DIME International Conference “Innovation, sustainability and policy”,
11-13 September 2008, GREThA, University Montesquieu Bordeaux IV

Energy and Material Efficiency in China and Germany: Specialisation patterns and Cooperation Potentials

Author:

Katrin Ostertag
Fraunhofer-Institute for Systems and Innovation Research
Breslauer Str. 48, 76139 Karlsruhe, Germany,
T: +49-721-6809-116, F: +49-721-6809-135,
E: katrin.ostertag@isi.fraunhofer.de

Date: August 15th 2008

Abstract

1 Introduction and objectives

The environmental problems in the rapidly growing economies are becoming more acute and global environmental problems cannot be tackled without timely action in these countries. Thus, anchoring the idea of sustainability in the economic development process as early as possible is gaining enormous significance. For the development process in the rapidly growing economies, the hope has been expressed that global objectives, such as stabilising the concentration of greenhouse gases can be achieved through knowledge transfer and technology cooperations. Conceptionally, this matches the environmental-economic concept of "Tunneling through the Environmental Kuznets Curve" (cf. Munashinghe, 1999; Walz, Meyer-Krahmer, 2003).

If the strong and constantly increasing links between China and Germany are considered, the question arises of how to design these links in a way that promotes global sustainability. When assessing potentials for knowledge transfer and technological cooperations, questions concerning the knowledge-intensity of the technologies and the differences in the knowledge base between the countries emerge as important factors. Research into economic catching-up processes (Fagerberg, Godinho 2005; see e. g.Nelson 2004) has further stressed the significance of the absorptive capacity, a concept going back to Abramovitz (1986) and Cohen and Levinthal (1990). Besides the knowledge- and technology-based factors, openness to new solutions, complementary branch clusters and functioning user-producer interactions are among its important constitutive factors (see Fagerberg 1995). With regard to sustainability innovations, further factors come in to play. Here, a dual or triple regulatory challenge exists (Rennings 2000; Walz 2007), because environmental policy and sometimes infrastructure specific needs must be accounted for in addition to the R&D needs. This explains why environmental policy at different levels matters for absorptive capacity as well. Furthermore, for the countries in the economic catching-up process, reduction of environmental pollution and availability of technology to build up modern infrastructure are important rationales. And the economic significance of sustainability innovations also plays a role for countries oriented towards foreign trade. Figure 1 sums up the different facets of absorptive capacity.

It is more and more acknowledged that the absorption of developed technologies and the development of abilities to further advance these technologies and their international marketing are closely interwoven (Nelson 2007). Knowledge generation, which can be used for the further technical development of products, and successes in international competition thus also become a yardstick of absorptive capacity, particularly as they also indirectly infer openness to new solutions and international developments.

Figure 1: Aspects of absortive capacity for sustainability technologies

Against this background, this paper contributes to an empirical basis for characterising the research and technology competences and – more broadly – the absorptive capacity of China in two technology fields with high relevance for a wide range of sectors and environmental problems. These are energy efficiency in buildings and material efficiency[1]. This may serve as a basis for identifying and implementing collaboration potentials between China and Germany with the aim to increase mutual knowledge and technology transfer.

2 Methodology and data sources

Measuring absorptive capacity is difficult, as numerous influential factors can only be quantified with difficulty. A widely accepted though certainly not complete approach to do so adapts indicators from various sub-fields of the innovation process (see Grupp 1997). It comprises patents as R&D output or intermediary indicators on the one hand, which are presumed to describe the direct result of the R&D process. At the same time they are assumed to be an early indicator for future technological development. On the other hand, foreign trade indicators are constructed which belong to the class of output indicators. They focus more on the application and diffusion of technologies in R&D-intensive product markets.

Unlike the traditional environmental technologies, no internationally comparable convention has emerged so far for the technology areas regarded here, which could be used to define and classify the technologies in the patent and economic statistics. Therefore it is necessary to come up with a definition tailored to the specific data situation. The methodology, as in the previous approaches (Edler et al. 2007), follows a 'potential approach', in which the sustainability-relevant technologies comprise those goods which could serve environmental protection and the modernisation of the subject areas mentioned or refer to technological knowledge with a similar base. This approach thus focuses not on the actually realised application for environmental protection, but on the technological capability which could be mobilised for environmentally-friendly production processes and products in the selected fields.

