Are IPR a Barrier to the Transfer of Climate Change Technology?

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EXECUTIVE SUMMARY

Access to technology for reducing greenhouse gas emissions is important for developing countries to help them address the challenges of climate change. The innovative technologies in this domain have become increasingly patented. In international climate change debates in the run-up to the 2009 Copenhagen Summit on Climate Change, the developing countries have regularly claimed that this strong presence of intellectual property rights on carbon abatement technology, owned by the developed countries, constitutes a major barrier to developing economies' greenhouse gas abatement efforts.

The purpose of this study is to examine the validity of this claim. It traces patent protection and ownership data for seven relevant emissions-reducing energy technologies in a representative sample of low-income developing countries and emerging market economies, over the period 1998-2008.

The study concludes that:

Carbon emissions can be reduced by means of a variety of technologies of which some reduce emissions at a low-cost and others imply a high cost of emission reduction. In terms of cost per unit of carbon emission reduction, IPR covered technologies are not necessarily more expensive than those not covered by IPR. The high cost of some innovative carbon abatement technologies is more likely to be due to the immaturity of the technologies rather than to patent rights. Developing countries can to a certain degree choose technologies that are not covered by IPR to reach their policy objectives.

The patent count on the relevant technologies covered by this study has indeed increased rapidly. Globally, some 215.000 patent applications were filed worldwide over the period 1998-2008, including some 22.000 in developing countries – out of which about 7.400 were actually owned by developing country residents. When the last four years of the period are compared to the first four years, the global patent count increased by 120%, but by nearly 550% in developing countries. Solar energy and fuel cell patents account for 80% of the count and for most of the growth as well, followed by wind energy as a distant third.

The gap between patent protection in developed and developing countries is wide, but narrowing fast. In 1998, 1 in 20 patents for the relevant technologies was protected in a developing country; in 2008 it was 1 in 5.

However, even more striking than the gap between developed and developing countries is the gap between different groups of developing countries. There is a small group of emerging market economies which accounts for nearly all patents protected in the sample (99.4% of all protected patents in the sampled countries), and there is a large group of

low-income developing countries that protect very few patents (0.6% only of the total sample).[1]
This leads to the conclusion that patent rights can not possibly be an obstacle for the transfer of climate change technologies to the vast majority of developing countries: there are hardly any patents on these technologies registered in these countries. A relaxation of the property rights regime for the relevant technologies in these countries would not improve technology transfer to these countries.

It is sometimes claimed that the exclusive ownership rights that patents bestow on their holders create a monopolistic market structure and drive up the price of the goods that embody these innovative technologies, thereby making these less affordable for low-income developing countries. The study provides a picture of the distribution of patent rights by country of residence of the patent holder, which could be considered as a good proxy to gauge the strength of monopolistic powers in the market. It shows that no single nationality actually dominates the market for a particular technology. In the most important patent domains (by number of patents), China and Japan hold the largest market shares of respectively 38% (solar energy) and 28% (fuel cell). These are important but not monopolistic market shares. Nationality-based proxies provide an upper limit indicator of market concentration. The study did not investigate the distribution of ownership rights across individuals and/or companies. If patent counts would be carried out at that level of detail, this would most likely show a much lower degree of market concentration. Moreover, to the extent that different carbon emission reduction technologies are substitutes and compete with each other, this should further decrease the market power of patent holders. In conclusion, there is no indication that monopolistic market structures drive up the price of these technologies.

The impressive increase in protection of climate change technology patents in a small group of emerging market economies, in contrast to the virtual absence of patenting in the rest of the developing world, is to a large extent led by foreign patent holders, mostly resident in developed countries. Though there is a rapid and very significant increase in resident patent holders in emerging market economies (33% over the period 1998-2008), this is in fact an almost exclusively Chinese phenomenon: of the 7.400 locally owned patents, nearly 6.800 are owned by residents in China. In China, 40% of the sampled technology patents are locally owned. On the other hand, in India, less than 14% of the registered patents are locally owned.

[1] The following emerging market economies were included in the sample for this study: Argentina, Brazil, Russia, Ukraine, India, China and the Philippines. The following low-income developing countries were therefore included in the study: (a) the African Intellectual Property Organization (OAPI), including Burkina Faso, Benin, Central Africa Republic, Congo, Ivory Coast, Cameron, Gabon, Guinea, Equatorial Guinea, Guinea Bissau, Mali, Mauritania, Niger, Chad, Togo, Senegal; (b) the African Regional Intellectual Property Organization (ARIPO), including Botswana, Gambia, Ghana, Kenya, Malawi, Mozambique, Namibia, Sierra Leone, Somalia, Swaziland, Uganda, Zambia and Zimbabwe; (c) Uruguay, Moldova and Egypt.

In conclusion, the study finds that intellectual property rights do not in themselves constitute a barrier to the transfer of carbon abatement technology from developed countries, neither to low-income developing countries nor to emerging market economies. Many other non-technological and more economic factors stand in the way of achieving the carbon abatement objectives of low-income countries. For the emerging market economies that have the technological capacity and market size to use innovative technologies, further improvements in patent protection could actually stimulate domestic innovation and the transfer of technologies from foreign patent holders. Emerging market economies also benefit from sufficient competition among patent holders within the relevant technology domains to avoid having to pay monopolistic prices for patents.

The reasons for an alleged insufficiency (if any) in the transfer of technologies to low-income developing countries should thus be sought elsewhere: insufficient technical knowledge and absorption capacity to produce these innovative technologies locally, insufficient market size to justify local production units, and insufficient purchasing power and financial resources to acquire the innovative products. Solutions, if needed, should be sought in policies that aim to overcome these insufficiencies. Even without access to technology, some domestic policies could have a high direct pay-off, for instance a reduction in energy subsidies that reduce the private incentive to deploy cheap but effective abatement technologies. Grant subsidies from developed countries to encourage developing countries' access to specific IPR-protected carbon abatement technologies may actually distort the market and result in the acquisition of not very cost effective carbon abatement technology. Instead, support should compensate low-income developing countries for the overall economic burden of carbon abatement while preserving the countries' incentive to minimise the costs of that abatement

Chapter 1 TECHNOLOGY TRANSFER IS KEY TO CLIMATE POLICY

Climate change due to greenhouse gas emissions is being discussed all over the world in recent years. The Copenhagen summit on climate change, to be held in 2009, seeks to reach a global agreement on binding green house gas emission reduction targets.

The more developing countries have to reduce emissions of GHG the greater is the economic costs to them. Recent estimates by the OECD (2008) suggest that ambitious world-wide abatement targets may both be costly for developing countries, and that the cost relative to GDP may be higher for developing than for developed countries.

Given this disparity in the distribution of abatement costs between developing and developed countries, the question is: how can the developed countries best help the developing countries achieve the necessary emission reductions in ambitious GHG abatement scenarios in a manner that does not put too much pressure on their economies.

Access to technology for reducing greenhouse gas emissions is an important part of the solution to the climate challenge; however, in recent years this carbon abatement technology has become increasingly patented.

Consequently, some of the least developed countries and emerging economies claim that this stronger presence of intellectual property rights on carbon abatement technology held by developed countries is a major barrier to the countries' abatement efforts. This report examines the validity of that claim.

Technology transfers from developed countries to the rest of the world were recently discussed at the Beijing international conference (November 2008) on carbon abatement technology transfers. On this occasion, China and India proposed that the TRIPS flexibility for medicines (compulsory licensing) should be extended to cover carbon abatement technology. The argument was that climate is a public good, just like health, and that hence the international community should follow the principle of "guidance by government – participation by enterprises". In contrast, the World Intellectual Property Organization, Japan and the EU argue that the situation is fundamentally different. In the pharmaceutical industry, one firm holds the patent of a key technology. In the carbon abatement technology industry patents are spread over a large number of firms; this limits their market power.

The next chapter looks at the technological options available for the least developed countries and the emerging economies to reduce carbon emissions, and the economic costs of using these technologies. Chapter 3 then analyses the role of IPR for the cost and availability of carbon abatement technology, considering the ownership structure of patents protected in the least developed countries and emerging economies. In chapter 4 we consider other potential barriers to technology transfer. Chapter 5 concludes.

Chapter 2 | INTELLECTUAL PROPERTY RIGHTS AS A BARRIER TO TRANSFER OF TECHNOLOGY

The purpose of this chapter is to answer the question: How important are intellectual property rights (IPR) as a barrier to developing countries' ability to access the technology necessary for meeting ambitious abatement targets?

2.1. THE PURPOSE OF INTELLECTUAL PROPERTY RIGHTS

IPR is an abbreviation for Intellectual Property Rights, which, under the traditional definition, consists of patents, utility models, design rights, trademarks, domain names and copyrights. Closely related are terms such as unfair competition legislation, trade secrets and know-how – but these areas of legislature are typically not forming part of what is referred to as "IPR".

Intellectual property rights are first and foremost a deal between inventors/creators and society; it reflects a trade-off in which society receives access to / publication of an inventor's creation of a new invention, and in return provides the inventor a temporary sole property right to a defined technology. During this limited time period the inventor may commercially exploit the invention as the sole proprietor and prevent others from unauthorized usage. IP rights can therefore be defined as a temporary monopoly that can only be enforced by using the available IPR legislations before relevant Courts or before national or international IPR administrations. Nowadays, only very few countries do not have IPR legislation available.

IP rights also give the inventors an incentive to share the information about the invention (instead of keeping their innovations secret), thereby enabling other creators to reach the same knowledge level or to continue the momentum with further technological development of the patented technology. The granting of IP rights is therefore one of society's important drivers for innovation and economic growth.

IPR protection adds a price premium and increases the price of accessing new technology over and above the normal market equilibrium price. IPR protection gives rise to a monopoly mark up above the marginal cost of production, which firms need to cover their fixed research and development (R&D) expenditure. The mark up drives up the economic cost of using a technology and it increases the necessary investment to purchase a given technology.

On the one hand, the mark up must be sufficiently high to allow the inventor to recover the historic cost and finance future R&D. On the other hand, the mark up also must to some extent reflect an increase in the technology's value relative to that of competing non-IPR protected technologies.[2]

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[2] The result follows from standard economic theory, c.f. e.g. Scotchmer (2004), and is relevant for all IPR protection, including climate change technologies.

However, even though IPR may raise the price of a technology, it does not necessarily increase the cost of the output or result produced by that technology. For instance, in the case of carbon emission reduction technologies, the carbon abatement costs (euros per unit of CO_2) need not increase because the new technology is normally more productive than older technologies.

The environmental benefits of climate change technologies extend beyond the borders of the country that has financed R&D and deployment of the technology. In this sense, climate change technologies are a "public good".[3]

The knowledge created in one country is to some extent available for all countries. Thus, countries that wish to join in the R&D effort can benefit from a patent pool and cooperation possibilities with inventors elsewhere. Furthermore, the environmental benefits are not constrained to the countries participating in abatement. R&D in carbon abatement technology thus has two important public good aspects: The knowledge externality and the environmental externality. This is why development of carbon abatement technology is an international issue.

2.2. Literature on IPR as a barrier

There are various schools of thought on this subject in the literature, including studies adopting a comprehensive approach to technologies and modes of transfer, as well as those examining selected cases more closely, can be found to provide evidence for IPR functioning either as a barrier and a facilitator.

One strain of literature, represented by ICTSD (2008) and Khor (2008), examines the issue of IPR protection from a wider perspective, exploring for example different modes of technology transfer, different kinds of climate change technologies, and provisions in the TRIPS agreement. Another strain of literature, represented by e.g. Branstetter et al. (2005) investigates the role of IPR protection in concrete cases of technology transfer, at particular points in time and places, particular firms, and involving particular technologies.

ICTSD (2008) concludes that "IP is potentially both an incentive and an obstacle to the transfer of technology". On the one hand, a certain amount of IPR protection is necessary to sustain innovation to deliver climate change technologies, but on the other hand too much protection can hamper transfer due to high costs. Khor (2008) acknowledges that there is already a range of climate change technologies in the public domain where IPR protection is not even relevant. And for those technologies covered by IPR, patents do not automatically constitute barriers to transfer, because the presence of cost-effective substitutes, high degree of competition among patent holders or low prices may work

[3] See, for example Mytelka (2007).

against the potential for IPR to become a barrier. Moreover, even in those cases where IPR does in the end increase the cost to the level where it becomes a barrier – or in cases where patents are used for a complete denial of access[4] – the TRIPS agreement offers certain mechanisms to overcome these obstacles. Finally, Maskus et al. (2004) point to the importance of potential barriers created by non-IPR issues, such as lack of institutional capacity to absorb technologies, preferences of local suppliers or infrastructure deficiencies.

