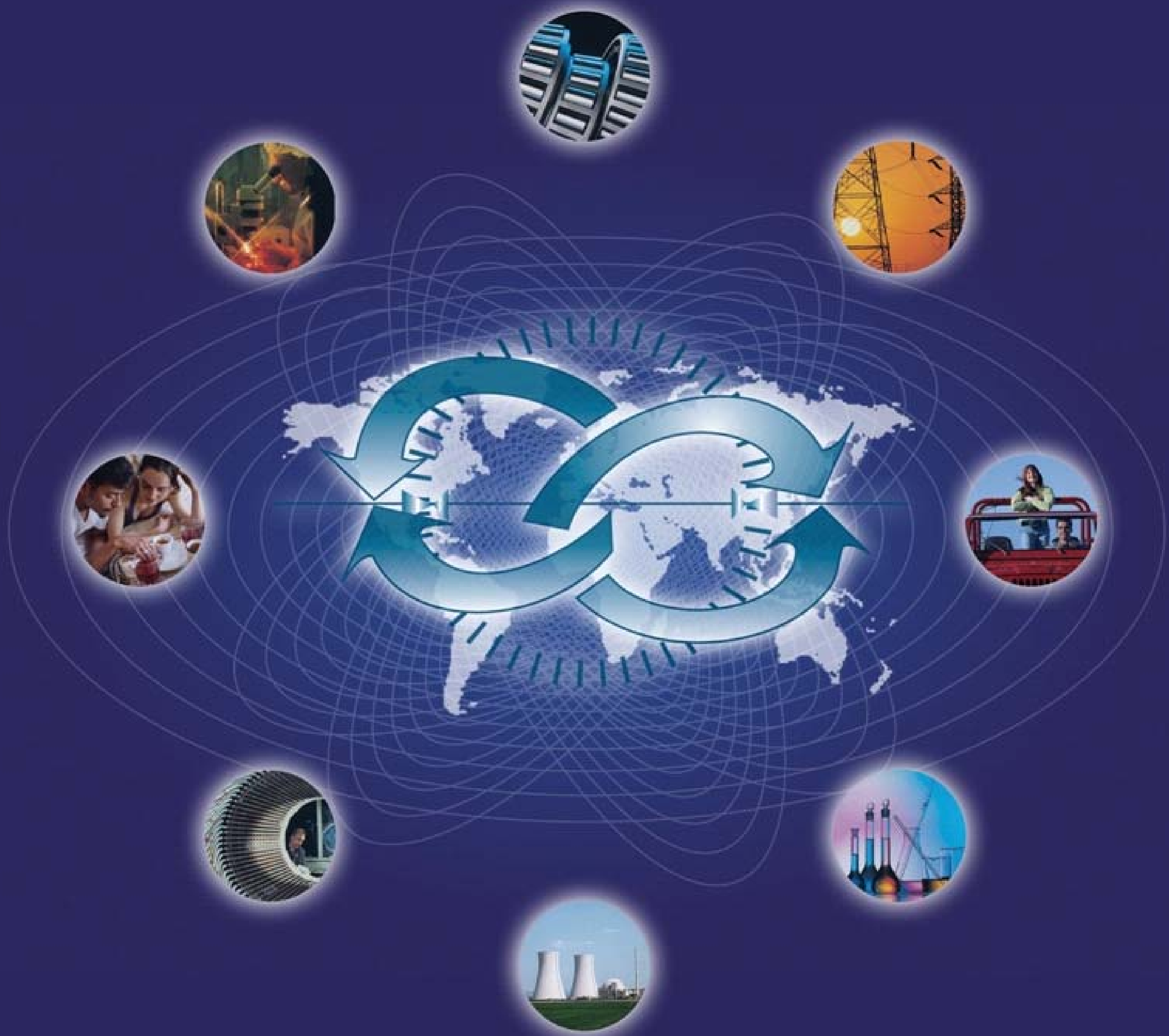


Mitglied der Helmholtz-Gemeinschaft

STE Research Report 09/2009

The Significance of Germany as a Site for Power Plant Construction Against the Background of an Increasing Internationalization of Innovation Processes

S. Vögele, P. Markewitz, W. Weimer-Jehle, G. Fuchs, S. Wassermann, K. Rennings, T. Hoffmann, U. Moslener, S. Voigt

Institut für Energieforschung
Systemforschung und Technologische Entwicklung (IEF-STE)

JÜLICH FORSCHUNGSZENTRUM

Content

The Significance of Germany as a Site for Power Plant Construction Against the Background of an Increasing Internationalization of Innovation Processes

Stefan Vögele[1], Peter Markewitz[1], Wolfgang Weimer-Jehle[2], Gerhard Fuchs[2], Sandra Wassermann[2], Klaus Rennings[3], Tim Hoffmann[3], Ulf Moslener[3], Sebastian Voigt [3]

[1] Forschungszentrum Jülich, Institute of Energy Research - Systems Analysis and Technology Evaluation (IEF-STE), 52425 Jülich, Germany
[2] Interdisciplinary Research Unit on Risk Governance and Sustainable Technology Development (ZIRN), University of Stuttgart;
[3] Centre for European Economic Research (ZEW), Mannheim