Technologies for energy efficiency in buildings and for material efficiency are neither a patent class nor a specific trade classification which can be easily detected. Thus, for each technology, it was necessary to identify the key technological concepts and segments. They were transformed into specific search concepts for the patent data and classification schemes for the trade data. This required numerous iterative steps and substantial engineering skills. However, further research is necessary to derive more complete search strategies.

---

1 For a broader analysis eg in terms of country coverage and technology fields see Walz et al. (2008)

The shares in global activity of the countries examined are used for both the patent applications and foreign trade:

- International patent applications are researched and the shares of China and Germany in these calculated.
- In foreign trade, the world trade shares (WTS) are calculated, i.e. the shares of the respective countries' exports in world exports.

Both the patent shares and the world trade shares are influenced by the size and general development of the country. It is therefore common to additionally construct specialisation indicators. These indicate the position of the technologies and goods of particular interest in relation to the average of all technologies and goods within the country regarded. Positive specialisation values show that the competence of the country in this field is above average, relative to the average of all technologies and goods. These specialisation indicators are constructed for both patents and foreign trade. They are standardised such that the indicators lie between -100 (extremely unfavourable specialisation) and +100 (extremely high specialisation), where a value of 0 corresponds to an average specialisation:[2]

- For patents, the revealed patent advantage (RPA) is calculated which compares the patent share of the country regarded in the sustainability technology with the patent shares of the country in all technologies. The RPA assumes a positive value if there is an above average patent share for the sustainability field. This means that, within the respective country, a disproportionately large number of patents are being applied for in the sustainability fields and therefore – compared with the other fields of technology – the national knowledge in this area is above average.
- The RCA (Revealed Comparative Advantage) takes both imports and exports into account and thus counts as a comprehensive indicator of the foreign trade position. It indicates to what extent the import/export relation of a country in the examined sustainability technologies deviates from the import/export relation of the country in all industrial goods. Positive signs indicate comparative advantages - a strong international competitive position of the regarded sustainability technologies in the country regarded.

The patent data primarily refer to patent applications at the World Intellectual Property Organization (WIPO) and thus international patents. In addition, the available data on national patents in China are analysed in sensitivity analyses in order to be able to take into account any distortions resulting from concentrating on international patents.

2 See Grupp, Schmoch (1992) on the method.

The economic power of the countries considered is derived by analysing trade flow data taken from the UN ComTrade data base and computing the revealed comparative advantage (RCA) for the countries under consideration. Together, innovation and trade specialisation in a particular technology field provides a useful indicator for the countries' short and longer term international competitiveness.

Complementary interview data with large German enterprises is presented. It provides contextual qualitative information based on their cooperation experiences in China in the respective technology fields. Further to the indicators it provides insights into which mechanisms can accelerate diffusion and innovation processes in the direction of sustainability. Therefore, we explored the market and cooperation experiences of German companies active in China by means of expert interviews. Interview partners were selected from companies and organisations who are shown to be leading innovators in a relevant technology. Concentrating on innovators is based on the premise that such companies

- have good knowledge of the social, marketing and regulatory mechanisms which contribute to the acceleration of the diffusion and innovation processes,
- are competent in assessing the competitiveness and specialisations of Germany and China.

Most of those questioned were involved in environmental and sustainability management, sales and marketing with a focus on the country in question or on research and development. The interviews were recorded, software encoded[3] and evaluated anonymously.

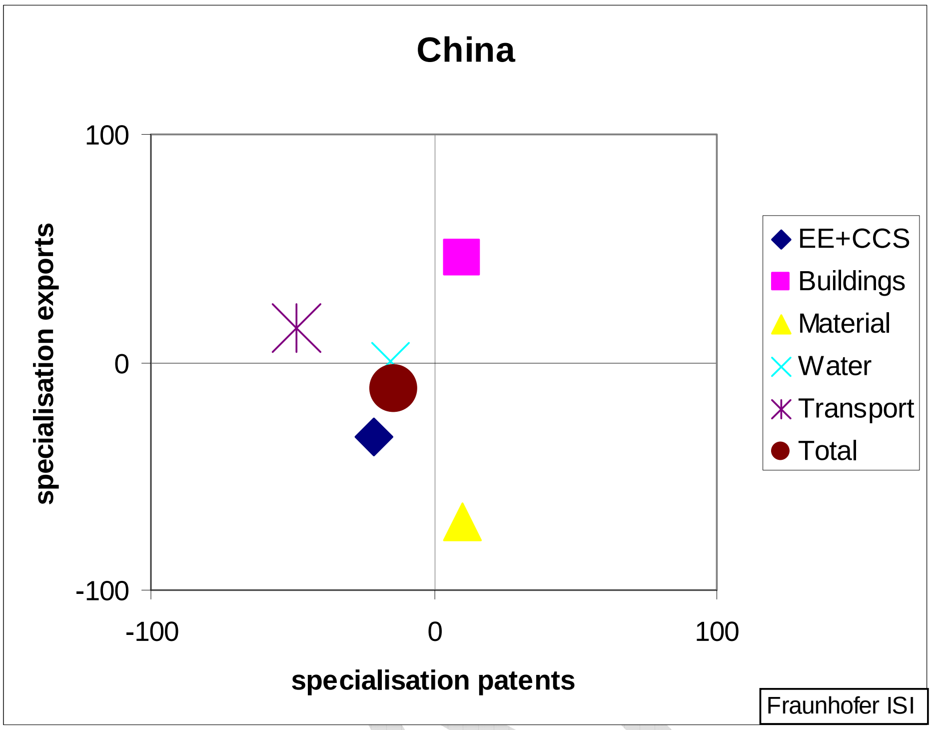
3 Specialisation patterns in energy efficient buildings