Another strain of literature looks more selectively into concrete examples of technology transfer, under specific circumstances. Branstetter et al. (2005) have examined technology transfer within US multinational corporations. They find that IPR reforms that strengthen protection in a set of emerging economies facilitate technology transfer. This is illustrated by an increase in royalty revenues from licensing following the implementation of the reform. Barton (2007) has examined the extent to which four renewable energy generation technologies are encompassed by IPR. He found that despite the presence of IPR protection for these technologies, the holders of patents could not demand higher prices for their products because of international competition and availability of substitute products. Smith (1999) has found that weak patent rights enforcement prevents the transfer of US technologies to destination countries where there is a high risk of imitation. When IPR protection improves in the destinations where the risk of imitation is high, technology transfers increase. Yi Quian (2007) has examined the effect of IPR reforms on the levels of innovation in the pharmaceutical industry in 85 countries over 20 years. He finds that patent law reforms have a mildly positive effect on domestic innovation although the effect is not immediate. Furthermore, there exists an optimal level of patent protection, beyond which the effect on domestic innovation is negative.

[4] There is evidence of patents used to deny access to climate change technologies to firms in developing countries, cf. e.g. Hutchison (2006).

Table 2.1: Summary of studies looking at IPR as a barrier to technology transfer

Reference	Research question	Results
Hutchison (2006)	Does TRIPS facilitate or impede climate change technology transfer into developing countries	TRIPS can both facilitate and hinder access in specific cases. Presence of patents may encourage local innovation but also increase cost of acquiring the technology via imports. In terms of volume of trade, there is no evidence that patenting increases trade with poor countries. Finally, IPR protection is not the decisive determinant for location choice of FDI.
ICTSD (2008)	Is IPR protection an incentive or obstacle to the transfer of climate change technology?	"IP is potentially both an incentive and an obstacle to the transfer of technology". On the one hand, IPR promote dissemination of knowledge but too much protection hinders access to knowledge.
Maskus et al. 2004	How does stronger IPR affect access of developing countries to advanced proprietary technologies from developed countries?	Strengthening IPR increases the likelihood of transfer but is not sufficient to ensure transfer. Other features are important, incl. absorption capacities, infrastructure, restrictions on inward technology, trade and investment flows, regulatory systems.
Barton (2007)	To what extent are different renewable energy generation technologies protected by IPR	Renewable energy technologies are protected by IPR but other issues, such as low market concentration or availability of substitutes are important. If IPR protection does not increase cost, it is not per se a barrier to transfer of climate change technologies,
Branstetter et al. (2005)	How does technology transfer within US multinational firms changes in response to IPR reforms?	**IPR protection increases technology transfer within US multinationals.** "US multinationals respond to changes in IPR regimes abroad by significantly increasing technology transfer to reforming countries" "Royalty payments for technology transferred to affiliates increase at the time of reforms, as do affiliate R&D expenditures and total levels of foreign patent applications".
Smith (1999)	Are US exports sensitive to national differences in patent rights? Are weak patent rights a barrier to US exports?	**Weak patent rights are a barrier** to US exports in countries that pose a strong threat of imitation (China). Stronger patent rights increase US exports to high-threat markets. Stronger patent rights in weak threat markets reinforce monopoly power and reduces US exports to these markets.
Glass & Saggi (2002)	How does strong IPR protection in the South affect innovation, imitation and FDI?	**Imitation**: Stronger IPR keeps multinationals safer from imitation. **Foreign direct investment**: More difficult imitation reduces FDI (more resources needed for imitation crowds out FDI, less FDI generates less innovation in the North) **Innovation**: More difficult imitation requires more resources which reduces innovation
Yi Quian	Does new implementation of patent policy on innovation affect the domestic level of innovation in the pharma industry, 1978-1999, 85 countries	**Patent laws do not promptly stimulate domestic innovation**. National patent laws with high levels of development and economic freedom do have a positive effect on innovation. Support for an optimal level of patent protection - inverted U shape.

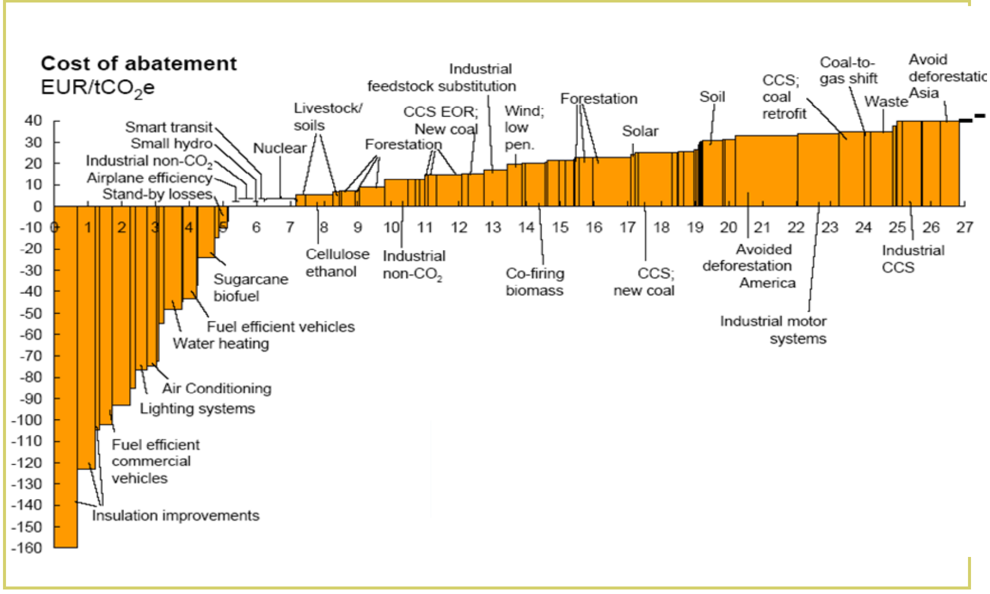
Source: *Copenhagen Economics.*

2.3. CARBON EMISSION ABATEMENT COSTS

An abatement cost curve is a way of graphically ranking the CO_2 abatement potential for existing GHG abatement technologies with respect to their unit cost. The technologies in the abatement cost curve are sorted according to increasing unit cost, i.e. the technologies with lowest unit costs are deployed first to realise their potential, followed by more expensive technologies, until the amount of abatement required by a scenario is realised. The total cost of abatement can be found by calculating the area between the abatement curve and the horizontal axis.

Figure 2.1 shows the abatement cost curve for the World under the 450ppm scenario that aims to limit global temperature increases to 2°C by the end of the century, as estimated by Vattenfall & McKinsey (2007).[5]

Figure 2.1: Potential for abatement by technology, the World, 450ppm scenario



Note: The horizontal axis shows the number of Gigatonnes (Gt) of CO_2 abatement in the world.
Source: Vattenfall and McKinsey (2007).

The total amount of required abatement depends on the specific abatement scenario which in this case is the 450ppm stabilisation one. Under this scenario, the World must abate about 27 gigatonnes (Gt) of carbon dioxide equivalents, CO_2e. The least developed countries and emerging economies must cut down about 17 $GtCO_{2e}$ of emissions by 2030 in six sectors; agriculture, forestry, power generation, transportation, buildings and industry. To bring about the entire reduction multiple technologies are required, with various costs and abatement potentials. Box 2.1 contains further details on the Vattenfall & McKinsey (2007) methodology for the abatement cost curve.

[5] We have chosen to base the discussion on the Vattenfall & McKinsey (2007) abatement cost curve because it has the widest geographical scope and covers most technologies. Other, more limited, versions of abatement cost curves have been developed by e.g. DTI (2007).

Box 2.1 Abatement potential of various technologies in the 450ppm scenario

Vattenfall & McKinsey (2007) have developed a global abatement cost curve, which ranks a number of abatement technologies in six regions of the global economy according to their unit cost and abatement potential. The study is based on the 450ppm scenario with respect to temperature stabilization by 2030.

The unit cost of abating one tonne of CO_2e by these technologies ranges from negative – including mostly technologies improving energy efficiency in transport and buildings – to a maximum of € 40 / tCO_2e which is the cost of technology achieving the last required tonne of CO_2 abatement. The study considers technologies whose cost today is in excess of € 40 / t CO_2e, but their implementation is not required to achieve climate objectives.

For each of the technologies, the study considers its abatement potential in one of six regions of the World. According to Vattenfall the regional figures are to be viewed as indications of order of size of the abatement, as the regional figures in many cases are less accurate than the aggregated.

Source: Copenhagen Economics based on Vattenfall & McKinsey (2007).

In addition, we have analysed the significance of IPR for a selection of the technologies using a sample of patent data extracted for this purpose. The patent data is described more thoroughly in box 2.2 and in Appendix B.

Box 2.2: Patent data

For the purpose of this study we have collected patent count data for relevant technologies, for the period 1998-2008, for a sample of developing countries, covering both least developed countries and emerging market economies.

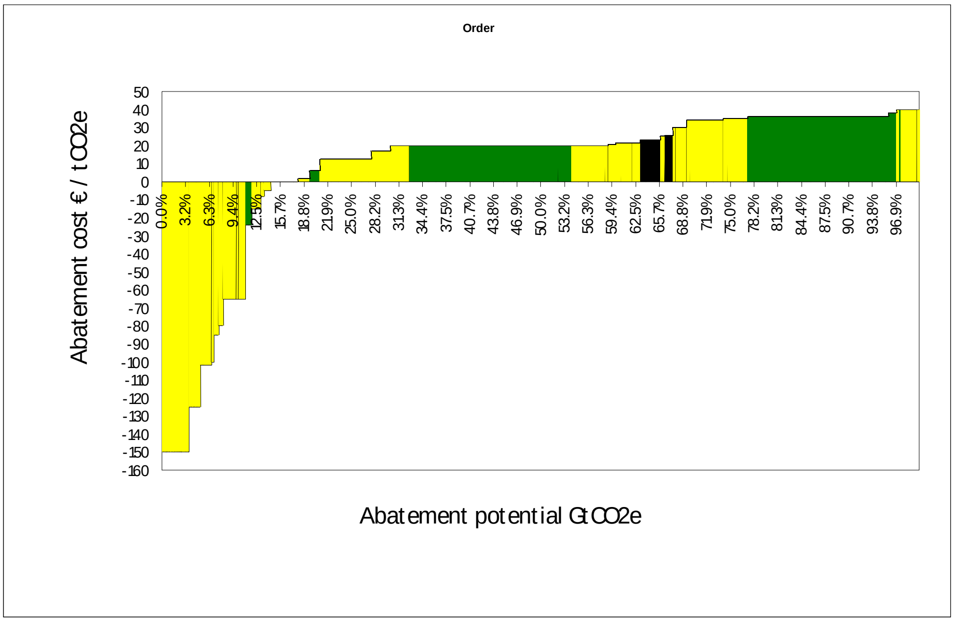
The countries covered are: Argentina, Benin, Botswana, Brazil, Burkina Faso, Cameroun, Central Africa Republic, Chad, China, Congo, Egypt, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea, Guinea Bissou, India, Ivory Coast, Kenya, Malawi, Mali, Mauritania, Moldova, Mozambique, Namibia, Niger, Philippines, Russia, Senegal, Sierra Leone, Somalia, Swaziland, Togo, Uganda, Ukraine, Zambia, Zimbabwe. The countries are categorized as "least developed countries" or "emerging economies". The emerging economies are Argentina, Brazil, China, India, Philippines, Russia and Ukraine. The rest are the least developed countries.

The patent data sources allow for the construction of patent counts within a large range of technologies, where for each patent we know the applicant country (the country of residence of the owner of the patent) and the countries where patent protection is sought.

We consider the following GHG abatement technologies: wind, solar energy, fuel cell, geothermal, ocean, biomass and waste. These technologies are defined on the basis of IPC (International patent classification) classes of the patents, c.f. Appendix B.

Source: Copenhagen Economics.

Figure 2.2: Abatement cost curve for the least developed countries and emerging economies



Note: The abatement cost curve shows the potential for abatement from deploying 50 individual technologies, beginning with the cheapest ones and up to the level of abatement required by the implementation of the 450ppm scenario in the least developed countries/emerging economies, at about 17 Gt CO_2e.The marginal cost of the cheapest available technology is €-150/ t CO_2 e. The marginal cost of the technology achieving the last required tonne of CO_2 abatement is €40/t CO_2 e. The black colour indicates a high degree of patent coverage, the green (or dark grey) colour indicates a low degree of patent coverage and yellow (or light grey) indicates that we do not know the level of patent coverage. The full list of least developed countries/emerging economies is presented in appendix B.

Source: Own calculations based on Vattenfall & McKinsey (2007) and own extraction of data from EPODOC, Pluspat and WPIX..

