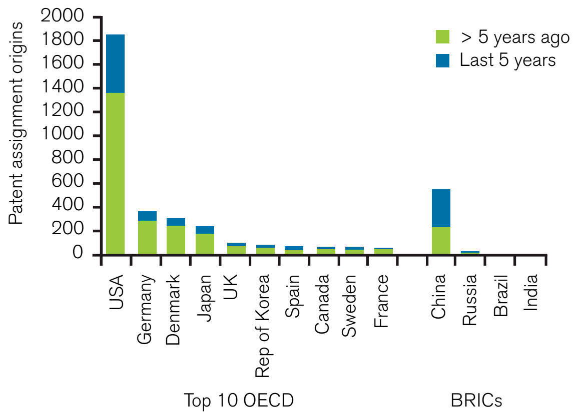
Figure 3.13: Cleaner coal – patent filing locations



Location of assignees

The number of assignees is dominated by organizations based in the United States, followed by Japan, Germany and South Korea. The United Kingdom and France are also in the top 10 in the OECD. These countries broadly correspond to the location of some of the leading turbine engineering companies globally. However, China comes ahead of Germany and Japan on the back of strong patent growth in recent years.

Figure 3.14: Cleaner coal – top patent assignee origins



IP ownership concentration

Higher IP ownership concentration of cleaner coal technologies is partly explained by vertical integration within the industry. Most are owned by US and European companies. Today, China, India and Russia are major markets for modernizing and installing new coal power plants. Specific market conditions play an important role in the extent to which IPRs may be a barrier to deployment of the latest technologies.

Table 3.14: Cleaner coal – concentration of IPR

Top 20 assignee patents as % of all patents in field	
Average all 6 fields	28.5
Cleaner coal: overall	43.2
PCC & PCFBC	42.9
IGCC	43.3
Emissions control	44.2
Biomass/co-firing	32.1
Advanced alloys	45.4

Box 3.6: Cleaner coal subsectors in detail

Table 3.15: Top five patent owners in cleaner coal sub-spaces

		No. of patents
PCC & PCFBC		
	Total	2,190
1	Hitachi	225
2	Mitsubishi Heavy Ind Ltd	103
3	Kawasaki Heavy Ind Ltd	63
4	Exxon Research and Engineering Co	54
5	Voest-Alpine Industrieanlagenbau GmbH & Co	45
IGCC		
	Total	1,333
1	Mitsubishi Khehvi Indastriz Ltd	86
2	Hitachi	72
3	General Electric Co	54
4	Air Products and Chemicals Inc	53
5	Toshiba Corp	35
BIOMASS/CO-FIRING		
	Total	305
1	General Electric Co	18
2	Hitachi	9
3	Ishikawajima-Harima Heavy Industries Co Ltd	7
4	Future Energy GmbH and Manfred Schingnitz	6
5	Manufacturing and Technology Conversion	5
EMISSIONS CONTROL		
	Total	1,635
1	Hitachi	321
2	Mitsubishi Khehvi Indastriz Ltd	82
3	Ishikawajima-Harima Heavy Industries Co Ltd	40
4	Kawasaki Heavy Ind Ltd	34
5	General Electric Co	30
BIOMASS/CO-FIRING		
	Total	305
1	General Electric Co	18
2	Hitachi	9
3	Ishikawajima-Harima Heavy Industries Co Ltd	7
4	Future Energy GmbH and Manfred Schingnitz	6
5	Manufacturing and Technology Conversion	5
ADVANCED ALLOYS		
	Total	262
1	Texaco Inc	21
2	Inco Alloys International Inc	9
3	Hitachi	8
3	Sumitomo	8
5	Conoco Inc	7

PCC: Coal is ground into powder, mixed with air and burned. Process efficiency is increased from the traditional 35 per cent to 45–50 per cent through higher burning process temperatures of up to 700°C, increasing the pressure of the steam. Key areas of innovation include improved alloy materials for the boilers, and improved emissions control (SO_2 and NOx).

PCFBC: Coal powder is mixed with crushed limestone, and placed on a bed or vessel, where it is turned to liquid at high heat – up to 800°C. The level of efficiency is similar to that of PCC, and the advantage is that NOx formation is lower in PCFBC (though N_2O is higher). Scaling up this technology remains a key challenge. While PCC plants can reach up to 1,000 MW in one boiler, for PCFBC so far maximum boiler capacity is 300 MW. That makes the technology less attractive for emerging markets such as India and China which have been focusing on rapid scaling up of their generation capacity.

IGCC: Ground coal is burnt in a low-oxygen environment: resulting in incomplete combustion; synthetic gas fuel is the side-product. The gas is then burnt in a combined cycle. While the technology is proven, innovative steps are needed for scaling it up cost-effectively. Part of the early wave of environmentally focused innovation in the coal-power generation space was focused on SOx and NOx emissions reduction. Some of the technologies developed for flue gas cleaning (especially amine-based systems for SO_2 control) are now being adapted for absorbent-based carbon capture.

Co-firing of coal plants with various types of biomass is seen as an intermediate step in the 'cleaning-up' of coal power generation, as discussed in section 3.4 above.

Advanced alloys are used to lower costs and increase the the performance of cleaner coal power generation at high temperature. Nickel-based alloys in particular have been used in many of the super-critical boiler applications.

3.6 Carbon capture

A number of technology families underpin the different stages in carbon capture and storage (CCS) systems. Despite significant industrial experience in individual areas, there remain great opportunities for advancing the integration of the CCS components, scaling up the process and de-costing the various processes.[14] The analysis here focuses on the technologies for carbon capture (see Box 3.7).

Carbon dioxide is a commonly found 'impurity' in oil deposits, natural gas and other industrial processes. Consequently CO_2 separation techniques have been applied in various industrial contexts by the oil and gas industry, including enhanced oil recovery, liquefied natural gas and oil refineries. Carbon separation processes are also used in fertilizer production and other chemical industry applications. While not all the existing technologies and approaches are directly transferable to carbon capture in power generation, significant capabilities in many carbon intensive industries can be deployed in scaling up carbon capture technologies in the near future.

Different technologies are required at different steps in the process: so chemical engineers may focus on the CO_2 removal step, oil companies on transport and storage, and turbine companies in gasification.

Table 3.16 therefore includes oil and gas companies (ExxonMobil, Shell, Texaco, Chevron, BP), equipment manufacturers (Alstom, General Electric, Mitsubishi), chemicals industry players (Air Liquide, Dow Chemical, BASF) and specialists service providers (such as Honeywell).

Most of the largest patent portfolio owners in this area are major players in the power generation, oil and gas and chemicals production. Oil companies ExxonMobil and Shell have respectively three times and twice as many patents as the third company on the list. In addition, ExxonMobil has top one or two positions in all the technology subsets analysed.

The strong presence of oil and gas companies and their suppliers reflects their capabilities in enhanced oil recovery and refinery operations. But there is a wider mix of organization types, including universities and research institutes, the US Department of Energy, and new entrants with novel technologies (outside the top 20 but across the whole technology space).

Table 3.16: Carbon capture – top patent holders

Rank	Assignee	No. of patents
	Total	9,160
1	ExxonMobil	978
2	Shell	414
3	UOP Inc (Honeywell Subsidiary)	223
4	Air Products And Chemicals Inc	180
5	Texaco Inc	120
6	Chevron	117
7	Conoco Phillips	111
8	General Electric Co	101
9	Praxair Technology Inc	100
10	Ashland Inc	83
11	Alstom	76
11	BP	76
13	Air Liquide	75
14	Mitsubishi	70
15	Dow Chemical Company	49
16	Ebara Corp	43
17	Engelhard Corp	40
18	Basf AG	39
18	Occidental Petroleum Corp	39
20	Union Carbide Corp	34

3.6.1 Areas of innovation within key sub-spaces

Current R&D and CCS demonstration efforts focus around several types of coal power generation: post-combustion, pre-combustion and oxyfuel. To overcome the high energy overhead or penalty and the relatively high investment costs, some industrial approaches are focusing on improvements through incremental innovation around proven technologies such as adsorbents, absorbents and solvents. Step-changes approaches centre on the use of membranes, enzymes and other novel approaches to capture carbon. Both approaches are examined in this analysis.

Post-combustion technologies are particularly relevant for retrofitting existing power plants to remove CO_2 from flue gas, usually through a chemical separation process. Pre-combustion carbon capture involves the removal of CO_2 prior to combustion, typically in the context of coal gasification (within an integrated gasification combined cycle plant design),[15] or another gas.

In oxyfuel combustion coal is burned in pure oxygen rather than air. The combustion process results in flue gas with 95 per cent or more CO_2 concentration, which can then be compressed for transportation and carbon sequestration. The majority of patents that explicitly note the combustion type are focused on pre-combustion. However, many relevant patents in this space do not make explicit mention of the applicable combustion type. Box 3.7 shows key types of CO_2 separation processes in more detail.

As shown in Figure 3.15, patents on sorbents remained higher from the mid-1980s onwards. With the exception of enzymes, patents across all the sub-spaces started to climb in the mid-1990s, a trend which continues to the present. There is a pronounced increase in separation technology patenting since 2000 across all technology types.

3.6.2 Key trends: geographical distribution and IP ownership concentration

Filing destinations

More patents were filed in the United States than in all other countries taken together. In combination with the data on location of assignees, this finding confirms overall US leadership in the carbon capture space.

Location of assignees

US-based assignees dominate the space. This can be attributed to factors including an early focus on enhanced oil recovery and industrial uses of separation technology in refineries and petrochemical plant. In addition, in the carbon storage field (which is not part of the analysis here), US-based oil companies pioneered reservoir studies and later brine reservoir studies, which can be used for 'sinks' for carbon sequestration. Even where non-US companies are operating in the carbon capture or EoR space, they often do so in partnership with US companies.