The specialisation indicators for China across different sustainability technology fields indicate a rather average activity rate, in part they are even below average, for example transportation (see Figure 2). The selected sustainability fields belong to those in which the principle of the 'extended workbench' is reflected in above-average foreign trade successes, such as in the buildings field. The positive patent specialisation in energy and material efficiency mirrors efforts in the research programmes to address foreseeable bottlenecks in the supply of energy and material resources, an area, in which the country has demonstrated weaknesses up to now. Nevertheless, it must be stated that China's technological capabilities have so far not been directed towards sustainability.

---

3 The software Atlas.ti V5.0 was used to analyse the qualitative data.

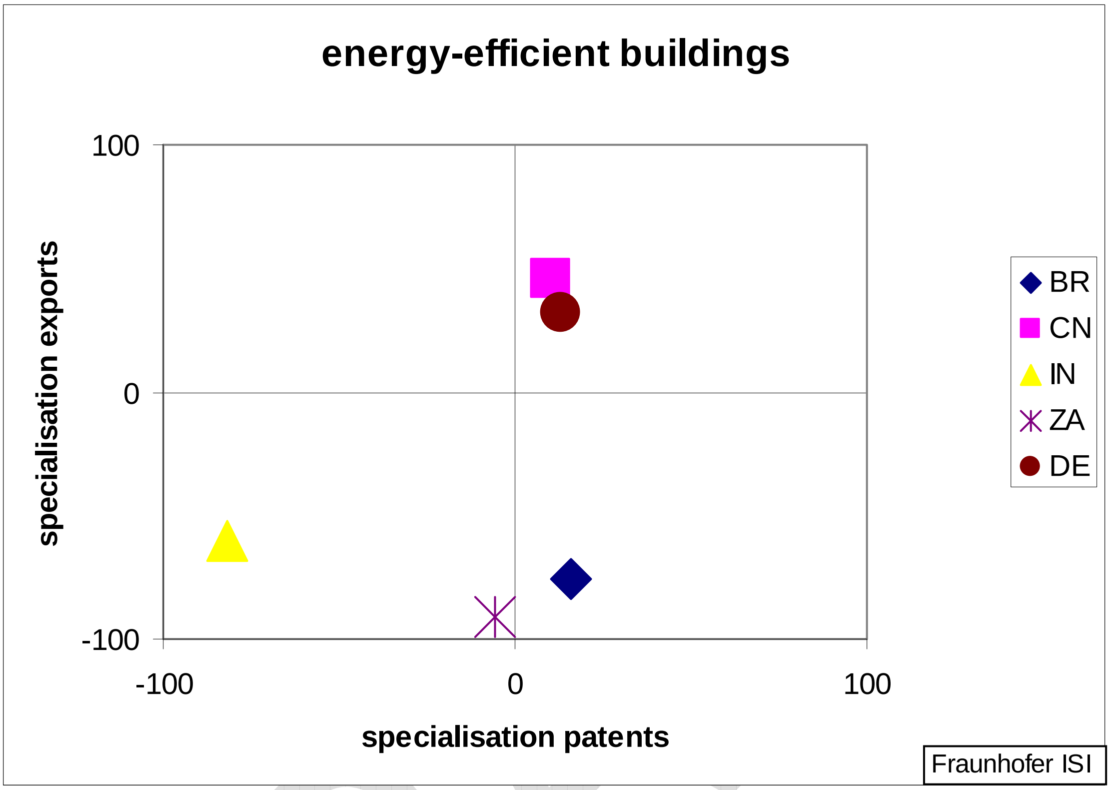
Figure 2: Specialisation of China in selected Sustainability Fields