The methodology for identifying the significance of IPR protection in the least developed countries and emerging economies of a given technology is to find out how likely it is that a given patent is protected in least developed countries and emerging economies. The idea is that IPR protection of a given technology cannot be a barrier for the transfer of a technology in the least developed countries and emerging economies, if the patents relating to the technology are not protected in these countries. If firms in developed countries do not seek patent protection in e.g. the least developed countries it is probably because there is no economic rationale for competition or counterfeiters to set up production in the least developed countries. These countries may lack the fundamental human capital and physical infrastructure for setting up production of counterfeits. Another reason is that even if one among the least developed countries set up the production, it would only be able to sell the product to other of the least developed countries where the product is not patent protected, but the economic importance of this market may be too small to make the production economically viable. In these cases IPR is not the relevant

barrier to transfer of technology – it is rather the lack of human or physical capital or because the market is too small to warrant production.
Based on this understanding, we calculated for each Carbon abatement technology the fraction of world wide patents which are protected in the least developed countries and the emerging economies. We classify the technologies according to their level of patent protection such that technologies where less than 10 percent of the world wide patents are protected in the least developed countries or emerging economies are considered to be non-IPR protected. These technologies are biomass energy, fuel cell technology, waste management and forestry.[6] Technologies for which we do not know the extent of IPR coverage are shown in the graph with yellow (or light grey) colour. The classification shown in Figure 2.2 is conservative. With our classification the technology for about 55 percent of the necessary greenhouse gas abatement in the least developed countries and emerging economies is potentially patent-covered. Vattenfall & McKinsey (2007) assess that about 30 percent of the technology is covered.

Figure 2.2 covers both the least developed countries of the world, such as e.g. Burkina Faso, and emerging economies such as e.g. China. The relatively high amount of patenting in some of the technologies is driven by patenting activity in the emerging economies, whereas the least developed countries have only little patenting activity.

This ranking of technologies according to carbon abatement costs does not indicate that IPR protected technologies are systematically more costly to achieve CO_2 abatement relative to non IPR protected technologies. Even if all the technologies for which the IPR coverage in developing countries is currently not known turn out to be important –and all the rightmost yellow (or light grey) bars in Figure 2.2 were instead black – the area of the black coloured technologies would not exceed that of the green (or dark grey) coloured technologies. Hence, suggesting that abatement of 1 tonne CO_2 by IPR protected technologies will always be more costly than 1 tonne CO_2 abatement by non-IPR protected technologies does not seem to hold.

What drives the unit cost of deploying a certain technology is its level of maturity defined as the number of units of products sold. In other words, a mature technology is one which has penetrated the market in which it is sold in so large quantities that a great deal of learning by doing has been achieved. Currently, technologies such as wind turbines at sea, photovoltaic technologies, biomass or second and third generation biofuels have a very high unit cost because they are immature. In order to meet ambitious abatement targets, it may, however, be necessary for the least developed countries and emerging economies to deploy some of these expensive technologies. In order to meet less ambitious abatement targets, more mature and consequently cheaper technologies may be deployed only, thereby reducing the total cost of abatement.

[6] The classification is sensitive to the level of the cut off. If instead the cut off were set at 15 percent then none of the analyzed climate technologies would be classified as IPR covered in the least developed and emerging economies.

The individual technologies on the abatement cost curve differ with respect to their unit cost and the abatement potential. For example, in the case of energy efficiency improving technologies, the cost of abating 1 tonne of CO_2 is sometimes negative, which means that the deployment of the technology will bring about a net gain to the user. In other cases, the unit cost can be positive, which means that abatement will be economically costly. In general, therefore, it is sensible to deploy the cheaper technologies first. However, each technology has a maximum limit on how much abatement it can achieve – e.g. once all homes, offices and factories are insulated the negative cost abatement potential in the construction sector will be exhausted. Further abatement – if required to meet the goals of a scenario – would need to take place in other sectors and employ other technologies with a different unit cost, e.g. efficiency in transport, or renewable power generation.

A large share of the worldwide carbon abatement necessary to meet even ambitious targets can be met by increasing forestation and decreasing deforestation in the least developed countries. We assess that the technology for forestation and reduced deforestation does not rely on the use of IPR protected technology to any significant extent. Hence for the least developed countries a large part of the economic burden of abatement is unrelated to IPR.

There is reason to believe that China may have to rely to a significant extent on carbon abatement technology which is protected by patents. However, a great deal of carbon abatement necessary for this country to comply with the 450 ppm scenario can be obtained using carbon abatement technology that actually saves economic resources. In fact, the net economic burden of carbon abatement for China is relatively small, according to Vattenfall & McKinsey (2007). Hence, even though some modern carbon abatement technology may be associated with an IPR premium, many of these technologies are much more cost efficient and the economic gains are large so that the net economic burden of carbon abatement is small for China.

Chapter 3 PATENTS FOR CARBON ABATEMENT TECHNOLOGY

We collected patent registration data 1998-2008 for several low or zero emission energy technologies (waste and biomass energy; solar, fuel cell, ocean, geothermal and wind power) for the entire world, for a sample of emerging market economies and for low-income developing countries. For a complete description of the collection methods, see Annex B.

For the period 1998-2008, some 215.000 patents were registered worldwide for these low-emission energy technologies, of which about 10% in the sample of emerging market economies (see table 3.1). Since the sample does not cover all emerging markets and fast-growing economies, the latter figure is an underestimate. Only 0.1% of these patents were registered in low-income developing countries. Although the sample of developing countries is incomplete, the very low number of registrations makes it unlikely that the real figure is significantly above this. At first glance, this picture seems to confirm the developing countries' claim that the developed countries have a strong grip on patented climate change technologies. However, a first qualification already needs to be applied: It is a small group of emerging market economies that accounts for nearly all registrations outside the developed economies, with China clearly in the lead.

Table 3.1 also shows that patent registrations for these technologies underwent strong growth. The worldwide growth rate in registrations for the period 2004-2007, compared to 1998-2001, is about 120%. Clearly, these technologies are subject to rapid innovation and increased patenting that may give the impression that access is difficult for developing countries. However, a second qualification needs to be added here: the growth rate of patent registration in emerging market economies (+545%) by far outpaces that in the developed world. At this pace, emerging market economies will soon come level in patenting activity with the developed world. In 2008, emerging markets registered patents already accounted for 20% of worldwide patenting in these climate change technologies, compared to less than 5% in the late 1990s.

By contrast, the growth rate in patenting activity in low-income countries (52%) lags behind the world average. That does not imply that these countries do not have access to the technology: they can buy the products in which the technology is embedded, even though the patents are not registered in these countries. Copying the technology in these countries would not be illegal but patent holders probably refrain from incurring the cost of registration because the risk of copying is extremely low: the technical knowledge to copy these patented technologies is probably not available in low-income countries; moreover, market size is most probably too small to make an economic case for setting up a copycat production facility there. An important conclusion from table 3.1 is that IPR protection of climate change technologies is mainly an issue between developed OECD economies and emerging market economies, not between the OECD economies and the developing countries as a group. IPR protection for these technologies simply doesn't exist in low-income developing countries.

Table 3.1 Summary of patent data for carbon abatement technology

Year	Waste			Solar			Ocean			Fuel cell			All technologies		
	All countries	Emerging Markets	Low-Income Dev. Countries	All countries	Emerging Markets	Low-Income Dev. Countries	All countries	Emerging Markets	Low-Income Dev. Countries	All countries	Emerging Markets	Low-Income Dev. Countries	All countries	Emerging Markets	Low-Incom Dev. Countries
2008	447	123	0	9,757	2,234	3	412	87	0	7,077	978	0	19,701	4,037	6
2007	570	46	0	13,111	1,744	5	494	77	2	10,647	1,070	0	27,505	3,439	10
2006	594	41	1	11,808	1,741	7	483	87	8	10,409	1,052	0	25,633	3,324	20
2005	784	46	1	13,877	2,388	0	444	59	2	10,954	1,158	0	28,787	3,992	8
2004	878	38	0	10,823	1,444	7	361	38	2	9,956	706	0	24,508	2,479	17
2003	853	40	0	9,235	857	8	330	26	5	8,007	433	1	20,795	1,530	22
2002	806	23	0	10,376	535	2	281	28	1	6,878	316	3	19,982	992	10
2001	665	30	0	9,580	400	1	249	15	1	4,436	233	2	16,458	752	10
2000	566	10	0	7,598	292	3	220	16	1	3,036	163	2	12,557	535	9
1999	555	13	0	6,102	230	10	196	14	0	2,106	107	3	10,099	420	14
1998	501	11	0	5,588	218	0	174	11	0	1,699	56	0	9,118	342	3
Total, 1998-2008	**7,219**	**421**	**2**	**107,855**	**12,083**	**46**	**3,644**	**458**	**22**	**75,205**	**6,272**	**11**	**215,143**	**21,842**	**129**
Total, all years	**15,936**	**468**		**197,238**	**13,950**		**10,626**	**558**		**103,882**	**6,753**				
%-shares of activity, 1998-2008	94.1	5.8	0.0	88.8	11.2	0.0	86.8	12.6	0.6	91.6	8.3	0.0	89.8	10.2	0.1
Ownership															
- EM residents		**171**			**4,436**			**280**			**1,260**				
- Chinese residents		149			4,249			175			1,224				
%-growth from 1998-01 to 2003-07	**23.6**	**167.2**	**-**	**71.9**	**541.8**	**35.7**	**112.4**	**366.1**	**600.0**	**272.1**	**613.1**	**0.0**	**120.7**	**545.9**	**52.8**

Source: *own extraction of data from EPODOC, Pluspat and WPIX.*

Table 3.1 (continued)

Year	Biomass			Geothermal			Wind			All technologies		
	All coun-tries	Emerging Markets	Low-Income Dev. Coun-tries	All coun-tries	Emerging Markets	Low-Income Dev. Coun-tries	All coun-tries	Emerging Markets	Low-Income Dev. Coun-tries	All coun-tries	Emerging Markets	Low-Income Dev. Coun-tries
2008	248	29	0	187	70	1	1,573	516	2	19,701	4,037	6
2007	297	22	0	285	36	0	2,101	444	3	27,505	3,439	10
2006	270	26	0	232	38	0	1,837	339	4	25,633	3,324	20
2005	497	37	0	288	43	0	1,943	261	5	28,787	3,992	8
2004	473	20	0	244	38	0	1,773	195	8	24,508	2,479	17
2003	478	14	1	291	27	0	1,601	133	7	20,795	1,530	22
2002	333	16	1	194	18	0	1,114	56	3	19,982	992	10
2001	470	13	0	189	10	0	869	51	6	16,458	752	10
2000	366	20	0	167	8	0	604	26	3	12,557	535	9
1999	478	28	1	208	6	0	454	22	0	10,099	420	14
1998	500	13	0	261	7	0	395	26	3	9,118	342	3
Total, 1998-2008	**4,410**	**238**	**3**	**2,546**	**301**	**1**	**14,264**	**2,069**	**44**	**215,143**	**21,842**	**129**
Total , all years	**13,600**	**320**		**7,591**	**319**		**25,508**	**3,217**				
%-shares of activity, 1998-2008	94.5	5.4	0.1	88.1	11.8	0.0	85.2	14.5	0.3	89.8	10.2	0.1
Ownership												
-EM residents		**28**			**194**			**1,028**				
- Chinese residents		18			144			824				
%-growth from 1998-01 to 2003-07	**-15.3**	**41.9**	**0.0**	**27.2**	**400.0**	**-**	**229.6**	**891.2**	**66.7**	**120.7**	**545.9**	**52.8**

Source: *own extraction of data from EPODOC, Pluspat and WPIX.*

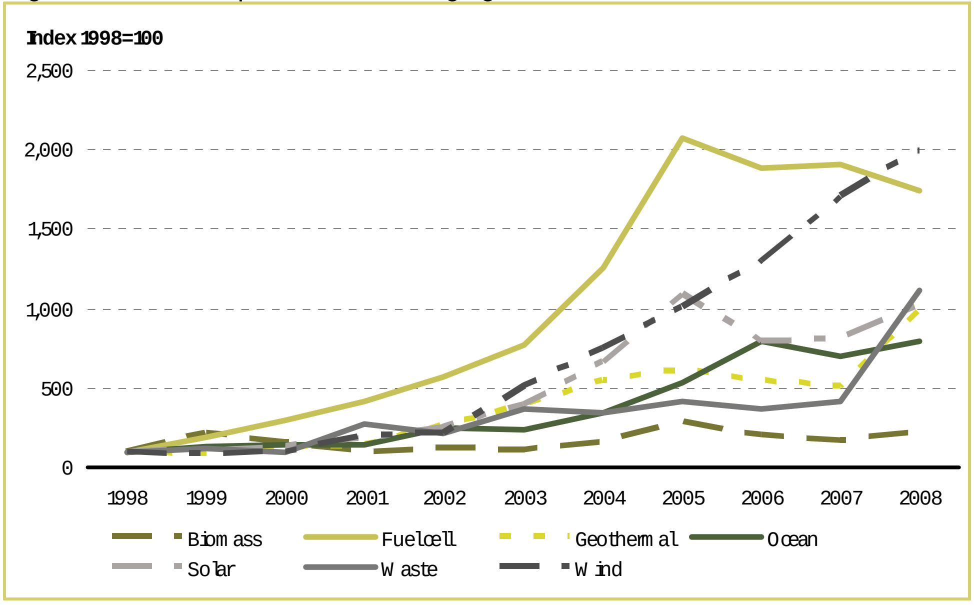
Another conclusion is that, as discussed in the previous chapter, emerging economies may have the technological capacity to copy technologies but they will also have to develop their capacity in IPR law to practically manage licensing and other kinds of technology transfer, and in order to attract and manage innovation in carbon abatement technology.