Figure 3.15: Patenting rates by selected carbon capture technologies since 1976

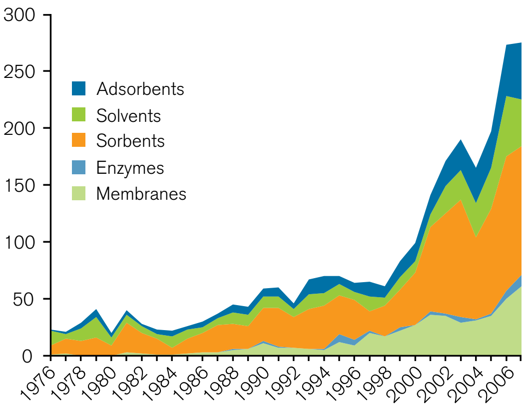
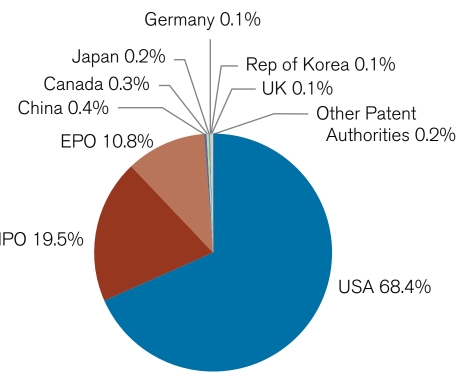


Figure 3.16: Carbon capture – patent filing locations

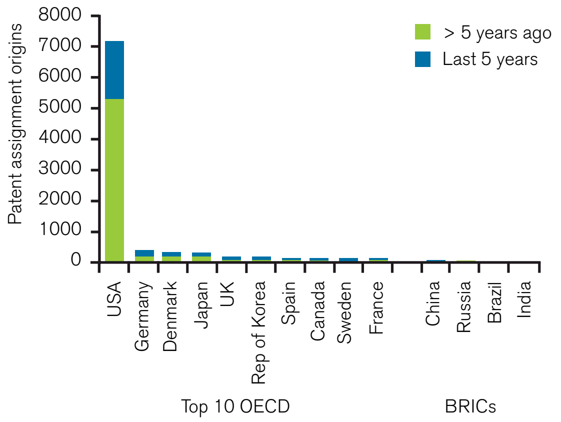


IP ownership concentration

There is a relatively high IP ownership concentration in this field, with the top 20 assignees accounting for 32.4 per cent of all patents. The level of concentration is even higher in selected technology fields, such as membranes. Many of the most likely 'first deployment' technologies have been in industrial use for decades. As mass deployment is only expected around 2020, it is likely that many of the fundamental technology patents will have expired. Provided that the patent owners are willing to participate, invest or share, patents in this area should be not pose significant barriers given their use in many industrial fields.

However, when patents expire, the owners of the technologies can protect their IP by use of trade secrets, know-how embedded in their technologies, and also

Figure 3.17: Carbon capture – top patent assignee origins



by extending and renewing design rights around the product systems. Also, current R&D in scaling up and integrating carbon capture in plant design as well as the development of novel approaches will result in a fresh generation of patents which will be valid for up to another 20 years – spanning the critical mass deployment period. In addition, crossover technologies such as enzyme-based carbon capture may already be backed by strong patent portfolios from within the biotech industry.

Table 3.17: Carbon capture – concentration of IPR (%)

Average all 6 fields	28.5
Carbon capture – overall	31.8
Adsorbents	34.7
Solvents	25.4
Absorbents	46.1
Membranes	31.1

While developers of novel carbon capture methods are not dominant in this space, the novelty of their approaches may increase their relative impact in the move towards commercialization. It is also of interest that the leading companies differ significantly between the carbon capture and cleaner coal spaces. As

Box 3.7: CCS in brief

Carbon capture at source: Carbon capture technology at scale is likely to be applied beyond the power generation sector to cement, steel and chemical production and transportation and the built environment.[a] However the bulk of current R&D and deployment efforts is focused on integration of carbon capture at coal power plants (soon to be followed by natural gas combined cycle plants). Carbon capture was the only area of CCS covered by the current study.

CO_2 transportation: Innovation in this area is most likely to result from adaptation of existing pipelines to CO_2 transport (e.g. mature pipeline technologies used in the oil and gas industry), addressing problems such as the prevention and detection of corrosion and leakage, or the transportation of CO_2 by marine tankers.

Carbon storage: Most current discussion is focused around the storage of CO_2 in deep geological sites (most likely saline aquifers), depleted oil and gas reservoirs (providing additional investment incentives through enhanced oil and gas recovery) and possibly unusable coal mines. Other storage proposals include oceanic sequestration, and solid CO_2 capture techniques. (A preliminary search identified in excess of 20,000 patents in this space – a very large number that is probably accounted for by the overlap with enhanced oil recovery and other oil and gas industry technologies.)

Direct capture/geoengineering solutions: There is also research into more radical technologies that aim at 'direct capture' of CO_2 from the atmosphere and its storage or disposal.

a Committee on Climate Change (2008), *Building a Low-Carbon Economy – The UK's Contribution to Tackling Climate Change.* UK Stationery Office. www.theccc.org.uk/pdf/TSO-ClimateChange.pdf.

Box 3.8: Carbon capture subsectors in detail

Table 3.18: Top 5 patent owners in cartbon capture sub-spaces

Top Assignees		No. of patents
CARBON CAPTURE: ADSORBENT		
	Total	504
1	Air Products and Chemicals Inc	27
2	Praxair Technology Inc	21
2	Questair Technologies Inc	21
4	UOP Inc	14
5	BOC Group Inc	11
5	ExxonMobil	11
5	General Electric Co	10
CARBON CAPTURE: ABSORBENTS		
	Total	1,395
1	ExxonMobil*	78
2	ConocoPhillips	54
3	UOP Inc (Honeywell Subsidiary)	30
4	Air Products and Chemicals Inc	28
5	Praxair Technology Inc	22
CARBON CAPTURE: SOLVENTS		
	Total	568
1	ExxonMobil	32
2	BP	17
3	UOP Inc (Honeywell Subsidiary)	16
4	Marathon Oil Company	15
5	Shell	14
CARBON CAPTURE : MEMBRANES		
	Total	623
1	Air Products and Chemicals Inc	28
2	ExxonMobil	25
3	General Electric Co	16
4	Praxair Technology Inc	15
4	Shell Oil Company	15

Absorbents and adsorbent-based technologies are seen as the most likely first applications of carbon capture. Absorbents based on amines use chemical reactions to absorb CO_2. The technology was initially used for SO_2 capture, and many of the patents identified originate from desulphurization experiences. Absorbents based on sodium-containing materials can be introduced in the fluidized bed, allowing direct capture of CO_2. Adsorbents are amorphous solid carbon materials that can capture CO_2 on their surface, and release it by reducing the pressure.[a] Absorbent technologies are seen as the most advanced, with adsorbent technologies still in R&D stage. More advanced solid-sorbent based technologies include simple porous crystals (zeolites, hydrotalcites, and activated carbon), functionalized solid sorbents (nitrogen enhanced or amine enhanced) and dry regenerable (based on carbination/calcination of natural limestone, calcium-based, alkali carbonate based). Absorbent technology can also be used in air stream purification for oxyfuel applications.[b]

Solvent-based technologies are used to capture CO_2 from flue gas from coal fired power plants. Current carbon capture technology is based on a general purpose solvent, monoethanolamine (MEA), which chemically absorbs CO_2 – one that has been used in other industries. However it has a number of disadvantages: it is non-selective, corrosive, requires large-scale equipment, and only effective under low to moderate partial pressures of CO_2. The scalability, energy efficiency and pressure requirements of CCS are stimulating research into improved solvent efficiency and behaviour, e.g. ionic liquids, potassium carbonate (K_2CO_3) and chilled ammonia (NH_3).[c]

Membranes-based technologies[d] are relatively immature, with applications suitable for pre-combustion capture processes, where membranes are used for air purification. Other efforts focus on increasing the membrane effectiveness in separating CO_2 gas from the remainder of the gas stream (flue gas). Bringing it to market may require additional systems such as vacuum pumps.

Enzymes-based approaches exploit the natural power of a biocatalyst – carbonic anhydrase – an enzyme that enables humans and other mammals to manage CO_2 during respiration. Some companies are applying the biomimetic approach to CO_2 capture, working to adapt enzymes to function within an industrial environment. While only a small number of patents are identified in this area, this technology is likely to play an increasingly important role in the CCS industry.

a *Carbon Capture Journal* (2009), CO2CRC H3 capture project launched, 9 July, http://www.carboncapturejournal.com/displaynews.php?NewsID=416; Gough, C. and Shackley, S. (2006), *Carbon Capture and its Storage,* Ashgate Publishing Group, Farnham, UK.

b Praxair (2008), Gasification: Upgrading fuel values, http://www.praxair.com/praxair.nsf/AllContent/BD2C39F89858F865852572A000574BC4?OpenDocument&URLMenuBranch=284146C36EAFABD6852572A50074F169.

c Kothandaraman, A., Nord, L., Bolland, O., Herzog, H., and McRae, G. (2008), *Comparison of Solvents for Post-Combustion Capture of CO_2 by Chemical Absorption*, presented at the 9th International Conference on Greenhouse Gas Control Technologies, Washington, DC, November. http://sequestration.mit.edu/research/solvents.html; Energy Efficiency News (2008), Screening method could lead to more efficient carbon capture, 24 July, http://www.energyefficiencynews.com/power-generation/i/2290/.

d See the following example of a membrane technology: Bellona (2009), *Novel Technologies*, 16 February, http://www.bellona.org/ccs/Artikler/novel_technologies/#2.

carbon capture technologies evolve, power generation equipment manufacturers may seek to acquire, license or develop in-house some of the technologies identified, especially in the integration of carbon capture in power plant designs.

Many of the patents are held by large companies in both the oil and gas and heavy equipment sector. Emerging IP issues may be related to vertical integration, and the embedding of technology in the design of equipment. Many oil and gas companies may be in the position of holding large patent portfolios (and underlying technology capabilities) across the full chain of CCS.

Notes

1 Global Wind Energy Council (2008), *Global Wind Energy Outlook.*

2 For instance, the building of onshore wind farms in more densely populated areas has revealed the need for innovation around noise reduction and reduced radar impact of wind farms on air traffic control.

3 Enercon GmbH v. USITC, 97-1554 (08/12/1998), www.ll.georgetown.edu/Federal/judicial/fed/opinions/97opinions/97-1554.html.

4 European Wind Energy Association (2009), *Wind Energy – The Facts*. www.ewea.org/fileadmin/ewea_documents/documents/publications/WETF/1565_ExSum_ENG.pdf.

5 *The Guardian* (2009), 'Winds of change come to country plagued by power blackouts', 30 December.

6 IC Insights (2009), *Solar Energy: Growth Opportunities for the Semiconductor Industry*. See www.icinsights.com/news/bulletins/bulletins2009/bulletin20090720.html.

7 See IC Insights, *Research Bulletin*, 20 July 2009, http://www.icinsights.com/news/bulletins/bulletins2009/bulletin20090720.html.

8 In the settlement, Nanoco agreed to terminate its current US business for its core-shell quantum dots. Those quantum dots were sold in the US by its US distributor, Sigma-Aldrich, under the name Lumidots. In the settlement, Nanoco did not admit that the asserted patents are either infringed or valid. Additional terms of the settlement were not disclosed. Jason Hartlove, chief executive officer of Nanosys, said: 'By enforcing ownership of our intellectually property, the manufacturers remain the real winners in having access to proven, trusted advanced material architecture, including quantum dot applications.' [See Reuters (2009), 'Nanosys Reaches Settlement of Patent Infringement Lawsuit Against Nanoco Technologies for Quantum Dot Technology', 23 July 2009, http://www.reuters.com/article/pressRelease/idUS165155+23-Jul-2009+BW20090723.