Source: (Walz et al. 2008)

Comparing Germany and China in the field of energy efficient buildings, both are clearly above average in exports and slightly above average in patents (see Figure 3). In comparison with other emerging economies China is clearly better placed. The specialisation is even more apparent when looking at China's national patents. Behind the same patent specialisation there is, however, a much higher absolute patent activity in Germany. This implies that Germany achieves its export success in the higher quality and higher priced segment with correspondingly high energy efficiency, whereas China is more successful in the market segment characterised by price competition. Overall this interpretation suggests that China could mobilise considerable capabilities for a more sustainable design of the building sector, but at the same time that there is still a substantial gap between potential and actual applications for increasing building efficiency.

Figure 3: International Comparison of specialisation patterns in energy-efficient buildings



In China, efforts for energy-efficient buildings began in the 1980s; in 1986, the first energy efficiency code for residential buildings was introduced for selected regions (Lee, Chen 2008). According to our interviews, there are high potentials for energy saving in new buildings in China due to the continued building boom taking place in this country with double digit growth rates. The refurbishment of existing buildings (for instance through thermal insulation) is of secondary importance. Private home building hardly exists in China. Mainly professional investors and project developers operate in the high-priced segment of new building developments. They can make between 400 and 1000 % profit on the sale of a new building[4]. According to the experiences of the interviewees, in spite of these high profit margins, these professional builders are still not prepared to accept any cut in profits due to additional costs for energy efficiency measures. Their short-term and profit-oriented calculations result in quality deficiencies with regard to energy consumption. It is therefore seen as important to change investors' views in the direction of the long-term property value retention of the buildings. Inter-

4 For comparison: In Germany, those questioned estimate the returns at between 5 and 15 %.

viewees considered the emergence of a broad and politically active middle class, which is increasingly opposed to the worsening environmental devastation, as having a favourable impact.

The Chinese government is currently developing efficiency standards for buildings further with the participation of international experts. In the interviews, it was controversial whether this international collaboration is sufficiently oriented towards energy efficiency. The existing Chinese building standards are specified in so-called "Standards books". These contain nationally agreed and standardised construction details which have to be assembled by the architects. Finding the optimum combination of several technology options is decisive when it comes to energy efficiency. This key understanding is not yet present in China.[5] The building planning practice in China is assessed as being especially problematic. Building projects are not planned by one body, but the architect's designs are given to so-called Design Offices. This patchwork procedure prevents a comprehensive approach.

Further, interviewees reported considerable deficits in implementing the legal regulations in China. As a result, buildings are constructed which do not comply with the prescribed threshold values. A particularly counter-productive regulation in the eyes of two interviewees forbids heating south of the Yangtze. In the course of the continued economic growth of China and the climatic conditions in this region, tenants are increasingly heating their rooms by subsequently installing small electrical systems. Compared with non-electrical heating systems, these measures are inefficient from the viewpoint of primary energy consumption and, as a result, electricity consumption in the residential sector will probably continue to increase rapidly in China in the next few years.

Energy prices are very low in China so that the profits to be made with energy conservation measures are low. As a consequence, energy efficiency measures offer customers few directly recognisable economic advantages. Their diffusion therefore has to be pushed using other advantages of energy-efficient building such as improved living quality. According to the experts it must be promoted much more strongly through suitable marketing strategies in the public and private sectors.

In China, German architects compete primarily with international suppliers, especially from the US, Canada and France. The protectionist market represents a large obstacle to all foreign suppliers equally. Up until 2006 it was only possible to set up foreign branches in China as joint ventures. Certain prohibitions in the call for tenders for large projects exclude foreign companies from competing. It is therefore advantageous to be

5 According to the interviewed experts, this is only slowly becoming adopted in Germany too. The relevant German degree courses have only appeared recently.

resident in the country. Since the search for Chinese partners is very time consuming, for the most part only large architectural offices are represented by branch offices in China.

In international comparison, Germany is assessed as being a technology leader in the sector of energy-efficient building. However, to some extent this good international position is not being successfully communicated to foreign clients. One reason for this cited by several experts is that German companies receive less political and financial support for expanding their business to China than their international rivals. So far, German companies have been winning clients through chance (personal) contacts. The American government's approach, in contrast, is described as being very proactive.