Among the technologies most actively patented in emerging market economies, solar power is clearly is the lead with about have of the patenting activity there, followed by fuel cell technology and wind energy. Others technology domains register fairly low patenting activity levels.

Figure 3.1 and 3.2 give a more graphic perspective of these figures. In these figures, annual patent numbers have been rebased with index = 100 for the year 1998.

Apart from rapid increases in the overall volume of patenting in emerging markets, it is even more important to note that, at the same time, a large percentage of domestic patents in emerging market economies are registered and owned by residents of these countries.

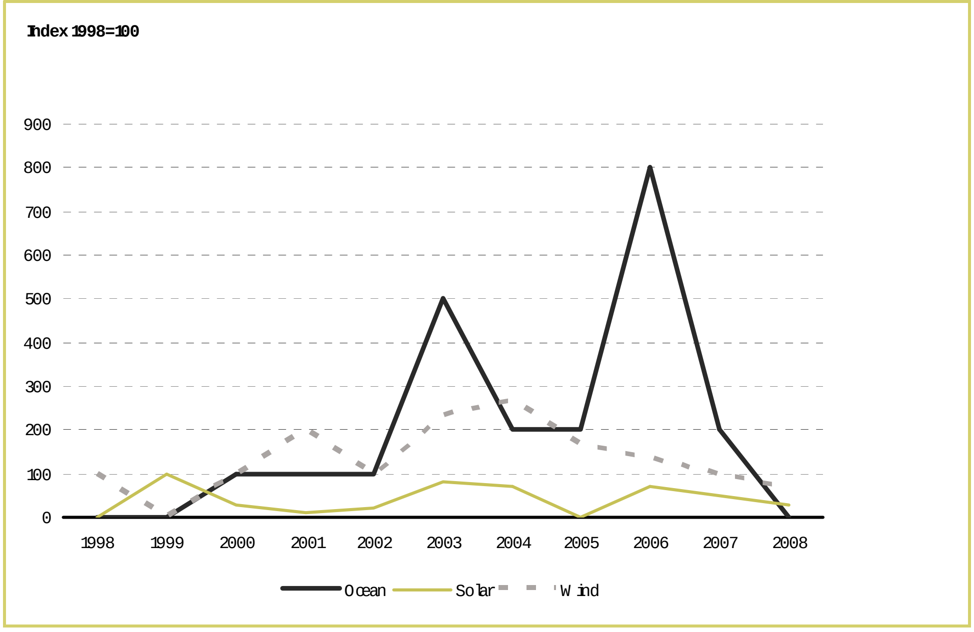
Figure 3.1: Patents protected in emerging economies



Source: Own extraction of data from EPODOC, Pluspat and WPIX.

The development in the number of patents protected in the least developed countries is very volatile, c.f. Figure 3.2. This is because the number of patents is so small that even minor changes in the number of patents can give rise to marked changes in the curves on the figure.

Figure 3.2 Patents protected in least developed countries



Note: Only ocean, solar and wind technology is presented, because for the other technologies the amount of patenting is too small to allow for exposition. For ocean and solar technology the index is set to 100 in 1999.

Source: Own extraction of data from EPODOC, Pluspat and WPIX.

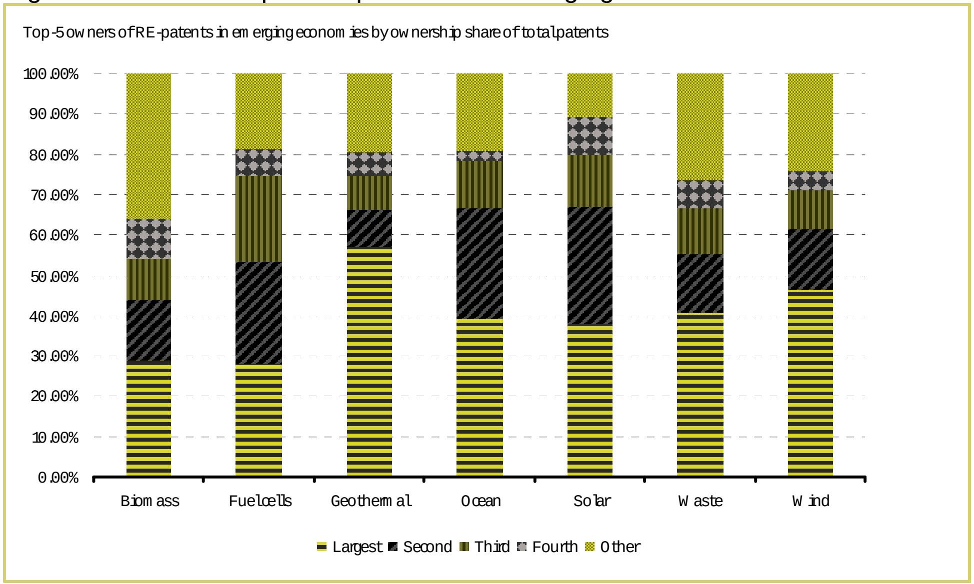
The vast majority of the patent applications sought protection in the emerging economies of Latin America, Eastern Europe, India and China, and only few sought protection of IPR in the least developed countries of Africa. Of the technologies covered by patent data in this study, wind technology is the carbon abatement technology which is most likely to be patent protected in emerging economies – 15 percent of all patent applications in the world within this technology seek protection of IPR in least developed countries and emerging economies. The least protected carbon abatement technology in our data is biomass for which about 6 per cent of patent applications seek protection in least developed countries and emerging economies.

Perhaps even more important than the rapid increase in the number of registered patents in emerging market economies is the rapid rise in local ownership of these patents. About a third of all patents registered in emerging market economies are owned by residents of these countries; two thirds is owned by foreign owners. The share of domestic ownership of patents has increased fast, from close to zero in the late 1990s to the present figures. At the same time, it should be noted that is phenomenon is very much dominated by China: out of the approximately 7.400 climate change technology patents owned by residents of emerging market economies in 2008, 92% are owned in China by Chinese residents. None of the other emerging market economies has taken such a huge step forward in domestic ownership of IPR.

It is somewhat surprising then to see China take the lead in the international debate on climate change technology transfers and advocate a more flexible IPR regime. That would clearly undermine the interests of Chinese companies that are rapidly building up a very significant stock of patents in these technologies. Brazil and Russia are also increasing domestic patent ownership but are lagging considerably behind China. At the other end of the spectrum is India, with very little domestic patent ownership in the relevant climate change technologies.

Figure 3.3 shows that the ownership structure of patents protected in emerging economies is relatively well dispersed. The combined patents of the four largest owners (by nationality) tend to be less than 80 percent of the patents designated in emerging economies. Furthermore, to the extent that nationality based ownership is only a proxy for individual ownership there are likely to be more than one firm within each country that compete within each carbon abatement technology. The conclusion that can be drawn from this is that climate change technology markets do not seem to be monopolistic, with a healthy degree of competition between several large players. This makes it unlikely that IPR owners can charge significant monopoly rents on their inventions and therefore unlikely that patent pricing is a major barrier to technology transfers. Pricing will be close to normal market prices.

Figure 3.3 Owners of patents protected in emerging economies

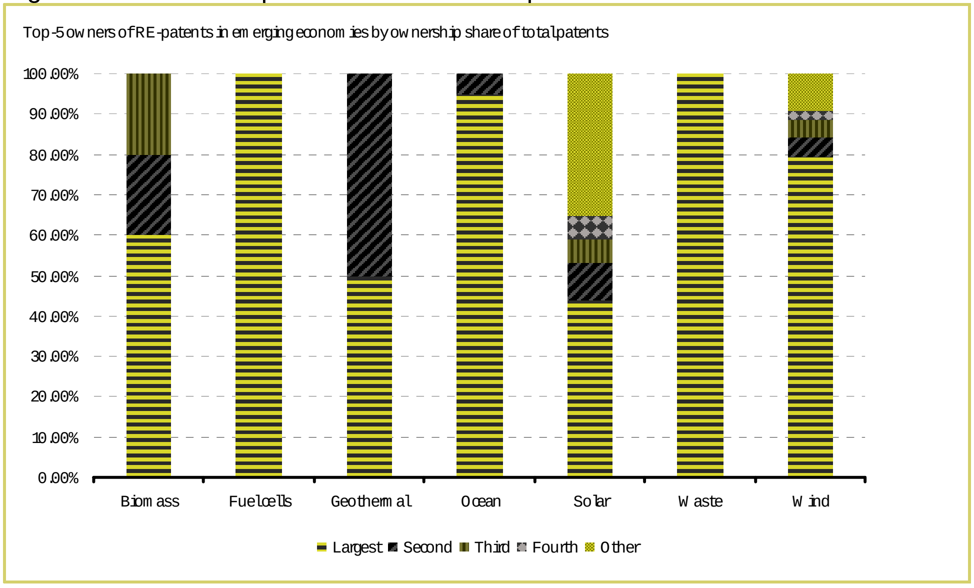


Note: For biomass the largest owner is USA (29%), second largest is Germany (15%), third largest is UK (10%) and fourth largest is China (10%). For Fuel cells the largest owner is Japan (28%), second largest is USA (25%), third largest is China (21%) and fourth largest is Korea (7%). For Geothermal the largest owner is USA (57%), second largest is China (9%), third largest is Japan (9%) and fourth largest is Germany (6%). For Ocean the largest owner is Brazil (39%), second largest is USA (28%), third largest is Norway (12%) and fourth largest is UK (3%). For Solar the largest owner is China (38%), second largest is Japan (29%), third largest is USA (13%) and fourth largest is Korea (10%). For Waste the largest owner is China (41%), second largest is USA (15%), third largest is Japan (11%) and fourth largest is UK (7%). For Wind the largest owner is China (47%), second largest is Germany (15%), third largest is USA (9%) and fourth largest is Brazil (5%).

Source: Own extraction of data from EPODOC, Pluspat and WPIX.

In the least developed countries the situation is somewhat different, according to our data. In these countries, ownership of the few patents which are protected in these countries is much more concentrated on a few countries, c.f. Figure 3.4. As the number of patents is very low it may be that ownership is even concentrated on a few firms world wide. While this may suggest limited competition on some carbon abatement technology in the least developed countries, it may also indicate that the size of the market in the least developed countries is currently too small to allow for more competition.

Figure 3.4 Owners of patents in least developed countries



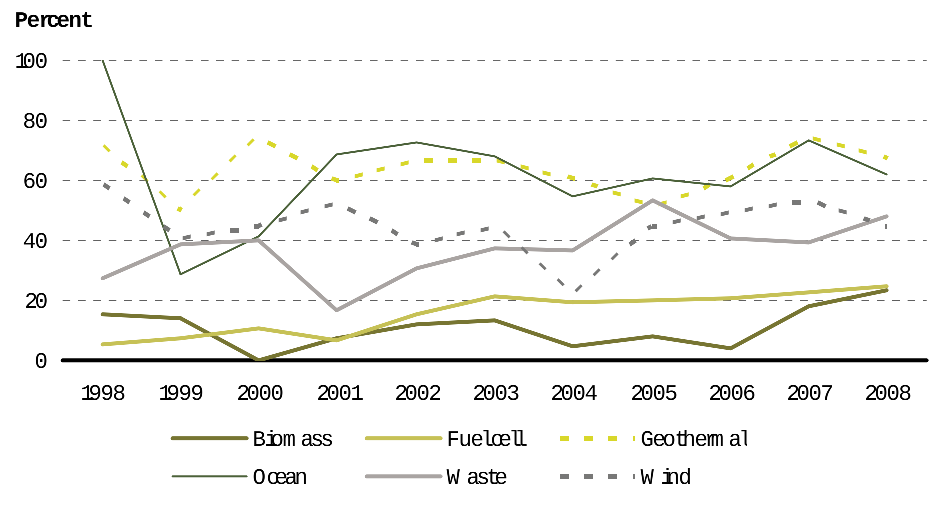
Note: For biomass the largest owner is USA (60%), second largest is UK (20%), third largest is France (20%). For Fuel cells the largest owner is USA. For Geothermal the largest owner is Moldavia (50%), second largest is Uruguay (50%). For Ocean the largest owner is Moldavia (95%), second largest is Ivory Coast (5%). For Solar the largest owner is Moldavia (44%), second largest is USA (9%), third largest is Senegal (6%) and fourth largest is Australia (6%). For Waste the largest owner is Ivory Coast. For Wind the largest owner is Moldavia (80%), second largest is Spain (5%), third largest is Norway (5%) and fourth largest is USA (2%).

Source: Own extraction of data from EPODOC, Pluspat and WPIX.