9 GE has a history of acquisitions in the energy/environmental space, enabling it to rapidly gain capabilities in new areas of interest. In 2001 it acquired Energy and Environmental Research Corporation (EERC) for its NOx control technologies. It had also acquired Praxis Engineers, providers of software solutions for improvement in coal-power steam plants. In 2001 it acquired Enron's wind energy portfolio, including the assets of Zond Energy (see section 3.1).

10 *The Financial Times* (2009), 'Solar power plants planned for Sahara', 12 July.

11 Waston, J., MacKerron, G., Ockwell, D. and Wang, T. (2007), Technology and carbon mitigation: are cleaner coal technologies a viable option?, *Human Development Report Office Occasional Report, Human Development Report 2007/2008*, May. http://hdr.undp.org/en/reports/global/hdr2007-2008/papers/Watson_MacKerron_Ockwell_Wang.pdf.

12 BP plc (2007), *BP Statistical Review of World Energy,* June 2007.

13 As there are significant systems/engineering overlaps between PCC and PCFBC, we combined our analysis of the two spaces.

14 IPCC (2005), *IPCC Special Report on Carbon Dioxide Capture and Storage*, prepared by Working Group III of the Intergovernmental Panel on Climate Change. Metz, B., Davidson, O., de Coninck, H.C., Loos, M. and Meyer, L.A. (eds), Cambridge University Press. Available in full at www.ipcc.ch. See also McKinsey (2008), *Carbon Capture and Storage – Assessing the Economics*. http://www.mckinsey.com/clientservice/ccsi/pdf/ccs_assessing_the_economics.pdf.

15 Scottish Centre for Carbon Capture and Storage (2007), Pre-Combustion Capture, http://www.geos.ed.ac.uk/sccs/capture/precombustion.html.

4. Understanding Technology Diffusion

There are two major innovation-related dimensions to a successful and timely transition to a low-carbon economy. On the one side is the rapid development of new and applied ideas through research and development. On the other is rapid demonstration, commercialization and deployment of these – and existing – technologies. While patents provide incentives for research and development investments, they may not provide the same incentives for speedy diffusion.

This chapter shows how the examination of patent data can shed light on the operation and effectiveness of different technology diffusion channels. It is important to note that there are tremendous methodological challenges associated with using patent-generated data in understanding technological diffusion. This is due to problems with data availability from different geographical regions, and to the absence of reporting requirements.

4.1 Technology systems interaction/ migration

Technological innovation does not follow a linear logic, nor are innovation processes restricted to boundaries of individual economic sectors. In most industries a wider range of technological solutions can be used to meet a specific need. General purpose technologies such as nanotechnology or advanced alloys have multiple applications across many industries. This means that in applied technology systems it is rare to find pure technologies, as the majority of industrially applicable innovations draw on multiple areas of science, technologies and business practices. Most of the breakthrough innovations occur when different fields interact. These convergences can lead to the dilution of industry barriers and norms.

As described in Chapter 3, gear and transmission systems technology in the wind sector are linked to both transport and other industrial applications. Blade technology owes its advance in part to aerodynamics, the use of advanced composites in aerospace and use of wind tunnels originally designed for aircraft testing.[1] Offshore and marine applications closely intersect with experience in oil and gas exploration and the operation of offshore platforms in extreme environments. CCS technologies originate from a range of petrochemical and enhanced oil recovery applications.

Innovation in solar technologies has benefited from developments in consumer and industrial electronics. Early development of PV cells was driven by advances in science in satellite and industrial laser technologies. Advances in concentrated solar power owe much to aerospace and satellite technologies. This is reflected in the strong patent portfolio owned by Boeing, an aircraft manufacturer. Seven out of the top 20 owners of cleaner coal technology patents are from the steel sector.

There are also examples in developing economies. The development of pre-paid metering technology in South Africa saw the combination of technological capabilities from the energy sector, and electronics technology and encryption algorithms first developed by South Africa's military industry.[2]

To drive global decarbonization, many different kinds of economic and physical linkages are needed among industrial sectors. Recent developments exemplify the disintegration of traditional industry barriers. In July 2009 ExxonMobil announced a collaborative initiative with Synthetic Genomics Inc. on the commercialization of fuels produced from genetically engineered algae. BP invested $90m into a cellulose biofuels joint venture with Verenium, and a separate one with DuPont.[3] This indicates a convergence between players from the oil and gas, biotech, biomass and chemicals industries into what may become a consolidated bioenergy sector.

Table 4.1: Examples of crossover technologies

Energy technology areas	Source industry
WIND	
Offshore Wind	Oil and gas offshore platform operations: rigging, maintenance, underwater transmission Nanotech: structural resistance/strength of wind turbine blades for offshore applications
Wings	Aerospace: aerodynamics, wind tunnels, advanced materials
Gearbox	Machinery and automotive: gears, bearings, transmission systems
Energy storage	Electronics: batteries
Monitoring	Electronics: sensing systems
Software	Meteorology: computer modelling and prediction of micro conditions; optimization of wind farms operations
SOLAR PV	
Concentrator technologies	High-grade concentrators developed in space technology: applied in third/fourth generation PV
Silicon production	Benefit from large volume silicon chip production – and recycling used silicon
Organic PV	Organic light-emitting diodes (OLEDs) in other industries
Solar tracker	Satellite guidance technology and concentrated solar power
CdTe-based PV	Satellite and laser industry advances in uses and generation of III-IV alloys
CSP	
Concentrator technologies	High-grade concentrators developed in space technology
Steam-cycle engines	From engine manufacturers for industrial applications
Organic Rankine Cycle engines	Biomass co-generation and other alternative energy applications with lower temperature cycles
Solar tracker	Satellite guidance technology
Heat transfer fluids	From industrial chemicals field
BIOMASS	
Combustion/gasification	Adaptation of basic technology from coal combustion: especially re: fluidized bed, and steam-based cycles (Rankine Cycle)
Waste combustion	Convergence of municipal waste incineration with energy conversion capture (as early as 1960s)
CHP	Central heating solutions: using experience/infrastructure of municipal/industrial central heating
NOx/SO_2 emissions	Operators in the Powergen industry, such as Air Liquide, are adapting their processes/technologies for use in biomass
CARBON CAPTURE	
CO_2 separation	Biotech: use of enzymes for carbon separation Separation of CO_2 from during the production of hydrogen, e.g. for ammonia production LNG terminals: separation of CO_2 from natural gas prior to entry in national gas networks
Oxyfuel	Entry by NASA-linked companies, using rocket engine technologies for more efficient oxyfuel burn
IGCC	Oil and gas industry: experience in coal transformation in to fuel
PCFBC	Advanced alloys from steel industry, developed in other industrial applications
PCC	Biomass co-firing

Where such convergence takes place, companies from different industries can bring frequently divergent IP practices. For instance, biotech companies may be influenced by the IP strategies of their pharmaceutical clients, for whom cross-licensing has not been the norm. Oil and gas companies come from a highly vertically integrated business environment, with large corporate patent portfolios. Electronics companies entering the space (for instance in software and control applications through all the energy spaces examined) may have relatively more experience with open-source software development and the software industry licensing regimes. As these energy systems mature, it will be important to observe how IP strategies evolve, and whether the emerging leaders rely on litigation and blockage, cross-licensing, or any one of the many corporate IP strategy variations identified in Chapter 1.

Table 4.1 provides examples of how key components of low-carbon energy technologies and capabilities have been adapted from technologies from other industries.

Natural endowments play an important role in determining the innovation pathways. Norway's strength in hydro, offshore technology and carbon capture can be clearly attributed to its abundance of water, oil and gas resources, and associated industries. The same factor underpins Spain's leadership in solar, or Denmark's and the United Kingdom's positions in offshore wind. However, natural endowments alone are not sufficient to drive domestic innovation efforts. Portugal, for example, has excellent wind resources, yet fewer than 10 patents originate from that country, whereas over 300 come from the United Kingdom, despite a similar amount of installed capacity in the two countries.

As shown in Chapter 3, the technological knowledge assets of carbon-intensive industries could prove to be the key in enabling the global transition to low carbon energy system. The fossil fuel and petrochemicals industries, for example, have major advantages in distribution networks and logistics capacity. These sectors are also among the most potent industrial assets of emerging economies such as China and India. These carbon-intensive sectors have considerable strength in areas such as capital and investment portfolios, access to finance, innovation capacity, skilled labour, logistics and supply chain management, integration with key local sectors, and political influence. The key question is how to identify the knowledge assets in high carbon industries and how can they be harnessed for low carbon development.

In this ever more complex technological and competitive environment, companies and investors need to be kept abreast of developments not only in their own field, but in other related areas – whether competing or substitutive. Without a clear understanding of the range of technological options available across different sectors, and how different technological systems interact with each other, policy-makers will struggle when making critical choices about national or local industrial development strategies and investments.

Companies and countries do not develop all parts of the energy system at the same pace simultaneously. Countries also differ in terms of natural endowments and inherited industrial capabilities. Proactive innovation and climate policy-makers therefore face a complex challenge in monitoring technological and commercial developments across a wide range of technological fields.

4.2 Diffusion channels

Collaborative and licensing activities are often a non-transparent part of the companies' economic activities. This is due in part to the absence of uniform reporting requirements, but also to the confidential and strategic nature of many such collaborations and arrangements. As a result, very few licensing data are available in the public domain. Data on actual licensing deals are also inconsistent, and rarely reported in media outlets or company websites or reports. Data on existing patent pools, cross-licensing agreements and other patent transactions are also very scarce. Some actors go out of their way to hide or disguise information, to maintain a competitive advantage.

There are many possible friction points and transaction costs that may contribute to a slow rate of licensing. These include information gaps and the lack of market benchmarks, but also the relatively high legal and other negotiation costs. In principle these can be alleviated through improved access to information and benchmarks for transaction values and types. Private-sector participants are likely to find full disclosure requirements difficult to implement in practice owing to confidentiality and strategic considerations.

4.2.1 Collaborative activities: are there enough?

To investigate collaboration in more detail, a dataset has been developed for this study based on co-assignment of patents (i.e. cases where more than one organization is listed as an owner of a patent). Co-assignment is an imperfect proxy for collaborations and licensing. For example, these data may exclude university–corporate R&D collaborations, where corporate partners often retain all ownership of the generated IP as part of academic research sponsorship.[4]

Figures 4.1 and 4.2 give snapshots of collaboration in innovation activities. Most collaboration takes place among OECD entities, mainly among entities within the same country; the sharing of patents on a transnational basis is much less common even within the OECD. This demonstrates the 'localized' nature of relationships between companies and universities and between leading corporations and key suppliers. This pattern is particularly noticeable among Japanese corporations. Some of the collaborations identified are among major companies that may not be competitors but have a supplier–client relationship. In solar PV, for example, glass manufacturers such as Asahi have collaborated with suppliers and clients alike in developing technologies around thin-film PV. The bulk of collaborations identified involved large national and multinational corporations.

Even though there are currently few data on collaborations and licensing, the expectation is that both will accelerate as investment in R&D and deployment in the energy sector increase. This calls for the establishment of some market benchmarks and more transparency.