At the level of component manufacturers, there was general agreement that there is competition in China from cheap domestic products of low quality. Investors in China request only Chinese components due to the price differences and as a consequence of a directive to use national products. Long drawn-out licensing procedures for foreign products in China represent another hurdle. Despite this, German companies are represented in the market segment of more complex components (such as for example high-quality glass or facade elements) in China because of the large market potential here. The raw materials and individual parts required are shipped to China and assembled there.

To conclude, the rather favourable specialisation indicators for energy-efficiency in buildings are contrasted by the reports of numerous implementation hurdles and market deficiencies. Since some of them are certainly specific to the Chinese culture and preferences, they may be difficult to be addressed in international collaborations. However, as the interviews revealed, the understanding for finding the optimal combination of technologies which is so necessary for energy efficiency is missing. An integral view of a building needs to be promoted in China. Cooperation efforts could therefore address these service innovation aspects in particular.

4 Specialisation patterns in material efficiency

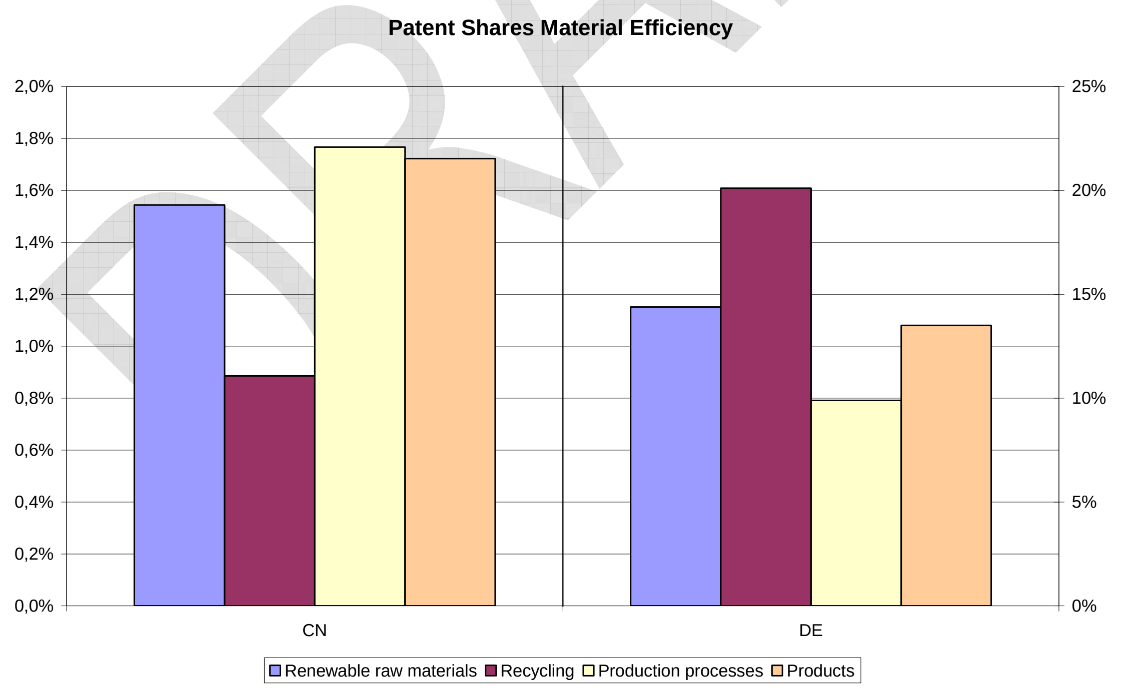
The indicators developed for measuring specialisation patterns in material efficiency cover four areas:

- **renewable raw materials**: recently more and more attention is being paid to renewable-based products because of raw material and degradability considerations. Feed stocks in the chemical industry should be listed here (e. g. sugars and starches, oils and fats) as well as products based on renewable raw materials (e. g. polymers, adhesives, varnishes, coatings and construction materials).

- **Recycling** is also part of the field of material efficiency. Here, the segments covered included the detection, separation and sorting of waste and its material recycling.
- material-efficient **products:** These include technologies such as, e. g. lightweight construction, lifespan extension, fibre reinforcement or corrosion protection. Important are also service sector concepts (e. g. car sharing, print-on-demand). However, we lack the necessary statistics for them.
- material-efficient **production processes** also incorporates various sub-aspects such as optimising the production processes (e. g. by reducing wastage or by standardising quality), a better utilisation of appliances, systems and specialised machinery or optimisations which affect the whole of the value added chain. These are also aspects which were only able to be partially researched.