Many of the patents protecting the emerging economies are owned by residents of the emerging economies themselves, with the exception of India. On the other hand, the (very few) patents protecting the least developed countries of Africa tend to be owned by firms in developed countries.

Developing countries in general are not without power in the patent market which they face. As mentioned above, in particular emerging economies own an important share of the patents which are protected in emerging economies, and there is no indication that emerging economies' position is weakening. This means that emerging economies can to some extent substitute western technology for their own and that the world market is not dominated by few countries or firms. Figure 3.5 shows the level and development of the share of patents protecting developing countries, which are owned by residents of developing countries. At the world level, major patent holding countries within renewable energy technology are Germany, USA and Japan, c.f. Johnstone (2008).

Figure 3.5: Percentage of patent applications in developing countries owned by residents of developing countries



Note: Almost all patents protected outside the developed world are protected in emerging economies. Therefore the figure reflects mostly the patterns of ownership of patents protected in emerging economies. Readers interested in the precise ownership information can see appendix c, where the raw data is shown.

Source: Own extraction of data from EPODOC, Pluspat and WPIX.

Chapter 4 BARRIERS FOR RECEIVING TECHNOLOGY

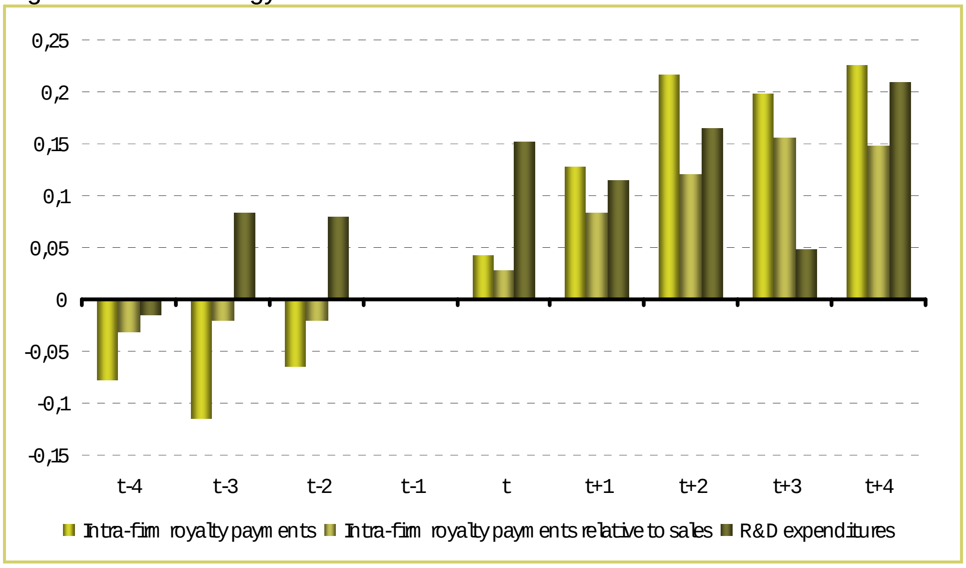
This chapter looks into possible barriers for technology transfer on the side of the receiving country.

4.1. ENFORCEMENT OF IPR

Several pieces of literature suggest that firms will be hesitant to transfer technology to countries known to be hesitant to enforce IPR law. Branstetter et. al (2002) has examined how the scope of technology transfer[7] within US multinationals change as a consequence when a series of IPR reforms[8] in a country[9] are implemented.

Branstetter et al. found that royalty payments for the use or sale of intangible assets made by affiliates to parent firms increase when IPR legislation is strengthened. This shows that US multinational companies are more active in engaging in transferring intangible assets (that might or might not be protected by IP rights) to own affiliates in a country, if the country has strengthened its IP legislations. Branstetter et al's results also suggests that trade is stimulated by strengthened IP legislation, because royalty payments represent the sale of IP rights between subsidiaries of a firm.

Figure 4.1: Technology transfer before and after IPR reforms



Note: At time 't' IPR reforms strengthening enforcement of IPR law are implemented.
Source: Branstetter et. al (2002).

[7] Technology transfer is normally defined as a comprehensive set of activities where a technology owner may on the basis of a concluded license agreement transfer rights to the use of a given technology to other persons or legal entities. In Branstetter article, the term "technology transfer" (most unusually) refers to the transfer of rights between company headquarters and group affiliates in other countries.
[8] IPR reforms which strengthen the IPR legislations
[9] Countries examined: Argentina, Brazil, Chile, China, Colombia, Indonesia, Japan, Mexico, Philippines, Portugal, South Korea, Spain, Taiwan, Thailand, Turkey and Venezuela.

Figure 4.1 shows the effect of IPR reforms in emerging economies. The horizontal axis shows time. 't-1' indicates the year before a reform is implemented, and 't-2' indicates two years before a reform is implemented. The vertical axis shows the logarithm of the indicators of transfer of technology and research and development (R&D) activity. The bars show the difference between transfer of technology and research and development in a given year and the levels at time 't-1'. The figure shows that the year after IPR is introduced, technology transfers and R&D activity increases. Branstetter (2002) interprets this as evidence that the presence of IPR increases technology transfer and innovation activity.

This evidence suggests that a sound and enforced IPR system may be a prerequisite for technology transfer. Accordingly, it could prove beneficial for some developing countries to improve their IPR system. However, in some countries it is difficult to enforce IPR law as the example in the box shows.

Box 4.1: Up coming competition legislation in China and contract enforcement in China

China has among international lawyers a reputation that enforcing a breached agreement before Chinese Courts is somewhat different and more troublesome than before European Courts in general.

Some evidence suggests that an upcoming review of Chinese competition law might put a western IP rights holder at further risk.

In Chinese technology transfer legislation, the Chinese partner receives all rights to improvements of a licensed invention, without any possibility of financial compensation to the licensor. Lee and Schelkopf exemplify these issues in the article: "How to transfer technology from the US to China" from 2006.

"When licensing a technology to a Chinese business partner, the non-Chinese transferor will generally want to be granted back the rights to the improvements developed by the Chinese licensee; however, Chinese law creates significant uncertainties in this area.

The Technology Regulations provide that during the term of a technology import contract, ownership of improvements to transferred technology belongs to the improving party. Thus, if a Chinese licensee makes improvements to the technology licensed by a foreign licensor, the improvements belong to the Chinese licensee. Under the Supreme Court Interpretation, the foreign licensor cannot require the Chinese licensee to assign the improvements, or grant an exclusive license to use the improvements, to the foreign transferor without compensation. However, there is no definitive guidance as to what constitutes adequate or reasonable compensation."[10]

China is furthermore on the brink of instigation new competition/anti-monopoly legislation (to enter into force 1. January 2009) by which it is expected that licensor's involved in technology transfer will be even further exposed to a risk of loss of rights than until now.

Source: The IPR Company and Lee and Schelkopf (2006).

4.2. ABSORPTIVE CAPACITY

Irrespective of whether or not a technology is protected by IPR, in particular the least developed countries, but also emerging economies may not be able to fully exploit or fur-

[10] From the article: "How to transfer technology from the US to China. By: Lee, Zhu (Julie), Schelkopf, J. Bruce, Managing Intellectual Property, Jul/Aug 2006, Issue 161

ther develop the technology once it has gained access to it. The reason is the pool of ‘tacit’ of non-formalised knowledge that might exist about the use of the technology.

Closely related to IP rights are know-how. Many products can only be manufactured if related know-how is available. For example, a company might over the years have found their own special ‘recipe’ for how to optimise the production processes or how to achieve certain product results. Know-how is typically not protected by IP rights. For many companies, especially small and medium sized enterprises, the reality is very often that the only protection they might have to prevent others from copying their products is to keep the cumulated know-how on how to best manufacture their product well-kept secrets. Any information that may be used in the operation of a business and that is sufficiently valuable to afford an actual or potential economic advantage is considered a trade secret. Examples of trade secrets can be formulas for products, such as the formula for Coca-Cola; compilations of information that provide a business with a competitive advantage, such as a database listing customers; and even advertising strategies and distribution processes.

Unlike patents, trade secrets are protected for a theoretically unlimited period of time, and without any procedural formalities. Trade secrets, however, tend to escape, and protection is not free. Under the best of circumstances, firms must restrict access to premises and documents, educate key employees and government inspectors, and closely monitor publications and trade show presentations. Although secrecy is expensive to maintain, large companies rely heavily on it when patents are not available. The larger the company, the more it needs legal protection for its commercial secrets.

Companies that cannot rely on a country's courts to help preserve important secrets must rely on self-help. They may, for example, severely limit the number of people with access to competitively important information. More likely, information needed for critical operations will be shared only if adequate trade secret protection is available. If not, few, if any, local employees will be trained beyond the level necessary to perform essentially unskilled assembly tasks.

Know-how is for example the knowledge needed to perform production of a product. When for example a new manufacturing plant is set up, a company is forced to transfer know-how to local engineers and local skilled workers in order to enable them to set up a well-functioning production site (both if the production is outsourced to a third party, or if the production is performed by a daughter company in the given country). The know-how transferred (e.g. written assembly instructions, Bill of materials, production secrets, secret raw materials and compounds and services related to manufacturing technology), is most often not available in patents obtained by the company. The know-how being transferred is therefore very valuable for the company, and it could be a devastating blow to the competitiveness of the company if competitors and/or counterfeiters obtained such information. With such know-how, third parties might be able to combine both the technologies (that are public available) with the know-how, and thereby manufacture a similar or identical product.

There is a great variety as to what kind of IP rights that are utilized and/or applied within different industry sectors; a recent study performed by Synovate during the period November 2007 to January 2008 among North-European companies (respondents were primarily managers), showed that the respondents ranked know-how and trade secrets as more important than trademarks, designs, copyrights and patents. Patents were ranked as the lowest[11]. The study also indicated that the perceived general importance of know-how decreases the larger a company becomes.

In addition, the study shows that while pharmaceutical companies define patents as being the most important intellectual asset, companies in the food industries finds trademarks to be of the most importance. The scale and content of a company's work with IP rights is often closely connected to characteristics of the specific industry, such as for instance the segment's general degree of developing technological innovations, how many years the industry has been using a common technological platform, the degree of competition within the specific industry segment, the size of the players in the industry, whether the products are sold to businesses or consumers, to which degree brands are important for businesses in the industry, etc.

Transfer of knowledge also requires that the recipient can make use of the knowledge, put it into the relevant contexts and understand the premises on which new knowledge builds. This requires both education and relevant experience. Hence a combination of educational level and economically active sectors relevant for carbon abatement technologies is a prerequisite for technology transfer.

Lack of access to capital in domestic or international credit markets may also be an important barrier, especially for developing countries with a history of difficulty with serving their debt. GHG abatement technologies which require substantial investments may not be feasible to some developing countries due to lack of access to capital.

Besides, some important GHG abatement technologies require special infrastructure. For example, windmills require extended net capacity which can accommodate the fluctuations in power generated by the change in the amount of wind. This infrastructure may require substantial additional investment for which some developing countries may not be able to find sufficient capital. Finally, barriers to trade in the form of tariffs or non-tariff barriers (e.g. standards) may also be a barrier to transfer of technology through trade, cf. Table 4.1.

[11] Know-how was ranked as the most important intangible asset, 89% of all respondents answered that know-how was either 'very important' or 'rather important'. Trade secrets (81%), Trademarks (75%), Domain names (75%), Databases (67%), Designs (69%), Copyright (52%) and Patents (38%) (41% answered that patents were not important).

These problems of lack of knowledge or know-how necessary for using foreign technology are most important for the least developed countries in which the level of education and the level of learning by doing obtained in relation to advanced technology is likely to be small. Emerging market economies on the other hand may in some cases have good absorptive capacity.

A final set of important barriers to transfer of carbon abatement technology concerns tariff and various non-tariff barriers to trade. Brazil, Russia, India and China have significant barriers to trade in carbon abatement technology, according to OECD (2008b). This country group often levies tariffs above 10 percent on such technology. The country group also applies substantial non-tariff barriers in the form of burdensome pre-shipment inspection and informal “additional payments”. OECD (2008) considered a range of non-tariff barriers to trade in carbon abatement technology, including among others pre-shipment inspection and customs proceedings, quantitative import restrictions and import surcharges or border taxes. Interviews were conducted with a selection of producers within solar-based energy industry, wind-powered electricity generation, geothermal-energy-based electricity generation, supercritical and ultra-supercritical steam generators, coal-mine methane recovery, steel manufacturing and cement manufacturing. The responses given by these producers on the significance of different non-tariff barriers to trade were the basis of the assessment of the significance of the barriers.