4.2.2 Measuring diffusion rate: timeline and geography

In any industry a relatively small number of highly influential patents receive the bulk of citations by future patents. By analysing the forward citations of a sub-set of influential and highly cited patents, this section explores patterns of diffusion including the estimated timeline for diffusing technology, the geographic composition, and the correlation between the maturity of the technological sphere and diffusion trends of a sector.

US patent citation data have been used to analyse the relative diffusion rate of the low-carbon energy technologies. Until recently the United States was regarded as the largest market for energy technologies. Many developing-world corporations file their patents in the United States

Figure 4.1: Domestic versus international collaboration

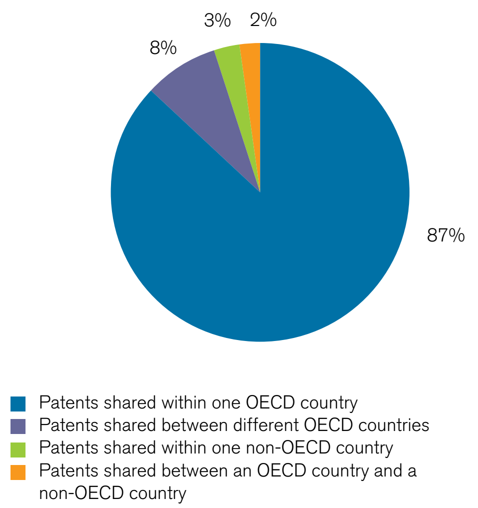
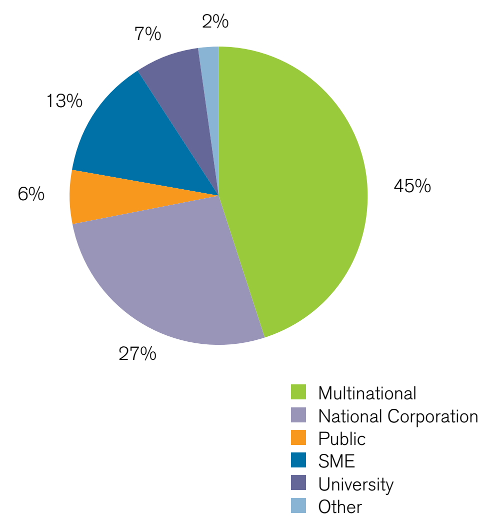


Figure 4.2: Collaborations by organization type



for strategic and legal reasons. So while imperfect, US patent citation data can act as a proxy for global diffusion of low carbon technologies.

Analysis of the top 30 most frequently cited US patents in each of the six fields shows that the majority (some of which can be understood as 'foundational') are owned either by companies or individuals (Table 4.2). Individuals are quite likely to have either formed a company on the back of the underlying IP or licensed it to corporate players. Only a small number of patents are obvious results of public sector research. One possibility is that private-sector players tend to acknowledge explicitly patents held in the private sector as foundational: university IP may be less visible to patent writers/examiners.

The average age of the top 30 cited patents ranges between 19 and 30 years across the six energy technologies. As patent protection lasts no more than 20 years, it would appear that protection on a significant part of what could have been considered as foundational IP has already expired. The analysis also illustrates that in energy technologies information diffusion is a slow process, and that it took a long time for these important patents to be used in a subsequent invention. This is a worrying conclusion given the urgent need for transformation of the global energy system.

Most of the technology underlying these patents would have become known in the industry within a few years of their filing. Yet they only became leaders in terms of citations towards the end of their economic life. This may be due to the fact that, until a few years ago, advanced energy technologies did not seem to be commercially attractive areas for investment.

Consistent with the findings in Chapter 3, most of the highly cited patents in the carbon capture space are owned by oil and gas companies. For wind energy technologies, owners of the top 30 most-cited patents are more diverse, and on average younger.

Many patents have been filed citing invention from the top 30 most cited patents. Looking at their patent-filing year provides insights into diffusion timelines, i.e. the spread of patent-related knowledge within a sector. The citation timeline for both wind and PV accelerated significantly in the 1990s, in contrast to cleaner coal (Figure 4.3). This is in part a function of the rising levels of patenting in these two fields. Even for these fast-moving sectors, significant technology diffusion seems to take more than 20 years.

The geographic spread of patent assignees that had used the top 30 most-cited patents shows the United States as the leading country, in contrast to cleaner coal. This is not surprising given the focus here on patents filed in the United States. Figure 4.4 shows the analysis of those held by non-US assignees, providing a better understanding of the geographical dimensions. Japan clearly stands out in comparison with other countries. There are far higher numbers of US patent citations by Japanese companies on solar PV and wind than by those from other countries. This is quite likely related to the presence of several influential US patents owned by Japanese organizations, which are in turn cited by the US-registered patents of other Japanese organizations. It is evident that US patents by other OECD countries including Germany, France, Canada, the Republic of Korea, Sweden and the United Kingdom have also been actively cited or used for technological improvements.

Table 4.2: Top 30 most frequently cited patents: six energy technologies

Field	Total no. of forward citations	Average age of top 30 patents	Public/private sector		
			Public	Private	Individual
Wind	1,515	19	5	19	6
PV	3,031	22	4	21	5
Biomass	1,342	25	3	26	1
CSP	1,370	30	4	13	13
Cleaner coal	1,825	27	0	27	3
Carbon capture	4,056	22	1	27	2

Figure 4.3: Diffusion timeline for most frequently cited patents

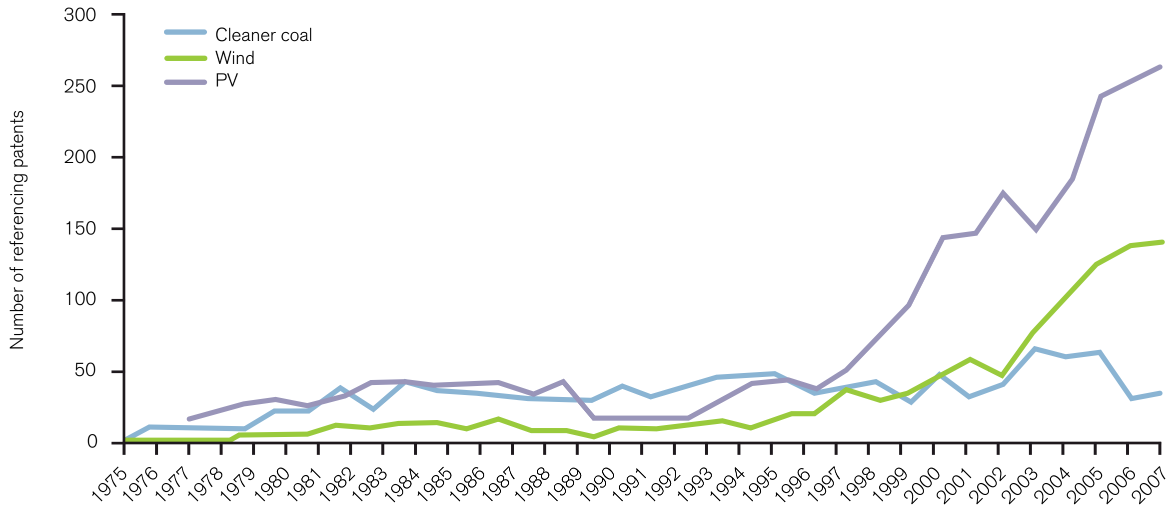
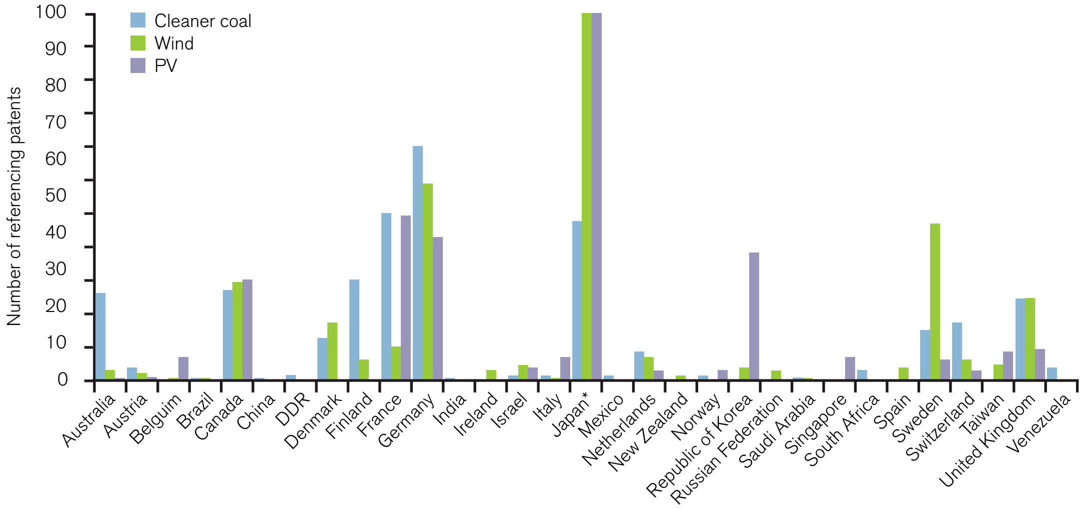


Figure 4.4: Referencing patents by assignee origins (excluding the United States)



Note: The Y-axis was truncated at 100 patents.

*For Japan, the number of referencing patents is 101 for wind and 824 for PV.

Figures 4.5, 4.6 and 4.7 describe the rate of citation for these top 30 most cited patents in wind, solar PV and cleaner coal. Five-year time slices show the periods in which these citations took place. The finding here is that the rate differs significantly between countries – and sectors. In cleaner coal, for example, the majority of German patents citing the top 30 were from the 1983–87 period, while for Japan they were filed between 1998 and 2007. The diffusion patterns in both PV and wind sectors are dominated by Japanese owners of US patents, the bulk of which were registered from 2000.

The reality on the ground is that inventors become aware of new technologies on the back of a combination of information sources: working experience, academic research, existing networks, invent-around or reverse engineering efforts and so on. Such experience provides the information and background with which inventions, entities and technology descriptions are developed. That in turn informs both the formulation of research and development programmes, the decision (and strategy) of patent-searching, and finally patenting strategies. So while the patent citation data are an important proxy, they probably lag several years behind the actual timeline of exposure to fundamental patents (and the embodiment of patent information in products, brochures, and so on). Expansion of this type of analysis to a larger subset of patent authorities may provide further understanding of the patterns of diffusion internationally.