The share of China in worldwide patents in the area of material efficiency is 1.3 %. This compares to 17 % for Germany and indicates a significant difference in the activity levels of technology development. Most of China's material efficiency related patents fall into the category "production processes" while recycling patents are the least numerous (see Figure 4). This is exactly the opposite for Germany, which is strongest in recycling patents and has the lowest patent share in "production processes".

Figure 4: Patent Shares (2000-2004) in the area material efficiency



With respect to exports, China has a global trade share of 3.3 %, while the German share amounts to almost 15 %. In China, the highest share is again found in the category "production processes" (see Figure 5). And for Germany, the highest share is again found in the category “recycling”. The lowest export share in China as well as in Germany is found for renewable raw materials.

Figure 5: World Trade Shares (2005) in the area material efficiency

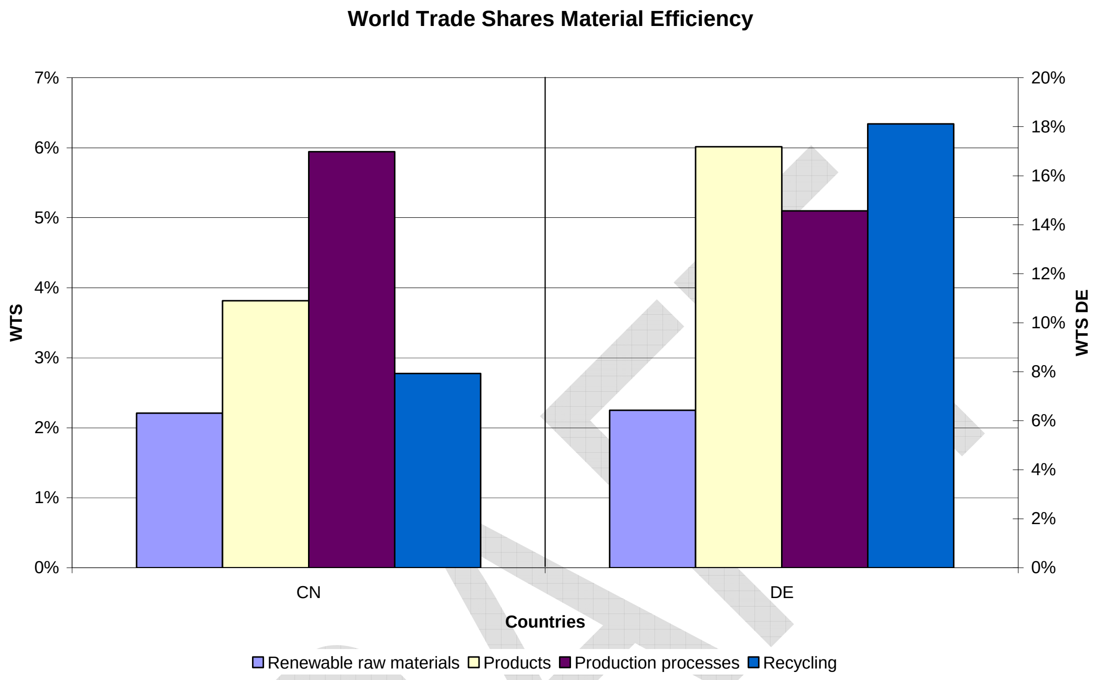
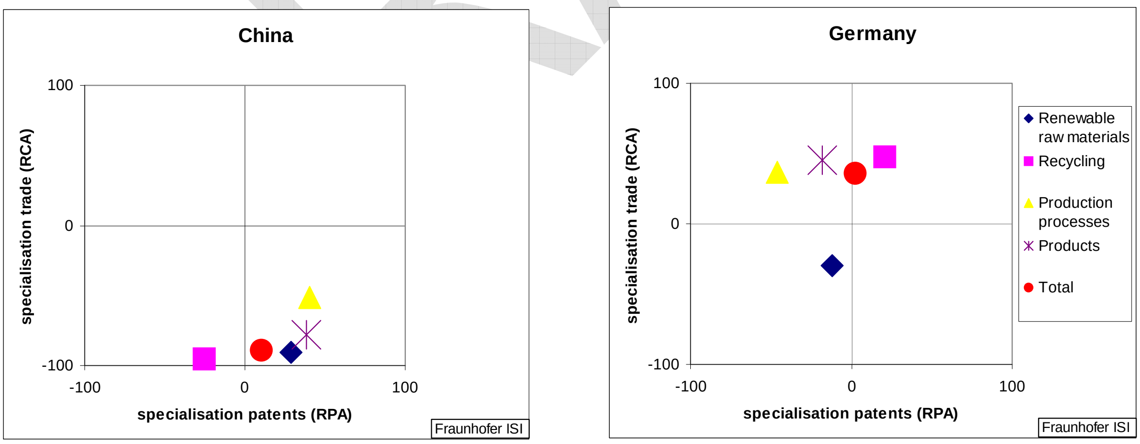