Table 4.1: Overview of studies of non-IPR barriers to technology transfer

Source	Conclusion	Method
Jasinski 2005	In Poland, the worst barriers to both domestic an international technology transfer are: 1. R&D units are not fully open to cooperate with firms 2. Inefficient system supporting firms' innovation and R&D 3. Lack of financial resources 4. Lack of innovative culture and mentality among firms' employees	Delphi survey among Polish and international experts.
Dechezlepretre 2008	Technological capability measured through the ArCo Index (a composite of creation of technology, technological infra structure and development of skills) has a significant positive effect on the probability of technology transfer to a country in the chemical and energy sector. In the agricultural sector the effect is negative, this is explained by that technological capabilities increase the local availability of technologies and that effect is apparently dominating in the agricultural sector.	Regression analysis on 644 CDM projects
Blackman 1999	Overall, there is evidence that high level of human capital leads to early adoption of new technology. Human capital influences technology transfer in a least two different ways. First, the search cost of a firm that lacks the right know-how is higher. In other words, if you do not really know about or understand new technology it takes more resources to locate it. Second, variations in human capital, in the sense of varying labour productivity lessen the profit of adopting new technologies for some firms.	Literature review
Lin 1999	High education leads to more frequent and more intense adoption of new technology. In the Chinese agricultural sector education level has a positive effect on the probability to adopt new type of hybrid rice.	Theoretical portfolioselection model and regression analysis on cross-section survey of 500 households

Source: *Copenhagen Economics.*

4.3. SUBSIDIES IN DEVELOPING COUNTRIES

Another important type of barrier for the transfer of carbon abatement technology is subsidies for the consumption of fossil fuels. This depresses the cost of using conventional technology relative to the cost of using carbon abatement technology, thereby reducing the incentive to use carbon abatement technology and slowing down the transfer of such technology.

We find that many of the least developed countries and the emerging economies could encourage adaptation of cheap technologies bringing about significant greenhouse gas reduction by starting or continuing to phase out existing subsidies on the consumption of fossil fuels. For example, Iran could reduce its CO_2 emissions by almost 50% if it abandoned its current energy subsidy programmes, cf. Table 4.2.

Table 4.2: Effects of dismantling energy subsidies on CO_2 emissions

Country	Average rate of subsidy (% of market price)	Annual economic efficiency gain (% GDP)	Reduction in CO_2 emissions (% relative to baseline)
China	10.9	0.4	13.4
Russia	32.5	1.5	17.1
India	14.2	0.3	14.1
Indonesia	27.5	0.2	11.0
Iran	80.4	2.2	49.4
South Africa	6.4	0.1	8.1
Venezuela	57.6	1.2	26.1
Kazakhstan	18.2	1.0	22.8

Source: *IEA (1999).*

As the table shows, not only Iran, but several countries subsidise energy thereby reducing the incentive of their firms and consumers to adopt even very cheap carbon abatement technologies. Hence, removal of energy subsidies would encourage the take-up of cheap carbon abatement technologies thereby reducing $CO_{2.}$

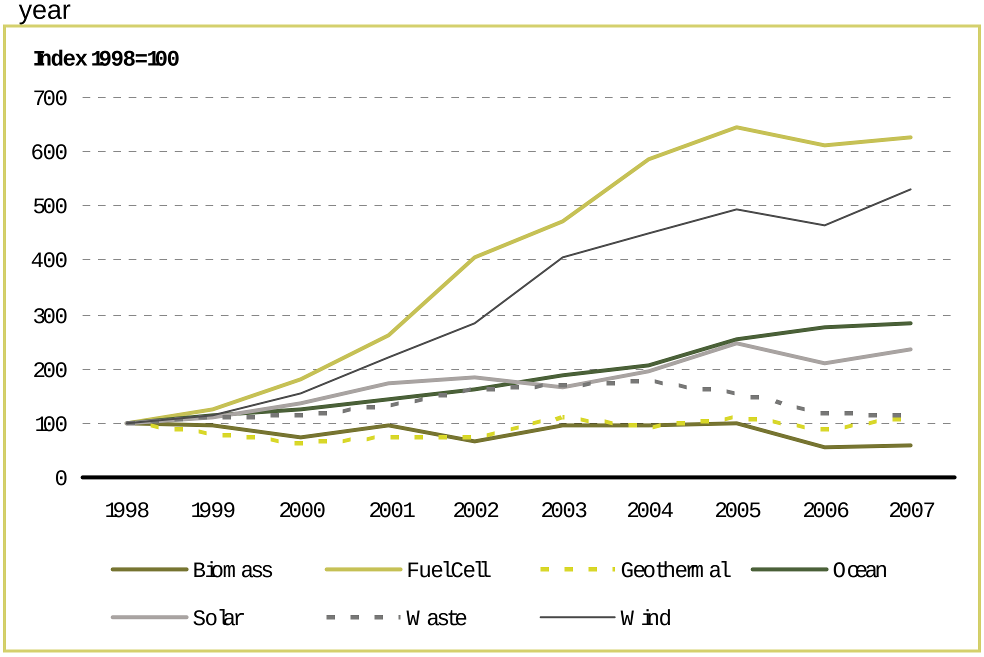
Another type of subsidy that may distort the market for climate change technologies is grant aid from bilateral and multilateral donors. If grant aid is earmarked for specific innovative technologies, it reduces the costs of applying these particular technologies compared to others. Unless prior feasibility studies have been carried out to ascertain that the selected technologies are economically optimal to reduce energy consumption and carbon emissions, there is no guarantee that this will be an efficient use of subsidies. The recipient country's investment would in that case be directed to economically suboptimal technologies.

Chapter 5 | CONCLUSIONS

Global warming is of concern for all. Reduction of greenhouse gas (GHG) emissions is at the core of policy making in the EU. The Copenhagen summit on climate change, to be held in 2009, seeks to reach a global agreement on binding emission reduction targets.

Recent years have seen an increase in innovative activity within carbon abatement technologies which reduces GHG emissions. This is evidenced by an increasing number of global patent applications per year, cf. Figure 5.1.

Figure 5.1: Number of patent applications for carbon abatement technology per year



Note: The Figure shows number of patent applications for seven energy technologies globally. The data extracted are patent applications from the following countries: Argentina, Benin, Botswana, Brazil, Burkina Faso, Cameroun, Central Africa Republic, Chad, China, Congo, Egypt, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea, Guinea Bissou, India, Ivory Coast, Kenya, Malawi, Mali, Mauritania, Moldavia, Mozambique, Namibia, Niger, Philippines, Russia, Senegal, Sierra Leone, Somalia, Soviet Union, Swaziland, Tongo, Uganda, Ukraine, Zambia, Zimbabwe. The sample is intended to be representative of patenting activity in the least developed countries and emerging economies of the world. There are widely differing patenting practices for different technologies which implies that the level of patenting can differ much. It would therefore be misleading to compare the development of patenting in different areas using a figure of levels of patenting – some areas would not be visible on the figure. Hence, in order to illustrate the broad development in patenting activity we have chosen to compare the patenting level in each year to the patenting level in 1998. In 1998 there were 500 patents extra protected in the biomass area, 1699 extra patents protected in the fuel cell area, 261 extra patents protected in the geothermal area, 194 extra patents protected in the ocean power area 5588 extra patents protected in the solar area, 501 extra patents protected in the waste area and 395 extra patents protected in the wind area.

Source: Own extraction of data from EPODOC, Pluspat and WPIX.

Furthermore, instead of seeking patent protection only in developed countries, patent applicants are now increasingly seeking intellectual property rights protection in emerging economies. There has been a strong increase in energy technology patent applications in emerging economies in the last ten years, especially within fuel cell and wind technology.

The observation of increasing patent activity taking place in emerging economies has raised concerns from some least developed and emerging countries that their access to these technologies may become very expensive. At various UNFCCC[12] conferences, developing countries have raised these concerns.

Least developed and emerging economies are mostly concerned that patenting hinders transfer of climate change technologies, and they claim that patents makes prices unaffordable for them. In this respect, they propose measures to decrease the cost of carbon abatement technology acquisition. For example, China and Brazil recently advocated the establishment of a "multilateral technology acquisition fund" to be financed by developed countries[13], in an attempt to lower the acquisition cost of carbon abatement technology. Brazil, furthermore, pleaded for formalising the conditions for using the so-called "flexibility rights" under the trade-related aspects of intellectual property rights agreement (TRIPS).[14]

The concern that the IPR protection may make carbon abatement technology too expensive is based on the premise that competition in carbon abatement technology is limited or will become limited, because IPR grants a temporary monopoly on a technology. The limited competition could allow the IPR holder to charge a monopoly mark-up beyond what the specific patented improvement delivers in terms of increased efficiency.

However, as a first observation, the existence of older variants of technologies within the same technology area, for which the patent protection period has expired, should ensure that the mark-up reflects the added efficiency of the patented improvement.

Furthermore, we find that competition within carbon abatement technologies is fairly high, cf. Figure 5.2. For example for Wind technology the country which protects most patents in the emerging economies accounts for only about 40 percent of all the wind technology patents protected in emerging economies. The second, third and fourth largest patent holding nations in total account for 30 percent of all patents in wind technology. The ownership of the remaining 30 percent of patents are scattered over a wide range of countries. This suggests the presence of competition in the emerging economies[15]. The case is somewhat different for the least developed countries, where there may be competition issues involved.

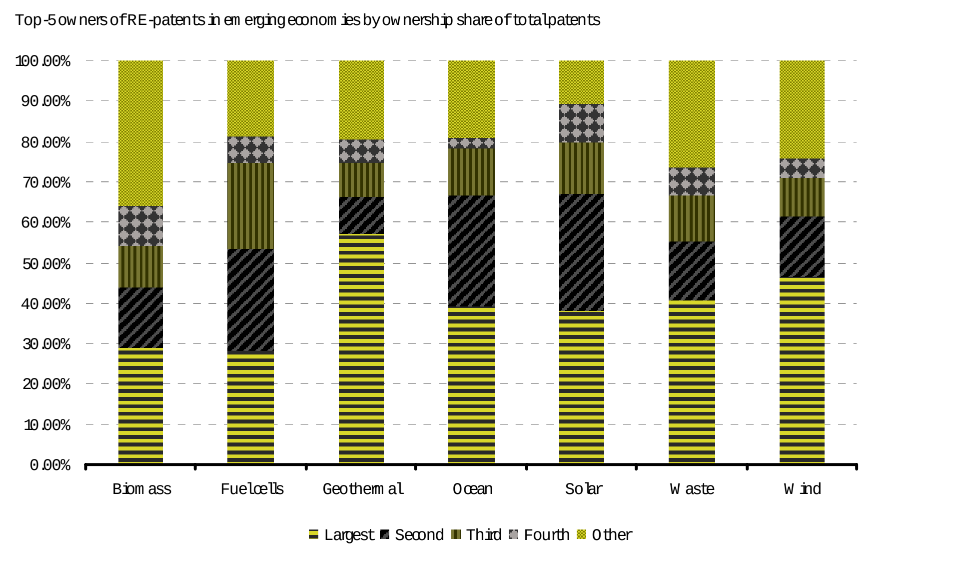
[12] The United Nations Framework Convention on Climate Change (UNFCCC) is the international forum for negotiations on climate change.

[13] Climate Change Talks in Bonn, Day 2, 3 June, 2008

[14] Khor (2008). Flexibility rights in this context encompass a range of rights among other compulsory licensing.

[15] It may even understate the degree of competition between different suppliers of carbon abatement technologies because there is also competition between different firms residing in the same country.

Figure 5.2: Percentage of patents filed in emerging market economies, by nationality of the owner, 1998-2008



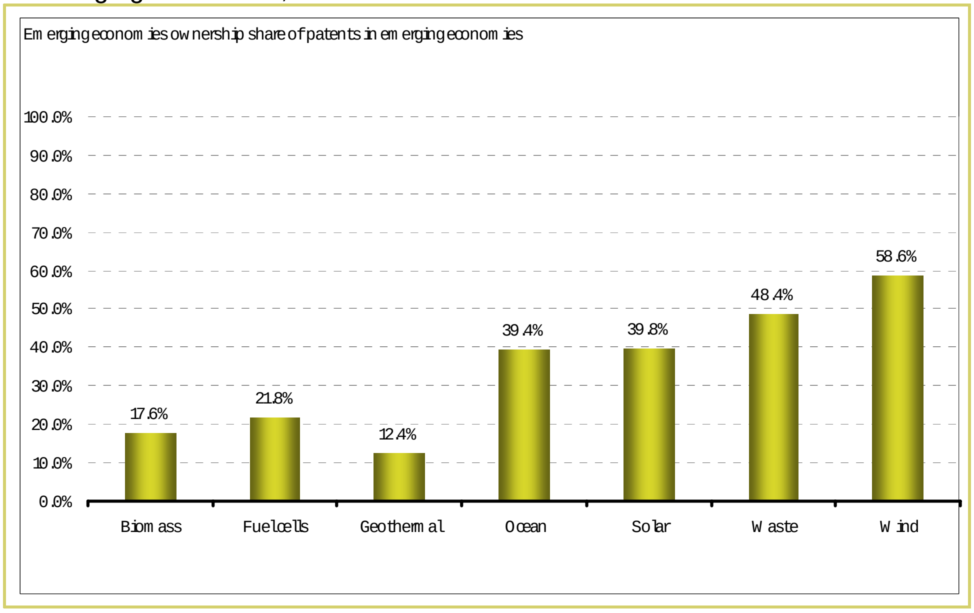
Note: For biomass the largest owner is USA (29%), second largest is Germany (15%), third largest is UK (10%) and fourth largest is China (10%). For Fuel cells the largest owner is Japan (28%), second largest is USA (25%), third largest is China (21%) and fourth largest is Korea (7%). For Geothermal the largest owner is USA (57%), second largest is China (9%), third largest is Japan (9%) and fourth largest is Germany (6%). For Ocean the largest owner is Brazil (39%), second largest is USA (28%), third largest is Norway (12%) and fourth largest is UK (3%). For Solar the largest owner is China (38%), second largest is Japan (29%), third largest is USA (13%) and fourth largest is Korea (10%). For Waste the largest owner is China (41%), second largest is USA (15%), third largest is Japan (11%) and fourth largest is UK (7%). For Wind the largest owner is China (47%), second largest is Germany (15%), third largest is USA (9%) and fourth largest is Brazil (5%).