Figure 4.5: Cleaner coal diffusion – geography and timeline

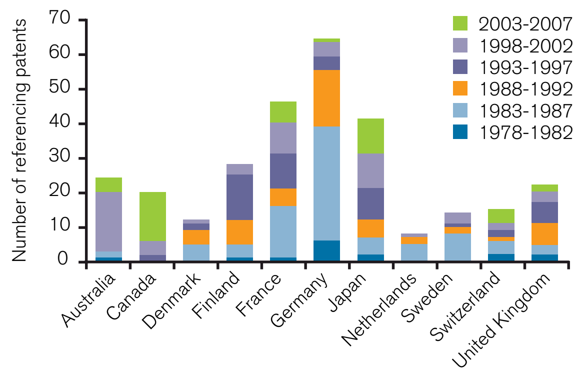


Figure 4.6: PV diffusion – geography and timeline

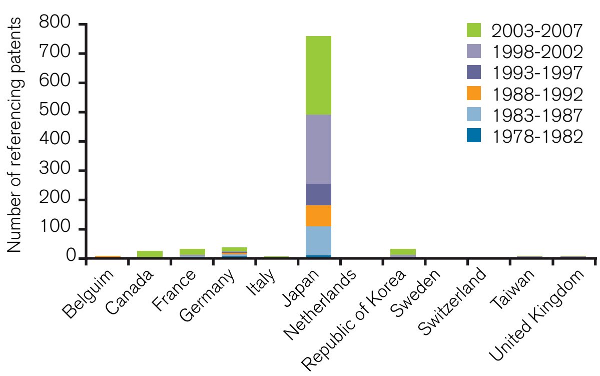
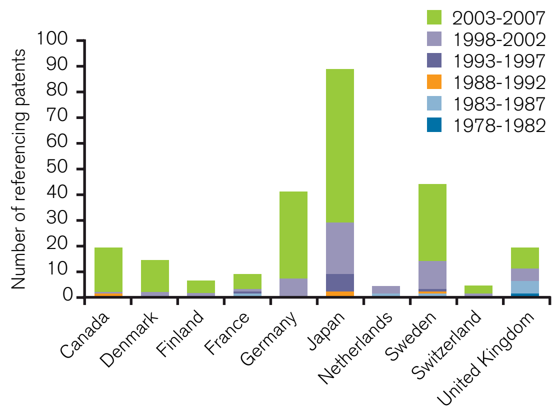


Figure 4.7: Wind diffusion – geography and timeline



4.2.3 Inventor networks

The networking and movement of inventors within the innovation system are important factors in the diffusion of technological know-how. As employees they may be requested to sign confidentiality and IP ownership agreements, but when scientists and engineers move between jobs or set up their own enterprises they carry knowledge of technologies and their professional networks. These can be used by competitors and in non-competing industries to adopt technologies from elsewhere, or invent-around patent barriers. Professional networks of former employers can accelerate the formation of collaborations, research projects or even new ventures. Research on the role of 'brain circulation' in accelerating technological development, inward technology transfer and access to export markets in emerging economies is available, an example being studies on Chinese entrepreneurs and the linkages between Silicon Valley and Chinese industry.[5]

Mapping these inventor networks at global, national or industry level could assist companies, industry associations and policy-makers in understanding the availability of domestic inventor networks on energy and related technologies, as well as their international linkages. If used strategically, this understanding can form the basis of global collaborations through identifying individuals and networks with the most relevant know-how in these sectors.

For this report, network analysis on specific companies and organizations was conducted to demonstrate the value of understanding these inventor networks as a proxy for technological diffusion. The maps produced illustrate linkages between inventors and assignees on the basis of co-inventorship or co-ownership of patents. The blue circles in Figures 4.8 to 4.10 denote inventors, while the red circles denote patent owner, with the lines denoting co-presence on a patent. The maps captures information for 'all time', and can therefore show the history of linkages of some inventors.

The diagrams show patenting portfolios are associated with a large number of inventors (in some cases numbering in the hundreds). At least in the corporate environment, the lonely genius inventor is a myth. Each of these inventors may have been a direct employee or a consultant of one company or another at the time of invention. In the cleaner coal space, a number of ExxonMobil's employees have also been inventors on patents owned by Esso, Tosco Corp, the US Department of Energy and the US Environmental Protection Agency. In the carbon capture space, PraxAir employees have linkages with Air Products and Chemicals Ltd, while in the CSP space Boeing employees have linkages with Pratt & Whitney, UTS and McDonnell Douglas (subsequently acquired by Boeing). Analysis of the network of inventors of the Chinese Academy of Sciences in the biomass field reveals linkages with the Shengli Power company. Finally on solar PV, Japan's Kyocera is shown to have network linkages with at least three companies.

This analysis of the inventor networks shows a very high level of private-sector cross-fertilization among companies and institutions in the development of new technologies. To speed up technology diffusion, these inventor networks need to be broadened to encourage rapid cross-fertilization between inventions from different sectors in different countries.