Figure 6: Specialisation patterns in the area material efficiency



For the field of material efficiency as a whole, China’s RCA is negative, i. e. in relation to other sectors of its economy material efficiency performs more weakly with respect to external trade. However, with respect to its knowledge base, the RPA reveals a slightly positive specialisation. This could build the bases for better external trade performance in the future. The examined areas of material efficiency are quite heterogeneous (renewable raw materials, recycling, material-efficient products and processes). China has a negative export specialisation in all of them. However, there are positive patent specialisations for renewable raw materials and material-efficient products or production processes. This indicates that there are efforts being made in these sub-sectors to build up the domestic knowledge base. Patent activities in recycling are below average; this implies that this sector is still being operated as a "low tech" one in China.

In Germany, recycling is one of the sectors with above average specialisation in patents as well as in exports. Many years of political efforts in this field can be seen in the above average output in patents and foreign trade. The weakest performance can be found in renewable raw materials – with negative specialisation with respect to both, knowledge base and external trade. In the field material efficiency as a whole, German patent specialisation is only very slightly above average. The exports are almost double the imports - this indicates a clear specialisation in material-efficient technologies.

From the indicators a certain complementarity between Germany and China with respect to their specialisation in recycling technologies could be assumed which might be interpreted as offering opportunities for cooperation. We examined such potentials in more detail through an expert interview in one specific field, i. e. the utilisation of shredder residues in the automobile recycling process.

In the EU, the 1999 Directive on End-of-Life Vehicles made automobile manufacturers responsible for their correct disposal. In the meantime, there has been a sharp rise in the prices of raw materials so that for strategic reasons scrapped vehicles now represent an important source of (secondary) raw materials for the automobile industry itself among others. These legal and market framework conditions have pushed the further development of recycling technology for end-of-life vehicles in Germany. A very good starting basis for this was the differentiated recycling system in the former GDR. With regard to the technological knowledge base, the interviewee sees Germany as having a long headstart. He sees a particular challenge in creating a suitable network of suppliers and consumers, which optimally combines the individual plants from the recycling pyramid. This has to consider country- or regional-specific material flows and transport routes and optimise the mechanical requirements made of the individual fractions of recycled materials by each consumer.

The technology for the utilisation of shredder residues is battling strong obstacles to its implementation. To date, no reference plant has been able to be built in Germany. The main obstacle is that, despite the provisions contained in the TA Siedlungsabfall (Technical Instructions on Municipal Waste), many landfills are still open for shredder residues and represent a more cost favourable disposal possibility. Another obstacle is the movement of waste from the EU mainly to China. According to the expert, since 1989 the quota of recycled end-of-life vehicles has decreased from 50 % to approx. 15 - 20 %. This is explained by the cost ratio between disposal using shredders and the comparably lower transport costs incurred for exporting the scrap vehicles to China or India.

The high waste exports are seen as a problem for a second reason: When recovering secondary raw materials from waste, recycled materials are used to some extent, i. e. recycling companies are simultaneously the consumers of recycled materials. If waste is exported instead of being recycled in Germany, this reduces the demand for recycled materials accordingly. For example, it was planned to use several fractions for slag formation in order to recover metals from electronic scrap. But the electronic scrap was exported and purchased by China.

This indicates already some possible lines of conflict. China is feared as a rival for recyclable waste, because raw materials and utilisable waste are relatively scarce there. On the political side, China has held talks with the interviewed German technology producer, in which it revealed an interest in the technology for recycling shredder residues and the intention to introduce a directive on disposing of end-of-life vehicles. Since at present there are only relatively few end-of-life vehicles occurring there (approx. 5000 per year), the Chinese also enquired about the possibilities of importing scrapped cars. In the eyes of the German technology producer the export of its recycling technology to China could run counter to its objective of safeguarding the domestic raw material supply. For the further identification of cooperation potentials in the field of material efficiency it is therefore important to carefully consider the market and actor constellations in particular segments.