Source: Own extraction of data from EPODOC, Pluspat and WPIX.

Therefore, if some of the technologies considered in Figure 5.2 are expensive to buy, it is less likely that the high price is due to limited competition. The IPR protection is not likely to be a barrier in the sense that it makes technology unaffordable to emerging economies.

Furthermore, in the case of emerging economies, we find that for most carbon abatement technologies the major owners of patents are actually emerging economies, and not developed countries, cf. Figure 5.3. This suggests that it is not the *transfer* of carbon abatement technologies from developed countries in it self that is the core of the problem. Notice, however, that we cannot rule out if the more important patents are actually owned by firms in developed countries. Based on our patent statistics, we cannot distinguish between different ‘qualities’ of patents.

Figure 5.3: Share of patents protection in developing countries, owned by firms in emerging economies, 1998-2008



Source: Own extraction of data from EPODOC, Pluspat and WPIX.

So far we have found evidence suggesting that competition exists *within* the same technology – i.e. competition exists between firms supplying e.g. wind mills. We have also found that for several of the seven most advanced technologies for which we have patent information, emerging countries account for a significant share of the patents which are protected in developing countries, making it less likely that patents and IPR constitute a major barrier for *transfer* of carbon abatement technology from developed to emerging economies.

Now we turn to the notion of competition *between* different technologies. For a given abatement target, we find that least developed and emerging economies will probably have to deploy a whole range of different technologies – up to as many as 50 – in order to make significant emissions reductions. This implies the existence of competition between providers of different technologies – which would tend to reduce the mark-up from holding a patent on a specific technology.

Furthermore, our analysis shows that the least developed countries can meet ambitious abatement targets by applying mostly technology which is not protected by IPR, such as forestation and reduced deforestation. Hence, for the least developed countries, IPR protection does not appear to be a barrier for transferring the technology necessary for meeting the abatement targets which are currently being discussed.

The study finds no argument in favour of extending the use of TRIPS provisions on compulsory licensing to climate change technologies.

The TRIPs agreement contains generic provisions on the compulsory licensing of patents (Art. 31 – "*Other use without authorization of the right holder*"):
While such provisions have been used in the pharmaceutical field, this has happened only very exceptionally. Moreover, while a particular drug is often the only way to treat a specific disease, it would be difficult to argue that one specific technology is necessary to address climate change problems, or even one related sub-problem. Usually, a number of alternative technologies can be used to address energy and emission reduction problems. Thus, it would not appear useful to impose compulsory licences on a limited number of specific environmental technologies.

Furthermore, as the study demonstrates, IPR protection is not the main barrier preventing the transfer of environmental technologies to developing countries. A large number of relevant technologies are not patented in low-income developing countries, and in emerging market economies a significant number is patented by local companies. Finally, there is a serious risk that a broad use of compulsory licensing (or other measures weakening IP rights) would constitute a disincentive for companies engaged in that sector, which might reduce their investment in such technologies. This would clearly be detrimental in the long term.

This study concludes that competition exists both within and between carbon abatement technologies. This implies that IPR as such is not what makes technology too expensive for the least developed countries and emerging economies to access.
The economically relevant issue therefore becomes whether the total cost of greenhouse gas reducing technologies is too expensive for the least developed countries and emerging economies - not whether the technology is covered by intellectual property rights per se.

Whether the GHG abatement technologies are too expensive for the least developed countries and emerging economies also depends on how much it costs to use conventional technology which emits much CO_2 . If conventional technology is cheap, then the economic disadvantage from using Carbon abatement technology is large. Part of the explanation for why conventional technology is cheap in many countries is that the countries subsidize the consumption of fossil fuel. The IPR system can hardly be blamed for making Carbon abatement technology exceedingly expensive in cases where the cost of using conventional technology is being kept artificially low by energy subsidies.

We find that the presence of strong intellectual property rights systems, especially in emerging market economies is rather a prerequisite for western firms to be willing to transfer technology to the developing countries - as well as a prerequisite for the creation of innovative new technologies. Therefore dismantling or weakening the intellectual property rights system would not only hinder the access of developing countries to costly technology, it would also hinder the access to low cost technology as IPR protected technology is also to be found among the low abatement cost technologies.

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APPENDIX A: VOCABULARY ON IPR

What is IPR?

IPR is an abbreviation for "Intellectual Property Rights". Included under this term are patents, utility models, designs, trademarks and copyrights.

First of all, before introducing the content of the different IP institutions, it is important to be aware that the different IP rights in general are defined almost homogenously all over the world, however, a range of different local case-law and interpretations of the laws makes the operational sphere of protection of such IP rights less transparent.

Copyright[16]

Copyright is a legal term describing the economic rights given to creators of literary and artistic works, including the right to reproduce the work, to make copies, and to perform or display the work publicly. Copyrights offer essentially the only protection for music, films, novels, poems, architecture, and other works of cultural value. As artists and creators have developed new forms of expression, these categories have expanded to include them. Computer programs and sound recordings are now protected, too. In many European member states, industrial design of a certain artistic height is also protected by default.

Copyrights also endure much longer than some other forms of IP. The Berne Convention, the 1886 international agreement under which signatory states recognize each other's copyrighted works, mandates that the period of copyright protection cover the life of the author plus 50 years. Under the Berne Convention, literary, artistic, and other qualifying works are protected by copyright as soon as they exist. No formal registration is needed to protect them in the countries party to that convention.

Only an author or those deriving their rights through the author -- a publisher, for instance -- can rightfully claim copyright. Regardless of who holds them, however, rights are limited. Copyright protects arrangements of facts, but it does not cover newly collected facts as such. Moreover, copyright does not protect new ideas and processes; they may be protected, if at all, by patents.

Patents

One might say that a patent is a contract between society as a whole and an individual inventor. Under the terms of this social contract, the inventor is given the exclusive right to prevent others from making, using, and selling a patented invention for a fixed period of time -- in most countries, for up to 20 years -- in return for the inventor's disclosing the details of the invention to the public.

Many products would not exist without patent protection, especially those that require substantial investments but, once sold, can be easily duplicated by competitors. At least

[16] Definitions found at http://usinfo.state.gov/products/pubs/intelprp/glossary.htm

since 1474, when first granted by the Republic of Venice, patent protection has encouraged the development and distribution of new technologies. When patents are not available, technology is closely held. If inventors had to rely on secrecy to protect their inventions, much important but undisclosed information often would die with them.

Patents, however, are not easily obtained. Patent rights are granted not for vague ideas but for carefully tailored claims. To avoid protecting technology already available, or within easy reach of ordinary artisans, those claims are examined by experts. Because patent claims vary as much in value as the technologies they protect, applicants must negotiate claims of appropriate defensible scope. (Defensible scope means that applicants must be careful in setting the boundaries of what their invention consists of and what can be protected from infringement in their invention.) This often takes two or more years and is expensive.

Utility Models

Known as petit / small patents with demand of less novelty documentation than patents; will not be further touched upon here.

Design protection

Design protection is used to protect shapes and distinctive designs; a design can be granted for a novel, nonobvious/distinct and ornamental design. A design right confers the right to exclude others from making, using, or selling designs that is identical or closely resemble the registered design. A design right covers ornamental aspects of a design. A design is registered for a fixed period of time - for up to 25 years in some countries.

Trademarks

Trademarks are commercial source indicators, distinctive signs that identify certain goods or services produced or provided by a specific person or enterprise. In villages, cobblers' names used to serve that function. Trademarks are especially important when consumers and producers are far away from one another. Children ask for Barbie dolls, Lego building blocks, and Hot Wheels toy cars. Some adults dream of Ferrari automobiles, but more can afford to buy Toyota or Honda brands. These consumers need trademarks to seek or avoid the goods and services of particular firms.

Throughout most of the world, trademarks must be registered to be enforceable, and registrations must be renewed. Yet, while copyrights and patents eventually expire, brand names from companies that treat customers well become increasingly valuable over time. If trademark rights were to expire, consumers would be collectively harmed as much as owners. Imagine the confusion if unaffiliated firms could sell products under another company's trademark. And consider, for example, the dubious quality of counterfeit and fake drugs and their potential for causing great harm, if not death, to unsuspecting users.

Table 5.1: Classification of technologies according to patent coverage.

Sector	Technology	Cost € / tCO_2e	Description	Patent coverage in developing countries	Remarks
Industry	Conventional - Energy efficiency in existing basic materials production process	21,5	Enhanced efficiency based on existing technologies for basic materials production; Especially relevant in developing countries and transition economies	Not known	Latest products / processes to be implemented
Industry	Conventional - Feedstock substitution	17,2	Substituting feedstock, e.g. using slag, fly-ash and pozzolan as clinker substitutes in cement industry; biofuels as substitute for petrochemical feedstocks and using bioplastics	Not known	Latest products required (biofuels, bioplastics)
Industry	Conventional - Various non-co2 measures	12,5	Various measures in ozone depleting substances substitution, industrial production and energy production - e.g. refrigeration recovery, distributed systems and HFC-secondary loops, new solvent substances, catalytic reduction methods and high and low temperatures in nitric acids, thermal oxidation, replacement of high bleed pneumatic devices in natural gas, etc.	Not known	Latest products required (new solvents, new processes)
Industry	Advanced - process innovation	20,8	Innovation in basic materials production processes, e.g. direct casting of steel, smelt reduction in steel	Not known	Latest by definition
Industry	Conventional - Material and product efficiency	20	Increasing product life span recycling and making same product with less material	Not known	Latest technologies required
Industry	Conventional - Motor systems	34,3	Efficiency improvements in electric motor-drive systems e.g. matching the scale of the motor service to the work demand; efficient control to respond to variations in load; high efficiency motors; reduction of system losses	Not known	knowhow involved in matching size of motor to task
Industry	Conventional - Cogeneration	21,6	Combined heat and power (CHP), an application of technologies that cogenerate heat and electricity to reduce total energy demand and therefore reduce CO2 emissions	Not known	latest products and knowhow relevant
Industry	Conventional - Steam systems	21,5	Increase efficiency in steam production and distribution systems; improvement of the supply systems in developing countries; improvement of maintenance in OECD countries	Not known	latest products and knowhow relevant
Industry	Conventional - Fuel substitution	25,7	Substitute current fuel for less CO2 intensive alternatives, e.g. natural gas as substitute for coal and oil; using biomass or waste in certain sectors in parts of the world	Not known	Knowhow and latest products required
Industry	Advanced - CCS	40	Conducting carbon capture and storage in large energy intensive industrial facilities line, e.g. ammonia plants, blast furnaces, cement kilns, etc.	Not known	Latest by definition
Agriculture/Waste	Rice - reduced flooding	1,5	Mid-season drainage of rice fields to reduce anaerobic conditions / shallow flooding / shift to upland rice that does not require flooding	Not known	Mostly farming knowhow
Agriculture/Waste	Soils - fertilizer shift	-5	Reduces use of fertilizer / split fertilization into smaller pieces over time / nitrification inhibitors are chemical agents that retard or inhibit nitrificatino in soil	Not known	Mostly knowhow
Agriculture/Waste	Soils - conservation tillage	20	Cultivation of soils with reduced or no ploughing	Not known	mostly knowhow
Agriculture/Waste	Landfills - capture CH4 & reduce by recycling	38	Build system of wells and pipes in the landfill to collect and flare CH4, with some additional equipment the CH4 may be compressed and used	Not known	Knowhow and technology (at various levels of sophistication)