Figure 4.8: Linkages of Boeing in concentrated solar power

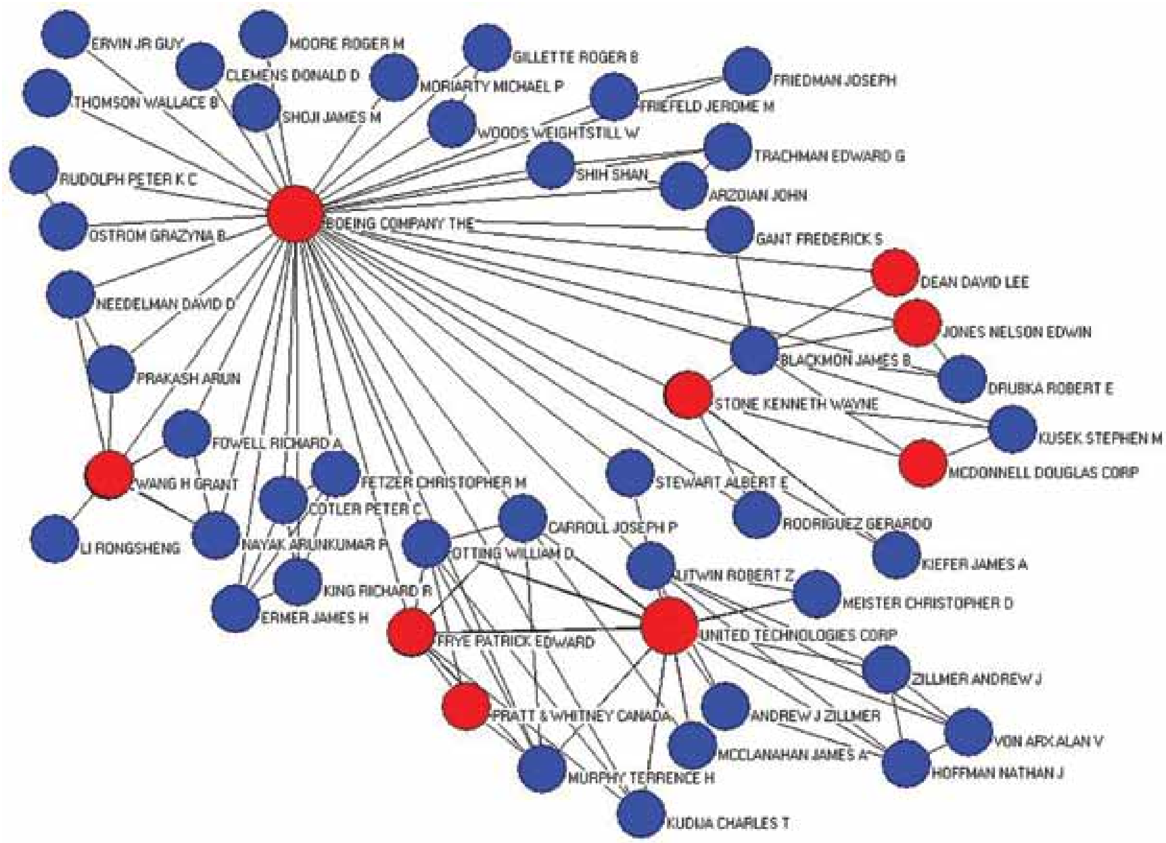


Figure 4.9: Linkages of Praxair in carbon capture

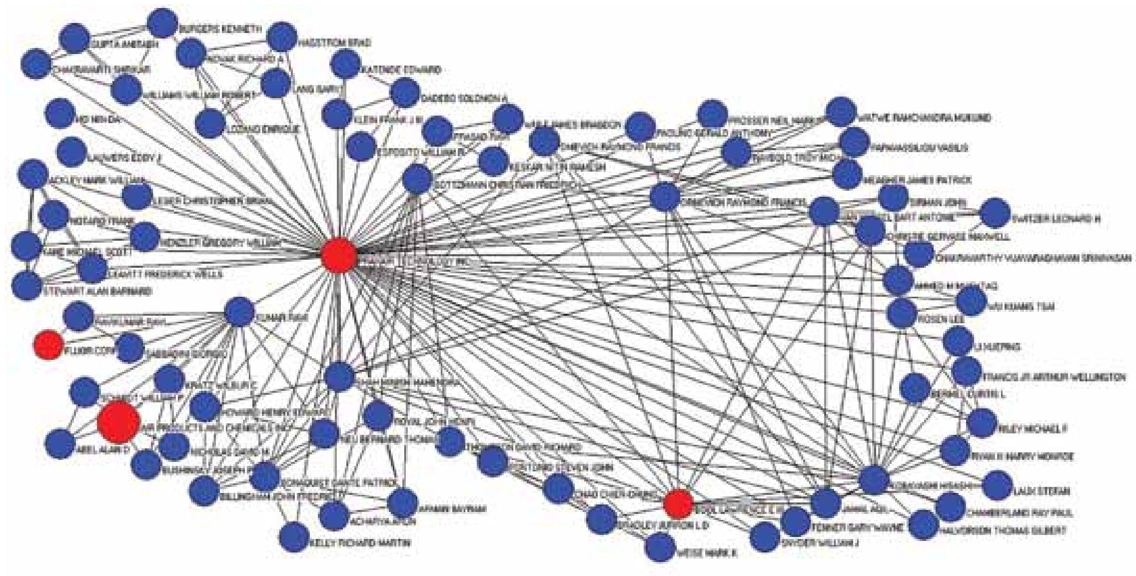


Figure 4.10: Linkages of ExxonMobil in cleaner coal

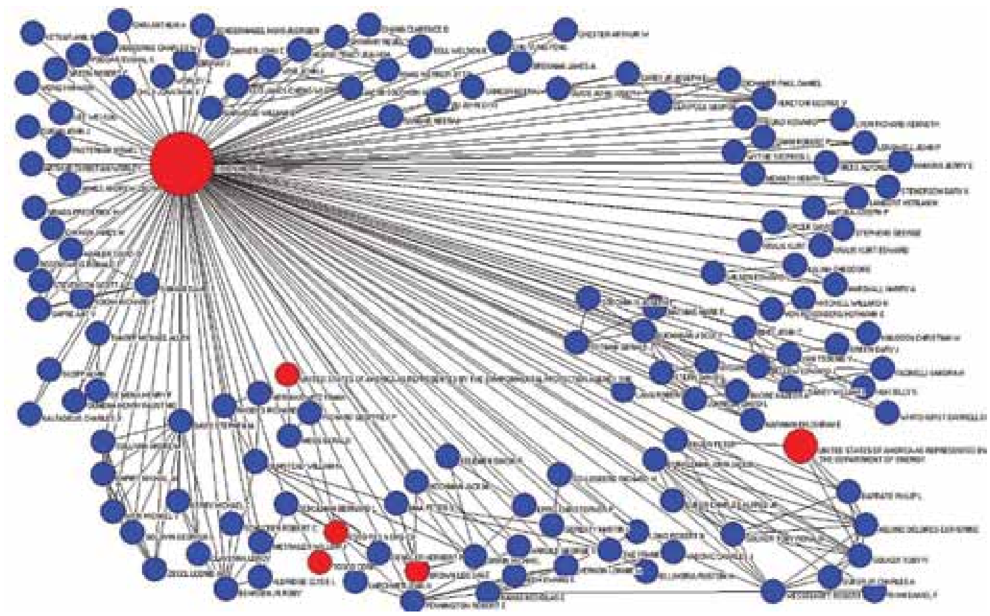


Figure 4.11: Linkages of Chinese Academy of Sciences in biomass-to-electricity

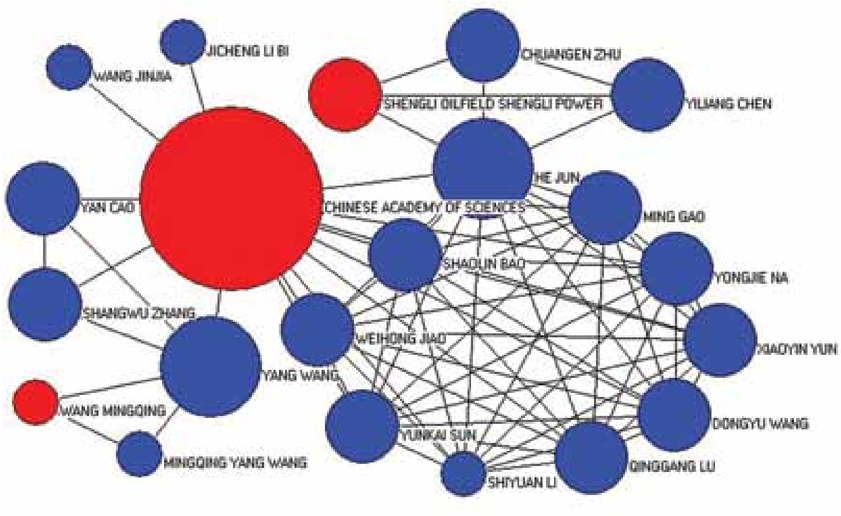
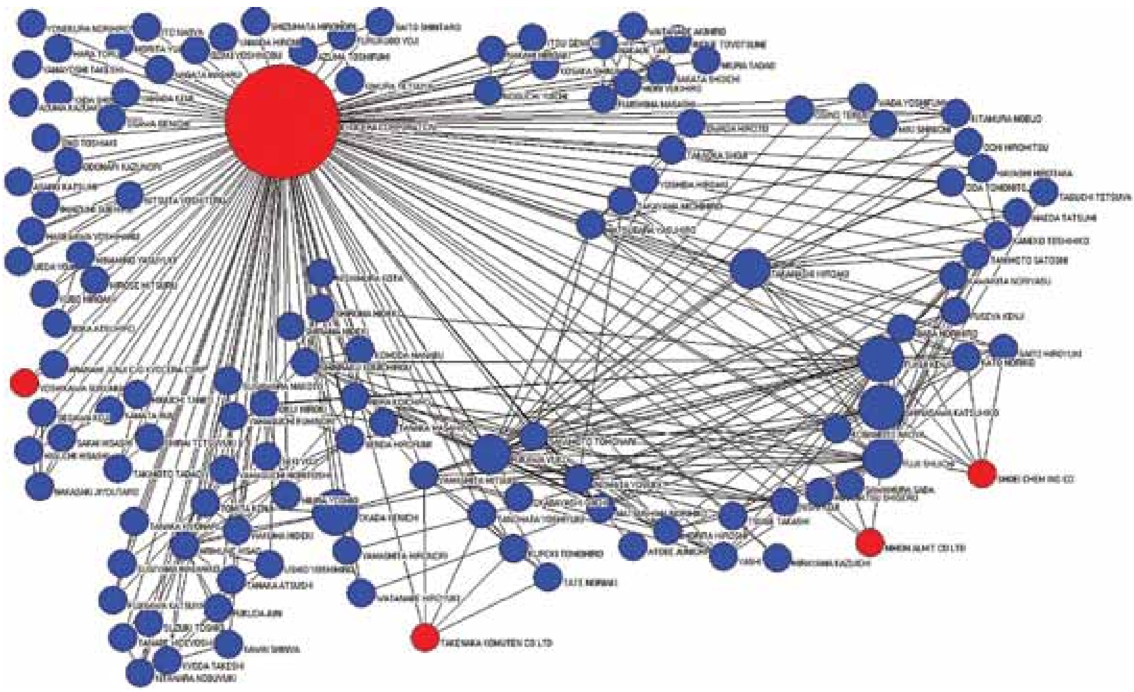


Figure 4.12: Linkages of Kyocera in solar PV



Box 4.1: Litigation

The cost of patent litigation is very high, frequently running into tens of millions of dollars. The likelihood of patent litigation increases with the maturity of an industry or a company – when litigation becomes affordable and commercially sensible. Patent litigation can occur in many contexts, including:

- *Licensing:* a patent owner approaches an alleged infringer of a patent, seeking to enforce a licence for royalties. In most situations such alleged infringement cases are settled out of court
- *Strategic/blockage:* a patent owner approaches an alleged infringer seeking to block their use of a technology in a market. This type of litigation tends to occur between competitors in an industry.

Though this study did not set out to map litigation activity across the six low-carbon energy sectors, it became clear through the research on patent analysis that there had been a number of high-profile patent litigations in the wind and solar PV sectors, driven by aggressive corporate IP strategies. For instance, Germany's Enercon was involved in several lawsuits as well as a broader cross-licensing agreement with industry-leader GE. In 1997 Zond Energy Systems won a lawsuit against Enercon through the US International Trade Commission after having alleged patent infringement relating to its gear transmission system. The ITC ruled in Zond's favour, and ruled Enercon could not sell its products into the US market until the expiry of the patent in question in 2010. Subsequently Zond Energy was bought by Enron. After the collapse of Enron in 2001, GE bought its wind-generation assets. In the mid-2000s GE and Enercon entered a cross-licensing agreement that provided Enercon with enhanced access to the US market.

Meanwhile, Enercon began to assert its IP position vigorously on an international basis: in 2005 it brought a lawsuit in Germany against Vestas, alleging infringement of its lightning protection for blades (which was ejected by the Federal Constitutional Court in 2007). It brought another case against Vestas in 2006, this time in the United Kingdom, alleging infringement of a patent related to grid transmission systems (which Vestas won in 2007). Other cases had been filed in the Netherlands, Ireland and Canada. The dispute was finally settled out of court in November 2008 under undisclosed conditions.[a]

Another case involves GE, which in June 2009 called on the ITC to block Mitsubishi turbine imports. The ITC rule in favour of GE in August 2009 (and the case is currently subject to review).[b]

As the solar PV sector matures, the amount of patent-related litigation has also increased. For instance, the United States' Nanosys is a producer of nanotech quantum dots, which are used in lighting, solar power and electronic display systems. In July 2009 it settled a patent infringement lawsuit against Nanoco Technologies Ltd of the United Kingdom. The lawsuit claimed that the Nanoco's quantum dot technology infringed upon five seminal quantum dot patents held by Nanosys. In the settlement, Nanoco agreed to terminate its current US business for its core-shell quantum dots. Those quantum dots were distributed in the US by Sigma-Aldrich under the name Lumidots. In the settlement, Nanoco did not admit that the asserted patents were either infringed or valid, and the additional terms of the settlement were not disclosed. Jason Hartlove, chief executive officer of Nanosys, said: 'By enforcing ownership of our intellectually property, the manufacturers remain the real winners in having access to proven, trusted advanced material architecture.'[c]

As well as direct involvement in projects, some Californian CSP manufacturers have recently engaged in licensing deals including agreements within the US and overseas.[d] The enforcement of licensing business models frequently depends on a credible capability to enforce a patent portfolio. There is therefore a possibility of increased litigation rates in the CSP space as the different technology systems enter into commercial exploitation.

Currently patent infringement litigation in the energy sector is predominantly a US and EU affair. Yet through increased deployment in emerging markets, export strategies and maturing IP systems make it likely that patent litigation will affect emerging-market companies. In a way it is a sign of success for which there are precedents in the semiconductor industry. When Samsung first entered the US market it was successfully sued for patent infringement by Texas Instruments, forcing it to enter a cross-licensing agreement. Yet Samsung is now one of the top three leaders in the semiconductor industry.

Nevertheless, the higher level of public policy interest and participation in the energy industry may make patent litigation in this space more controversial, especially if it results in delays in the deployment of key energy technologies.

a Forbes (2007), Vestas wins Enercon patent infringement case, 25 May, http://www.forbes.com/feeds/afx/2007/05/25/afx3758873.html; Vestas (2007), Status on lightning protection patent dispute with Enercon GmbH, Aloys Wobben, 25 May, http://www.vestas.com/files/Filer/EN/Investor/Company_announcements/2007/070525MFKUK23.pdf.

b Bloomberg (2009), 'GE wins ruling in bid to Mitsubishi turbines', 7 August, http://www.bloomberg.com/apps/news?pid=20601103&sid=aGu_roNQwMKU.

c Reuters (2009), 'Nanosys Reaches Settlement of Patent Infringement Lawsuit Against Nanoco Technologies for Quantum Dot Technology', 23 July 2009, http://www.reuters.com/article/pressRelease/idUS165155+23-Jul-2009+BW20090723.

d For a recent example see LaMonica, Martin (2009), 'eSolar Plugs Solar Plant into California Grid', ***Green Tech***, 4 August, http://news.cnet.com/8301-11128_3-10302824-54.html?tag=mncol;title.

4.3 Capitalizing on the global market

As the analysis in this chapter shows, it has taken several decades before some of the energy technologies under scrutiny became diffused and adopted worldwide. To have a realistic chance of meeting climate mitigation ambitions, the time for clean technologies to diffuse globally must be halved by 2025.

In a global market the cost of technological deployment can come down fast through economies of scale. To harness the potential of the global market, cross-border trade and investment in low carbon and energy-efficient goods, services and technologies need to be encouraged and scaled up. Stimulating low carbon trade will create virtuous cycles, providing further investment opportunities and expanding the market for key technologies. There is also a need for targeted policies to encourage technological uptake at the fastest possible rates. This would involve strengthening linkages and cooperation between institutions and companies from developing and developed economies.