5 Conclusions

The indicators on patent and foreign trade activities and specialisation patterns give valuable insights into the strengths and weaknesses of China in comparison to Germany. A look to two different fields of sustainability technologies – energy efficiency in buildings and material efficiency - and to the more disaggregate level within each technology field reveals considerable differences between these fields and points to the need to adapt the design of international cooperation strategies to specificities of the technology field considered.

As the interviews reveal, cooperation potentials may not only lie in the area of technology development but also in the development of complementary services, e. g. engineering and planning services in the building sector. Furthermore, the specialisation indicators need to be seen in the broader context of the national innovation system which opens up further areas for cooperation. For example, one could be the joint development of building standards.

Further research is needed to ameliorate the coverage of technologies in the specialisation indicators and to specify cooperation potentials more concretely.

Acknowledgements

The financial support of the German Council for Sustainable Development for carrying out this research gratefully acknowledged.

References

Abramovitz, M. (1986): Catching Up, Forging Ahead, and Falling Behind. In: Journal of Economic History, 46, pp. 386-406.

Cohen, W.; Levinthal, D. (1990): Absorptive Capacity - A New Perspective on Learning and Innovation. In: Administrative Science Quarterly, 35, pp. 123-133.

Edler, D.; Blazejcak, J.; Walz, R.; Ostertag, K.; Eichhammer, W.; Angerer, G.; Sartorius, C.; Doll, K. (2007): Wirtschaftsfaktor Umweltschutz. Vertiefende Analyse zu Umweltschutz und Innovation, Umweltbundesamt (ed.), Umwelt, Innovation, Beschäftigung 01/07, Dessau: Umweltbundesamt.

Fagerberg, J. (1995): User-producer interaction, learning, and competitive advantage. In: Cambridge Journal of Economics, 19, pp. 243-256.

Fagerberg, J.; Godinho, M. (2005): Innovation and Catching-Up. In: The Oxford Handbook of Innovation. Fagerberg, J.; Mowery, D.C.; Nelson, R.R. (eds.). Oxford: Oxford University Press, pp. 514-542.

Grupp, H. (1997): Messung und Erklärung des technischen Wandels. Grundzüge einer empirischen Innovationsökonomik., Springer-Lehrbuch, Berlin, Heidelberg, New York: Springer.

Lee, W.L.; Chen, H. (2008): Benchmarking Hong Kong and China energy codes for residential buildings. In: Energy and Buildings, 40 (9), pp. 1628-1636.

Nelson, R.R. (2007): The changing institutional requirements for technological and economic catch up. In: International Journal of Technological Learning, Innovation and Development, 1 (1), pp. 4-12.

Nelson, R. (2004): Economic development from the perspective of evolutionary economic theory - The Second International Globelics Conference "Innovation Systems and Development - Emerging Opportunities and Challenges", Beijing, 16-20 October 2004, http://www.globelics-beijing.cn/ (14.08.2008): Global Network on Economics of Learning, Innovation and Competence Building Systems (Globelics).

Rennings, K. (2000): Redefining innovation - Eco-innovation research and the contribution from ecological economics. In: Ecological Economics, 32 (2), pp. 319-332.

Walz, R. (2007): The role of regulation for sustainable infrastructure innovations - The case of wind energy. In: International Journal of Public Policy, 2 (1/2), pp. 57-88.

Walz, R.; Ostertag, K.; Eichhammer, W.; Glienke, N.; Jappe-Heinze, A.; Mannsbart, W.; Peuckert, J. (2008): Research and technology competence for a sustainable development in the BRICS countries, Stuttgart: Frauhnhofer IRB.

Grupp, H.; Schmoch, U. (1992): Wissenschaftsbindung der Technik - Panorama der internationalen Entwicklung und sektorales Tableau für Deutschland, Wirtschaftswissenschaftliche Beiträge, Heidelberg: Physica.

Munasinghe, M. (1999): Growth-oriented economic policies and their environmental impacts. In: van den Bergh, C.J.M. (ed): Handbook of Environmental Economics, Edward Elgar, Cheltenham, p. 678-708.

Walz, R.; Meyer-Krahmer, F. (2003): Innovation and sustainability in economic development. Invited paper, Global Network on Economics of Learning, Innovation and Competence Building Systems (Globelics) First Conference on “Innovation Systems and Development Strategies for the Third Milennium”, Rio de Janeiro, November 2-6 2003