Abstract

The search for novelties and their diffusion must increasingly be seen in an international context. In this study different approaches have been applied to highlight the influences of important factors on the dynamics of selection and co-evolution processes in an interdisciplinary way using the example of power plant technologies. The Lead Market approach was used to assess the possibilities to explain innovation processes in Germany, the USA, Japan and China with aggregated indicators. The results show that the application of the Lead Market approach for coal-fired power plant technologies is not appropriate for long time periods and that countries can only maintain a leading position if they manage to strengthen their advantages by investing in further R&D. With the help of the National Innovation System approach significant differences between the selected countries can be identified. Beside differences in the availability of resources (e.g. mineral resources, R&D expenditure), there are also disparities in the regulation/policy framework, the R&D networks and the market structures which influence the technology mix significantly. Due to the specific sectoral characteristics, we find only a limited amount of globalization of R&D activities. In addition to the ex-ante analysis, a Cross-Impact Analysis was conducted to assess whether and under what conditions internationalization strategies of multinational enterprises (MNE) may weaken Germany's leading position as an R&D-site for coal-fired power plants by 2020/25. Based on workshops with experts in the fields of innovation research and of the power plant sector only one consistent scenario could be identified which reflects all assumed relations of interdependence. This scenario describes a development until 2020/25 which rests upon the idea that the CCS-technology will be available on the world market, the German power plant R&D retains its lead over China. All in all, it can be expected that even if more and more new manufacturing facilities in low-cost countries are established by MNE (or by companies with partnerships with MNE) Germany will still remain an important R&D site. Since the German market for power plants is very small, the R&D activities have to be focused not only on the national but also on the global market.

Keywords

Coal-fired power plants, technology transfer, innovation processes

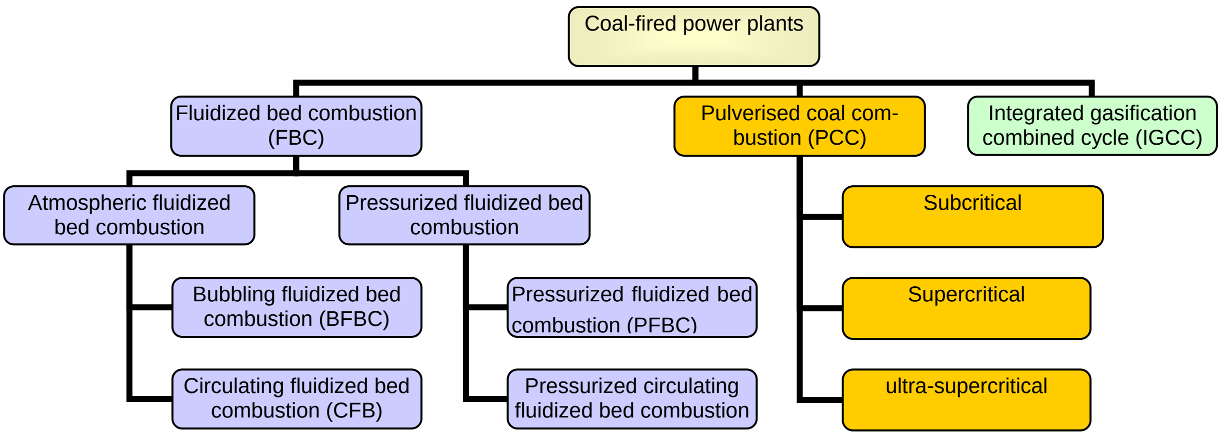
I Introduction

The aim of the project was to investigate the generation of novelties and their diffusion in an international and interdisciplinary context using the example of coal-fired power plant technologies. Special attention was given to the activities undertaken by multinational enterprises (MNE) and other important players (e.g. governments) as well as changes in important framework conditions.

II Coal Technologies in the Power Plant Sector

Using coal to produce electricity has a long history. The first coal-fired power plants were introduced in the 1880s. Currently pulverised fuel combustion is the most common technology. Power plants with steam conditions (i.e. the temperature and pressure of the steam when entering the turbine) of less than 220 bar/540°C are called subcritical, with 221.2-250 bar/540-570°C supercritical and with more than 600°C ultra-supercritical. (Figure 1)