Since the 1970s, the costs of energy production from all technologies have fallen systematically through innovation and economies of scale in manufacture and use (apart from nuclear power). Technologies such as solar energy and offshore wind all show much scope for further innovation and cost-reduction.[6] The same is true for energy efficiency. For example, adoption of 'ultra-supercritical' technology and building many identical power plants means now it costs a third less to build an ultra-supercritical power plant in China than a less efficient coal-fired station in the United States.[7]

The scale of China's domestic market and its specialization as a supplier of consumer and industrial goods to international markets puts it in a unique position to bring new, clean energy technologies to maturity. This is also consistent with its strategic aspirations for an innovation-based economy. Patent analysis demonstrates that as energy technologies mature, advances in design, site selection and operation increasingly depend on innovation in information and communication systems.

Many of them are also dependent on innovation in advanced materials like alloys. Countries like India and South Africa are therefore in strong positions to capitalize on the growth opportunities as these technology systems evolve.

Adopting advanced technologies – and developing innovation capabilities – would present developing economies with an opportunity to leapfrog the process of resource-intensive, highly polluting growth experienced by Western countries. There is global benefit in ensuring that climate and technology policies would support such a shift.

Notes

1 See http://www.energyefficiencynews.com/power-generation/i/2290/, or for instance the wind tunnel being developed by the University of Texas under a Department of Energy grant for blades up to 100m.

2 Iliev, I. (2005), *Pre-Paid Metering Technology – Systemic Innovation in the South African Energy Sector, Resource-based Technology Innovation in South Africa*, HSRC, October, http://www.hsrc.ac.za/research/output/outputDocuments/4251_Iliev_Prepaidmeteringtechnology.pdf.

3 DuPont (2007), Biofuels Processing, http://www2.dupont.com/Renewably_Sourced_Materials/en_US/proc-biofuels.html.

4 The data coverage could be enhanced by combining patent data with journal article information (where academics co-author a journal article with their corporate collaborators), and using commercial licensing databases.

5 Saxenian, AnnaLee (2002), *Local and Global Networks of Immigrant Professionals in Silicon Valley*, Public Policy Institute of California.

6 Anderson, Dennis (2006), *Costs and Finance of Abating Carbon Emissions in the Energy Sector,* paper commissioned by the Stern Review.

7 *New York Times* (2009), 'China Outpaces U.S. in Cleaner Coal-Fired Plants', 10 May.

5. Policy Implications

As pressure for the low carbon transition mounts, investment in low carbon goods and services will continue to accelerate. Economies that are run with high levels of efficiency (and which are less exposed to the volatility of the fossil fuel markets) are at a competitive advantage, and consequently companies and governments that are moving fastest on low carbon transition will reap the rewards. This is a twofold strategy, one which relies on implementing best available technologies and practices while simultaneously developing the next generation of technologies.

It is fair that developed countries should take the lead in cutting carbon emissions, as they account for over three-quarters of historical emissions, and far more on a current per capita basis. But emissions are now so distributed that any single subset of countries is not going to solve the global problem by itself, even including the richest economies that currently enjoy technological leadership in the energy sectors. The bulk of future emissions growth will come from rapidly industrializing countries such as China and India. The European Commission stated in a Communication in January 2009 that to keep to a 2°C global rise, developing countries as a group would need to reduce emissions by 15 to 30 per cent below business-as-usual projections by 2020.[1] It is critical that the best available technologies are deployed across the globe at the fastest rate possible.

5.1 Business-as-usual is not an option

This report has described patent ownership trends in six areas of energy technology where step changes in the pace and scale of innovation are needed to meet ambitious climate goals. It has also analysed the rate of market adoption of key technologies, exploring the linkages between the micro-dimensions of technological development (individual inventors, technologies and organizations) and the macro picture of relative national strengths in specific energy sectors and subsectors.

With climate change posing new security threats to all, finding technological solutions is a shared dilemma. The findings of this report confirm that the diffusion of energy technologies takes too long under business-as-usual practices. Chapters 2 and 3 showed that many key inventions in the energy sectors took two to three decades to reach the market. Looking within the six sectors, the top 30 patents most cited by follow-up inventors are, on average, more than 24 years old.

More encouraging is evidence that policy interventions to spur demonstration and deployment – learning-by-doing – can be a major accelerator of the innovation process. Patenting rates and deployment in wind, solar PV and CSP (a robust proxy for innovative activities) took off from the late 1990s, driven by policy interventions to create market demand in key countries such as Germany, Japan and the United States.

Much has been made of the fast growth in innovation capacities in emerging economies such as Brazil, China and India. Companies or organizations from these economies do not currently feature in the top 10 positions in any sectoral and subsectoral analysis, though some do appear in the top 20, indicating their growing capacities. This means that OECD countries can determine the pace of diffusion of advanced technologies for some time to come.

Concentration of patent ownership is not synonymous with blockage or monopolistic behaviour, but IP can be an important factor in determining the speed of technological demonstration and diffusion. A patent portfolio is a currency – for attracting venture capital, entry into strategic alliances, protection against litigation, as well as opening opportunities for mergers and acquisitions. Company strategies will vary owing to differences in industry composition, level of competition, stages of development, and market structure of specific energy systems.

Many of the energy patents owners listed in this report are established industrial giants. Their perceptions of market conditions and level of IP protection in developing economies will be decisive in the roll-out of the next generation of low carbon technologies – whether through investment, licensing, joint ventures or other forms of knowledge-sharing. One worrying trend is the increase in patent-related litigations in fast-maturing technologies. A litigation culture is unlikely to be consistent with rapid diffusion of technologies.

A serious shortage of data in the public domain on collaborative and licensing activities, including patent pools and cross-licensing, inhibits our understanding of technological development. This scarcity of information is due in part to the absence of uniform reporting requirements, but also to the confidential and strategic nature of many such collaborations. These activities are often an opaque part of the companies' economic activities.

Jointly assigned patents provide proxy measures to analyse collaboration in innovation. These suggest that most collaboration resulting in joint patents is conducted by institutions or companies within the same national jurisdiction. There is some collaboration among OECD countries, but very little between developed- and developing-economy companies and institutions.

Transformative change cannot be achieved through domestic action alone. To drive global decarbonization, many different kinds of economic, physical and innovation linkages need to be strengthened among all industrial sectors, especially those between developed and developing economies. Coordinated action is not just optimal but critical. Without a clear understanding of the range of technological options available across different sectors, and how different technological systems interface with each other, policy-makers will struggle when making crucial choices about national or local industrial development strategies and investments.

The findings of this study suggest that implementing technology neutrality in the energy system is difficult given the overlap of technology systems and the different stages of technological development in the six energy spaces. The types of investments or technologies that are most likely to take off in the coming decade are already predetermined, to some extent, by existing industrial structures, research capabilities and other supporting infrastructure. Proactive policy-makers working at the interface of innovation and climate change mitigation therefore face a complex challenge in monitoring technological and commercial developments across a wide range of technological fields.

In designing global solutions it will be necessary to strike a careful balance between private interests and the delivery of global public goods, and to take into account the social and economic needs of developing countries. New incentive systems and collaborative mechanisms at bilateral, regional and international levels are going to be essential to encourage technological innovation, demonstration and diffusion.

5.2 Building a global low carbon industrial future

Sticking to what we know, and already do, will not bring these technologies to markets fast enough. It is therefore critical for all actors to move beyond business-as-usual assumptions and practices. There is a mismatch between the urgency of climate challenges, as set out by the Intergovernmental Panel on Climate Change (IPCC), and the time taken for a technology system to evolve under normal circumstances. This does not mean that global action should focus only on diffusing existing, ready-to-market technologies. We also need to invest in new technological options as well as in the market and public institutions to deliver them. Of course, not all potential technological solutions will succeed. To ensure the delivery of climate outcomes, providing the space to deal with failures is part of a sensible risk management approach.

5.2.1 Monitoring technological diffusion

As this study shows, our low carbon future is determined not only by energy-sector R&D investments but also by learning and adaptation from the other major industrial sectors of today. It is inconceivable that any one government, or a small group of companies, can deliver all the solutions to their national climate challenge alone. So there is a need to adopt a genuinely collaborative approach to technological development – one that does not only favour incumbents but also encourages new entrants. The Electric Power Research Institute (EPRI), which pools the research capacities of US utility firms, illustrates the value of cooperation in an industry where no one actor has sufficient capacity of its own. As suggested in Chapter 4, there are many examples from Japan where competing companies are engaged in joint research and development.

Given the increasing interest in clean energy technologies and generally expanding research budgets across the globe, there are significant opportunities to accelerate bilateral and multilateral collaboration on R&D and technology development. The analysis suggests the following priorities:

Invest in information sharing and transparency. While there is no global appetite for setting up new international organizations, governments can establish channels for sharing information and knowledge among companies, universities and other relevant organizations. As discussed in Chapter 4, very few data on licensing deals and cross-licensing initiatives are available in the public domain. This not only impedes research on technological diffusion in a global marketplace but also imposes huge market-information barriers for new entrants – whether companies seeking to purchase the best available technologies or universities looking for the next generation of applied R&D research. Efforts are under way at the European level to adapt patent classification to give greater visibility to climate-friendly technologies. This could form of the basis of a change in global patent classification that would improve transparency.

Set up a global database on licensing data and best practices. The development of a reliable patent licensing database could support the establishment of benchmarks and determination of best practice in patent licensing negotiations between private-sector players or in public-private partnerships. Given that many of these data are confidential, there may be a role for an escrow service from a trusted third party in which private-sector data are pooled and shared on an anonymous basis with the marketplace.

Better still would be for an institution, such as the World Intellectual Property Organization (WIPO), to set up global databases on licensing and cross-licensing regimes as well as patent pools on climate-friendly technologies. WIPO and/or other patenting authorities should request patent owners to register their licensing deals within a specified time period such as 24 months to protect their latest commercial interests (on a voluntary basis). Only with more available information can best practices – whether in the energy sector or beyond – in innovation and diffusion of climate-friendly technologies be shared in a way that encourages innovation and respects the rights of patent holders. Companies and organizations could also make use of this facility to showcase their latest inventions available for licensing.

Invest in sectoral mapping. Existing efforts by WIPO, such as geographic patent mapping, should also be extended to cover sectoral mapping of the sort conducted in this research, which would help inform governments, companies and other key stakeholder groups. This report only covers six sectors. The analysis could be expanded to cover many more low carbon and climate-friendly sectors.

5.2.2 Supporting technological innovation and diffusion in developing economies

The building of national champions should not take precedence over reducing the global carbon footprint. Greater incentives are needed to help ensure that collaboration across national boundaries is accelerated without requiring national priorities to take second place, which is not politically sustainable. National innovation and technology investments are often used as an extension of national industrial policy. The desire to cultivate national champions is commonplace for rich and poor countries alike. Industrial policy reflects this through directing subsidies and tax credits towards a few leading firms. This is at odds with the reality of the global market.

Ultimately, the bulk of decarbonization needed in developing economies will be delivered by their own businesses and institutions. Adopting advanced technologies – and developing indigenous innovation capabilities – would present developing economies with an opportunity to leapfrog the process of resource-intensive, highly polluting growth experienced by Western countries. The scale of China's domestic market and its position as a supplier of consumer and industrial goods to international markets puts it in a unique position to bring new, clean energy technologies to maturity.