Sector	Technology	Cost € / tCO_2e	Description	Patent coverage in developing countries	Remarks
Agriculture/Waste	Livestock - drugs / vitamins	34	Antibiotics make livestock grow faster / bovine somatotropin increases milk yield / propionate precursors reduces methane / methane reducing vaccines under development	Not known	Use of new antibiotics, hormones, to faciltate growth and yield
Agriculture/Waste	Rice - fertilizer shift	1,5	Reduced use by 10-30% / slow release fertilizer / ammonium sulfate replaces urea and ammonium bicarbonate / off-seasons straw amendment reduced amount of available biomass for decomposition	Not known	Use of new fertilizer types (slowrelease) and knowhow
Agriculture/Waste	Livestock - feeding	-8	Improved feed conversion make livestock grow faster / intensive grazing by more frequent rotation between pastures	Not known	Use of new fodders
Agriculture/Waste	Livestock - manure management	-8	Collect manure and store it in various kinds of digesters, exacted CH4 can be used for power generation or cooking	Not known	Array of simple measures based on knowhow and more complex technological solutions
Agriculture/Waste	Wastewater - improved treatment & digesters	1,5	Split waste and recycle or treat components	Not known	Knowhow and technology (at various levels of sophistication)
Forestry	Reduced deforestation	36	Slowing the rate of destruction of pristine natural forests / possible mechanisms include increased use of modern cooking fuels to reduce fuel wood demand and improved management of commercial forestry lands to enhance long-term sustainable yields and reduce logging pressure on pristine forests	< 10%	Mostly knowhow, substitution of wood as fuel, logging reduction
Forestry	Forestation	20	Planting trees on degraded formerly forested land / permanent stands for carbon sequestration - managed forestry plantations - restoration of degraded forests to increase the total carbon stock per hectare - agroforestry: integration of trees into farmland	< 10%	Mostly knowhow, management of forestrly, planting trees, restoration
Power	CCS on new coal plants	20	Assumed technologically proved by 2015-2020; volumes assumed to ramp up 2015-2020 reaching an implementation rate of about 85% of coal new-builds 2020-2030 / Abatement costs assumed to decrease to 20-30 € / t CO2e for new-builds by 2030, more expensive for retrofit and gas / biomass applications	Not known	Mostly advanced technology with development potential
Power	CCS coal retrofit	35	Assumed technologically proved by 2015-2020; volumes assumed to ramp up 2015-2020 reaching an implementation rate of about 85% of coal new-builds 2020-2030 / Abatement costs assumed to decrease to 20-30 € / t CO2e for new-builds by 2030	Not known	Mostly advanced technology with development potential
Power	CCS on new gas plants	25	more expensive on gas applications	Not known	Mostly advanced technology with development potential
Power	CCS on biomass	25	more expensive on biomass applications	Not known	Mostly advanced technology with development potential
Power	CCS on early retirements	30	as above	Not known	Mostly advanced technology with development potential

Sector	Technology	Cost € / tCO_2e	Description	Patent coverage in developing countries	Remarks
Power	Renewables	23	cost of wind power is assumed to decerease driven by learning curve effects, becoming cost competitive by 2015-2025 at 40€/t CO2e / Solar could be cost competitive at 40€ / tCO2e by 2030 in some specifically attractive locations/applications but is minor share of the total renewables potential / Emerging renewables assumed to amount to 15-20% of power production by 2030 / Cost of biomas power production highly dependent on availability of cheap feedstock	> 10 %	Mostly advanced technology with development potential
Power	Nuclear	0	proven technology / moderate cost improvement assumed driven by increased standardization / Volume development driven by political decisions assumed in this sceanrio to approximately double in absolute volume through 2030	Not known	Mostly advanced technology with development potential
Power	Coal to gas shift new plants	25	Replace old plants with newer more efficient	Not known	Implies use of latest technology
Power	Co-firning biomass	20	cofiring biomass	< 10%	Knowhow and technological solutions
Power	Coal to gas shift merit order	35	Incentivize gas power production instead of coal	Not known	Knowhow and technology
Power	Accelerated retirements	30	Legislation / management practices	Not known	Implies use of mostly knowhow
Transport	Demand reduction - CO2 tax (higher oil prices)	40	Legisltion	Not known	Knowhow
Transport	Fuel efficient technologies - powertrain and non-engine	-102	Light weighting, aerodynamiccs, rolling resitance, smart-stop system, exhaust after gaas	Not known	Implies use of latest technology
Transport	Fuel efficient technologies - hybrids	40	battery and electric motor with integrated power management, transmission adaptation, electrification of auxillaries, etc.	Not known	Implies use of latest technology
Transport	Fuel efficient technologies - plugin hybrids	40	hybrid vehicle with a battery being charged through the grid	Not known	Implies use of latest technology
Transport	Fuel switch - cellulosic ethanol	6	Fuels made from biomass, technology in demosnstration phase, not yet produced in large scale	< 10%	2nd generation biofuel
Transport	Fuel switch - grain ethanol	40	fuels made from grain (mostly corn) mature technology with low scope to reduce costs further	< 10%	1st generation biofuel
Transport	Fuel switch - sugarcane ethanol	-24	Fuel from sugarcane, large scale and cost effective in Brazil with huge future potential	< 10%	1st generation biofuel
Transport	Biodiesel	40	Fuel made from recycled grease or oily crops. Technology does not apply much scope for cost improvement	< 10%	depending on production technology
Transport	Demand reduction - smart transit	0	Legislation / management practices	Not known	Knowhow
Building	Residential - lighiting	-85	Increased use of low energy light bulbs	Not known	Relatively mature technology, knowhow required for promotion
Building	Residential - household appliances	-65	increased unit efficiency e.g. freezers	Not known	incremental innovation, knowhow required for promotion
Building	Residential water heating	-15	more efficient water heating systems	Not known	incremental innovation, knowhow required for promotion

Sector	Technology	Cost € / tCO_2e	Description	Patent coverage in developing countries	Remarks
Building	Residential - Heating and ventilation	-150	improved insulation, change to three glass windows	Not known	incremental innovation, knowhow and incentives required
Building	Commercial - lighting	-65	fixtures, timers, LFLs	Not known	incremental innovation, knowhow and incentives required
Building	Commercial - lighting	-65	more efficient office appliances	Not known	incremental innovation
Building	Commercial - water heating	-100	more efficient water heating systems	Not known	incremental innovation, knowhow and incentives required
Building	Commercial - airconditioning	-80	improved A/C systems	Not known	incremental innovation, knowhow and incentives required
Building	Commercial - heating and ventilation	-125	Better insulation and improved heating / ventilation	Not known	incremental innovation, knowhow and incentives required

Source: Vattenfall & McKinsey (2007) and Copenhagen Economics; Puustjärvi (2003).

APPENDIX B PATENT DATA SOURCES AND DEFINITIONS

Technologies
Patent data (patent applications) were extracted for 7 technologies; a) Wind Energy Technology, b) Solar Energy (includes solar photovoltaic power and solar thermal power), c) Fuel Cell Technology, d) Geothermal, e) Ocean, f) Biomass and g) Waste.

IPC-classes
The IPC-classes for each of the 7 technologies were defined by using the classifications that WIPO and Johnstone applies. One IPC-class, Ocean IPC-class: F03B13/26 was defined by DKPTO as their patent specialists defined this IPC-class as being part of the IPC-classes which should be included in Ocean. An exhaustive list of IPC-classes analysed for each of the technologies is listed below.

Technology: Wind Energy Technology
Wind motors with rotation axis substantially in wind direction F03D 1/00-06
Wind motors with rotation axis substantially at right angle to wind direction F03D 3/00-06
Other wind motors F03D 5/00-06
Controlling wind motors F03D 7/00-06
Adaptations of wind motors for special use; F03D 9/00-02
Details, component parts, or accessories not provided for in, or of interest apart from, the other groups of this subclass F03D 11/00-04
Electric propulsion with power supply from force of nature, e.g. sun, wind B60L 8/00
Effecting propulsion by wind motors driving water-engaging propulsive elements B63H 13/00

Technology 2: Solar Energy (includes solar photovoltaic power and solar thermal power):
Devices for producing mechanical power from solar energy F03G 6/00-08
Use of solar heat, e.g. solar heat collectors F24J 2/00-54
Machine plant or systems using particular sources of energy - sun F25B 27/00B
Drying solid materials or objects by processes involving the application of heat by radiation - e.g. sun F26B 3/28
Semiconductor devices sensitive to infra-red radiation - including a panel or array of photoelectric cells, e.g. solar cells H01L 31/042
Generators in which light radiation is directly converted into electrical energy H02N 6/00
Aspects of roofing for the collection of energy – i.e. solar panels E04D 13/18
Electric propulsion with power supply from force of nature, e.g. sun, wind B60L 8/00
G02B 5/10, H01L 31/052. H01L 25/00, H01L 31/04, , H01L 31/00, H01L 31/048, H01L 33/00, H02J 7/35, H02N 6/00, H01L 31/18, E04D 1/30, G02F 1/136, G05F 1/67,

Teknologi 3: Fuel Cell Technology

H01M 4/00, H01M 4/86, H01M 4/88, H01M 4/90, H01M 8/00, H01M 8/02, H01M 8/04, H01M 8/06, H01M 8/08, H01M 8/10, H01M 8/12, H01M 8/14, H01M 8/16, H01M 8/18, H01M 8/20, H01M 8/22, H01M 8/24,

Technology 4: GEOTHERMAL
Other production or use of heat, not derived from combustion - using natural or geothermal heat F24J 3/00-08
Devices for producing mechanical power from geothermal energy F03G 4/00-06
Electric motors using thermal effects H02N 10/00

Technology 5:OCEAN
Adaptations of machines or engines for special use - characterized by using wave or tide Energy F03B 13/12-24
Mechanical-power producing mechanisms - ocean thermal energy conversion F03G 7/05
Mechanical-power producing mechanisms - using pressure differentials or thermal differences F03G 7/04
Water wheels F03B 7/00
F03B13/26 using tide energy

Technology 6: BIOMASS
Solid fuels based on materials of non-mineral origin - animal or vegetable C10L 5/42-44
Engines operating on gaseous fuels from solid fuel - e.g. wood F02B 43/08
Liquid carbonaceous fuels - organic compounds C10L 1/14
Anion exchange - use of materials, cellulose or wood B01J 41/16

Technology 7: WASTE
Solid fuels based on materials of non-material origin - refuse or waste C10L 5/46-48
Machine plant or systems using particular sources of energy - waste F25B 27/02
Hot gas or combustion - Profiting from waste heat of exhaust gases F02G 5/00-04
Incineration of waste - recuperation of heat F23G 5/46
Plants or engines characterized by use of industrial or other waste gases F012K 25/14
Prod. of combustible gases - combined with waste heat boilers C10J 3/86
Incinerators or other apparatus consuming waste - field organic waste F23G 7/10
Manufacture of fuel cells - combined with treatment of residues H01M 8/06

Developing Countries included in the patent search
A total of 40 developing countries are included in the patent search.

There is a great difference to how active Developing Countries are when it comes to granting patents, for this study both very active Developing countries as well as less active developing countries were analysed. Developing countries from four different categories were analysed:

a) Developing countries which does not or very rarely grants patents (in total between 0 and 100 patents granted a year)

b) Developing countries that are active, however at a very low level (in total granted patents between 100 and 1.000)
c) Developing countries which are active with granting patents (patents granted between 1.000 and 3.000 per year)

d) Developing countries that are very active granting patents (more than 3.000 patents granted per year)

The majority of Developing countries belong in either category A) or B), whereas emerging economies can be found in categories C) and D).

The Following Developing countries were therefore included in the study:

a) African Intellectual Property Organization (OAPI), including Burkina Faso (BF), Benin (BJ), Central Africa Republic (CF), Congo (CG), Ivory Coast (CI), Cameron (CM), Gabon (GA), Guinea (GN), Equatorial Guinea (GQ), Guinea Bissau (GW), Mali (ML), Mauritania (MR), Niger (NE), Chad (TD), Togo (TG), Senegal (SN)

African Regional Intellectual Property Organization (ARIPO), including Botswana (BW), Gambia (GM), Ghana (GH), Kenya (KE), Malawi (MW), Mozambique (MZ), Namibia (NA), Sierra Leone (SL), Somalia (SO), Swaziland (SZ), Uganda (UG), Zambia (ZM) and Zimbabwe (ZW).
Uruguay,

b) Moldova , Egypt,
c) Argentina, Brazil, India, Philippines .
d) Kina, Ukraine, Russia and Soviet Union .

Time Period
The time period included in this study is from 1998 to 2008.

In the study the number of ‘patents - total all years’ is also used, ‘patents - total all years’ refer to different time periods depending on the country studied. Below a list of time period for each country is listed.

Uruguay	2000-
OAPI	1966-2006
ARIPO	1988-2008
Moldova	1994-2008
Egypt	2002-2008
Argentina	2003-2008

Brazil	1973-2008
India	1973-2008
Philippines	1976-1999
China	1986-2008
Ukraine	2002-2008
Russia	1994-2008
Soviet Union	1973-2008

Patent database sources used to conduct patent searches

EPODOC from European Patent Office was used to extract data considering world wide patent application within each technology and each IPC Class.

Pluspat from QUESTEL was used to extract country specific patent data on number of patents application for each of the developing countries studied, as well as to extract data concerning applicant's country of origin.

WPIX from STN was used to extract country specific patent data for India and Philippines on patent applications as well as to extract data concerning applicant's country of origin.