Patent analysis demonstrates that as energy technologies mature, advances in design, site selection and operation increasingly depend on innovation in information and communication systems. This puts India in a strong position to capitalize on the growth opportunities as these technology systems evolve. Developing economies can greatly benefit from shifts in global investment patterns towards low carbon energy and production methods in developing countries. There is mutual global benefit in ensuring that climate policies would support such a shift.

The patent analysis also helps in identifying the location of specific and scarce technological capabilities in developing economies. Such information and analysis can be used to inform the development of industrial policies that aim to expand absorptive and indigenous innovation capacities in developing countries. Extending this approach to other industrial sectors will enable the development of country-specific low carbon technological transition paths that best serve national and collective interest as well as delivering long-term economic growth. This may be of particular importance in the post-Copenhagen world, if some of the support/mitigation funds and technology transfer programmes being discussed come into being.

To harness the potential of the global market, cross-border trade and investment in low-carbon and energy-efficient goods, services and technologies need to be encouraged and scaled up. Stimulating low carbon trade will create virtuous cycles, creating further investment opportunities and expanding the market for key technologies. There is also a need for targeted policies to encourage technological uptake at the fastest possible rates. This would involve strengthening linkages and cooperation between institutions and companies from developing and developed economies.

5.2.3 Collaboration, collaboration, collaboration

Public funding for climate-friendly research and development, financial support for incubation facilities and demonstration projects can be made conditional on some form of knowledge-sharing agreement that will be designed on the basis of sectoral needs. These could take the form of the following:

Cooperative R&D. Government support for clean energy innovation is more likely to be effective at the early stages of the development of technology systems, before particular standards or industry value-chains become embedded in national economies and the global industrial system. Research partnerships are also more likely to succeed if the technology is at an early, 'pre-competitive' stage. As shown in this study, cross-border R&D cooperation between OECD and non-OECD countries in the energy sector is very small. Given the importance of emerging economies in meeting global climate goals, governments should support the development of 'model' technology cooperation agreements that take into account different levels of development and different jurisdictional requirements that would limit the potential of patent-related conflicts and encourage joint development. This approach has been used in the pre-competitive research in the semiconductor field. National laboratories could be twinned, or new ones could be set up that are multilaterally managed and funded in pursuit of agreed key, long-term technology objectives, ideally with industry participation.

Publicly backed patent pools and cross-licensing. Through tax, other fiscal or investment incentives, the public sector should support the design and creation of patent pools and cross-licensing schemes to encourage innovation and mass diffusion for relevant technologies. These patent pools can be used to support SMEs and emerging markets innovation in exchange for a royalty fee (similar to the way technology standards management bodies such as ETSI work). There are also likely to be SMEs and individual inventors owning IP that is underused; they will benefit from pooling patents in a fast technological growth area.

Setting up knowledge-sharing platforms. Collaborative initiatives such as the European Commission's European Technology Platform for Zero Emissions Fossil Fuel Power Plants (ZEP) demonstrate the potential of stakeholder advice platforms, and can provide support for knowledge-sharing structures at the regional level (in this case the EU). These kinds of initiatives could be emulated in other regions or used as a starting point for multilateral efforts.

Supporting open innovation mechanisms. More climate technology prizes can be established at the global level to promote innovation in all areas that support climate mitigation and adaptation. This fund could function as a patent pool and/or a repository for the cross-licensing of technologies. Other forms of open innovation platforms should be developed to strengthen incentive structures for innovation and knowledge-sharing.

5.2.4 Transforming the global low-carbon marketplace

For the innovation and diffusion infrastructure to improve, it is critical for governments to adopt core energy policy that is supportive of low carbon solutions. Good climate-friendly energy policies and smart innovation policies are necessary ingredients for success, but neither is sufficient alone. In addition, to create markets for climate solutions, governments should invest in:

Expanding markets for near-to-market technologies. At the global level, the Copenhagen Summit must send unmistakable signals to global markets that change is imminent and inevitable. At the national – or more micro – level, the development of joint venture companies, cross-training programmes, cross-licensing arrangements, trade tariff exemptions on selected technologies and joint manufacturing programmes are all tried and tested methods that could be stepped up.

Global demonstration programmes are required for large-scale, high-risk technologies such as CCS and CSP. The size and complexity of demonstrating these technologies, which often includes complex planning and infrastructural support , make it difficult for the private sector to independently finance demonstration. Public funding in the form of grants, loans and risk guarantees is therefore necessary to ensure these technologies can become fully commercial. One international pilot project, the International Thermonuclear Experimental Reactor (ITER), provides an example of such a global collaborative programme. This joint research project was first proposed in 1985 but an agreement on the establishment of the research facility, to be based in France, was only reached in 2005. The ITER consortium now comprises seven parties – Russia, the United States, EU, Japan, China, Korea and India. Key plant components will be provided to the ITER organization through in-kind contributions from the seven members. Each member has set up a domestic agency, employing staff to manage procurements for its in-kind contributions. Members of the ITER consortium have agreed to share every aspect of the project – science, procurements, finance and staffing – with the aim that in the long run each member will have the know-how to produce its own fusion energy

Maximizing the potential of technology standards bodies. Technology standards can play an important role in accelerating innovation in an industry by removing bottlenecks around an industry and encouraging economies of scale. This report demonstrates the value of maintaining ongoing maps of potential technology standard hotspots, including the patents that underpin them. There is scope for formation of industry-level technology standards bodies to set increasingly high standards, bring in the laggards and accelerate diffusion.

Notes

1 EC Communication, 'Towards a Comprehensive Climate Change Agreement in Copenhagen', January 2009, SEC 2009 (101).

Appendix: Methodology for Patent Landscaping

Below is a description of the key steps undertaken in the patent landscaping for each of the six technology spaces:

1 **Defining research questions**: Chatham House, in consultation with Climate Strategies, the International Institute for Sustainable Development and CambridgeIP, defined the terms of reference and research questions for the project.

2 **Interviews with academic and industry experts and desktop research**: On the basis of interviews, desktop research, and reading of selected patents, CambridgeIP identified different technology subsystems, or subsectors, for each industry field. The combined information was used to develop a patent search strategy for each of the six selected energy technology spaces.

3 **Search algorithm and patent dataset creation**: A combination of Boolean search algorithms,[1] targeted IPC-based searches[2] and assignee-focused searches was used to compile the patent dataset from publicly available sources. Search algorithms were developed by CambridgeIP for each technology subsystem, as well as a broader search algorithm (to include other emerging inventions not identified by the experts). Searches were performed for Title, Abstract and Claims across all available patent databases. This methodology did not solely rely on International Patent Classification (IPC) codes. Even in a highly specific IPC it is difficult to distinguish between different technology systems and components. Using a semi-automated method, patent subsets focused on technology subsystems were developed. The boundaries of the resulting patent datasets reflect actual industry boundaries.

4 **Patent database sources**: The patent searches were conducted in the first quarter of 2009. A combination of ThomsonReuters and publicly available patent database services was used. The country and time coverage of the underlying patent databases is listed in the table below.

Patent datasets used	
INPADOC*	1968–present
US (Granted)	1971–present
US (Applications)	March 2001–present
European (Granted)	1980–present
European (Applications)	1979–present
WIPO PCT Publications	1978–present
Abstracts of Japan	October 1976–present
German (Granted)	1968–present
German (Applications)	1968–present

* Patent family documents from 71 patent offices worldwide and legal status information from 42 patent offices worldwide.

5 **Technology subsystem definition**: For each technology subsystem sets of technology descriptors most likely to be used by patents within the subsectors were developed. These were fed through CambridgeIP's patent ranking to generate a patent dataset representative of the subsector.

6 **Filtering and quality control steps**: A number of quality control steps were conducted including removal of false positives from the dataset, and benchmarking of the dataset results against initial datapoints. Data cleaning for names of assignees was undertaken, improving the accuracy of findings regarding the number of patents associated with companies, universities and other organizations.

7 **Value added database:** Using the patent datasets created, Chatham House and CambridgeIP extracted

lists of organizations active in each space. A follow-on analysis across all organizations with more than four patents was conducted. Searches were performed across publicly available website sources across various areas including company location, company ownership type, recent M&A or investment activity, strategic alliances, licensing activities, public-sector grant support and other factors.

8 **Analysis**: Analysis of the patent data was conducted by researchers at Chatham House and CambridgeIP. Some of the data analysis was performed through CambridgeIP's RedEye proprietary software for patent analytics.

Project limitations

To our knowledge, this is as yet the most extensive and thorough patent mapping effort for the six technologies in the public domain. But a number of challenges raised by this approach are not examined fully in the report owing to resource constraints or other factors. These include:

Lag in patent publications: There is a lag of up to eighteen months in the publication of patent data by various patent offices. In a fast-moving field there may be rapid changes.

Language: The searches were performed in English. This should capture the vast majority of commercially relevant patents and patent families, at least from their entry into the PCT system. However, owing to language differences a number of patents in the national phase are likely to have been missed.

M&A and company identity: Despite our best efforts in ensuring the harmonization of assignee names, the energy industry is undergoing continuous M&A activities. Following an acquisition, the patent names are frequently not reassigned.

Technology space definitions: The process of technology space definition was thorough and combined multiple approaches. Yet in selected fields some relevant technologies may have been missed. In addition, the boundaries of the technology spaces shift over time, so some radical areas of innovation may be missing from this study.

Technology subsystems: The list of systems and components is not exhaustive, but it demonstrates differences and commonalities between the most important system components. However, there are likely to be important areas that we have not identified.

Licensing data: Analysis on licensing used publicly available sources, including press releases and news items, as well as patent co-assignments. This methodology had limited success in identifying specific licensing deals.

Relevance of patents: We have approached the field in a top-down fashion, and have been able to identify key players on the basis of total numbers of patents. However, in many industries the most critical barriers for IP ownership are focused around only a small number of patent families. Consequently, in practice companies with smaller patent portfolios may on occasion play a more significant role than suggested by our patent rankings.

Patents issued in India: Only a limited amount of information is available electronically. We expect that this may have resulted in an underestimation of Indian innovation in some of the focus areas.

Notes

1 Boolean search algorithms are the most widely used patent search method. To demonstrate, a very simple search for wind turbine patents would be something like: (wind energy) or (wind turbine) or (wind and electricity). The patent searches we employed frequently use hundreds of technology descriptors.

2 IPC-based searches use patent examiner assigned International Patent Classification (IPC) codes as a way of limiting the space. We see IPC-based searches as insufficient on their own, but as a valuable complement to Boolean searches.

Chatham House, 10 St James's Square, London SW1Y 4LE
T: +44 (0)20 7957 5700 E: contact@chathamhouse.org.uk
F: +44 (0)20 7957 5710 www.chathamhouse.org.uk
Charity Registration Number: 208223

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