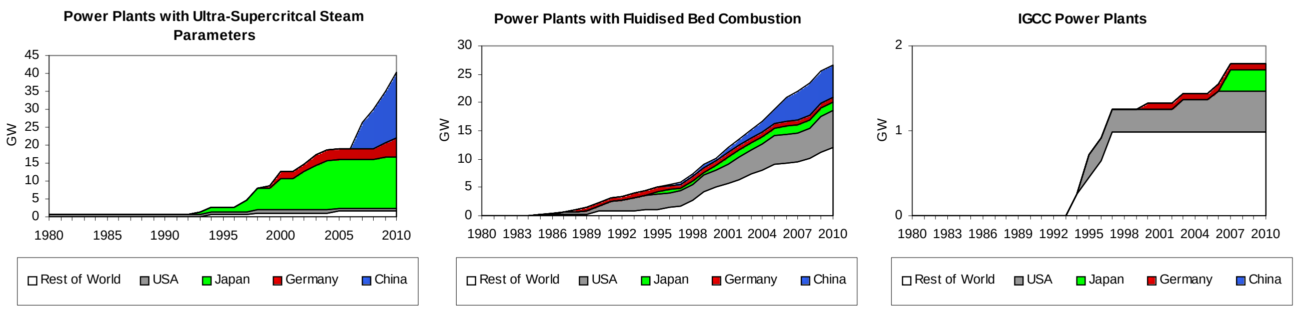
Figure 1: Main coal-fired power plant technologies



Quelle: IEF-STE 2009 IEF-STE 2009

Subcritical power plants dominate the coal-fired power market at the moment. However, it is the most inefficient technology of the above mentioned. Modern subcritical power stations achieve an efficiency of around 38%. In the 1950s the first power plants with very high steam conditions were put into operation in the USA. Due to mechanical and metallurgical problems the technology was not competitive. As time went by the material problems were solved. Currently supercritical power stations have an efficiency of up to 43%. The generation costs of ultra-supercritical power plants are higher than the ones of sub- and supercritical units. However, ultra-supercritical power plants achieve an efficiency of 45% and more. The possibility to burn poor-quality solid fuels in an efficient way and reduce SOx emissions without the need of an end-of-pipe application encouraged the extension of R&D in the field of fluidized bed combustion technology in late 1960s and the 1970s. Usually the BFBC unit has an efficiency of less than 30% whereas power plant units using the circulating fluidized bed combustion achieve efficiencies of 38-40%. Pressurized bubbling bed technology is more or less commercially available while pressurized circulating fluidized bed combustion is still in an early stage of development. High specific investment cost and lower efficiency than supercritical power plants are the main reasons why the technology is not selling well at the moment. Another relatively new technology for power generation is integrated coal gasification combined cycle technology (IGCC). High investment costs and risks regarding the technological performance affect the readiness to invest in this technology. In the last years R&D in the fossil-fired power plant sector have been extended to carbon capture and sequestration (CCS) technologies. With these technologies it will be possible to reduce the CO_2-emissions of coal-fired power plants by up to 90%. Three technologies are currently favoured. The first one (post-combustion) is an end-of-pipe technology for super- or ultra-supercritical power plants. The second technology (oxy-fuel combustion) is based on burning coal with pure oxygen and recycled flue gas. The third technology (pre-combustion) is characterized by the removal of carbon from the solid fuel used for the power plant prior to the combustion process. This procedure is used in IGCC power plants. All in all, the different technologies compete with each other and with other kinds of power plant technologies (e.g. technologies used for nuclear and gas-fired power plants). Some older technologies have been crowded out by the technologies described above. However, the figures show that most of the technologies have found their niches because of their different advantages and disadvantages. So the development in the coal-fired power plant sector could be described as a mix of co-evolution and selection processes.

Figure 2: Diffusion of advanced coal-fired power plant technologies



Quelle: [IEA Clean Coal Centre, 2008] IEF-STE 2009

III Ex-post Analysis

The developments in coal-fired power plant sector can be explained/analysed by using different approaches. In our study we used the Lead Market, the National System of Innovation and the Multinational Enterprises approach.

III.1 Lead Market Approach

Lead markets are markets that adopt an innovation before it is adopted by most other countries and therefore lead the global diffusion of the innovation. Using the lead market approach it is possible to explain why clean coal technologies diffuse faster and to a greater extent in some countries than in other nations with the help of more or less aggregated indicators. The approach was applied by carrying out both a qualitative and a quantitative analysis. The most important technological trajectory for coal power plants is the pulverised coal-fired steam cycle, which is the basis for all other coal combustion technologies. Modern PC technology is very advanced and accounts for over 90% of coal-fired capacity worldwide. Therefore it was taken as a reference technology for this study, with SC (Supercritical) coal-fired power generation technologies being selected as an innovative technology within this trajectory. Moreover, SC technology has diffused over sufficiently long time periods to be examined by ex post analysis. As for the diffusion of SC, our study concentrates on Germany, the USA, China and Japan. The analysis of the diffusion curves of SC technology shows that the typical lead market pattern applies only to a limited extent. In the 1960s and 1970s, the USA established a lead market for SC technology; diffusion rates were high and large numbers of SC units were built. Other countries adopted the American innovation design, but when the USA stopped building supercritical coal-fired power plants in the late 1970s, the picture changed and diffusion curves overlapped, which is unusual. Japan surpassed the United States, although Japan started out as a typical lag market in the early 1980s. Japanese companies manage to meet their demand almost entirely out of domestic production and American technology plays only a minor role in this country. Generally, countries that are the first to widely diffuse an innovation design in the domestic market become lead markets. So far, the lead market model argues that lead markets do not switch to other countries but are “stable”. This has been supported by several empirical studies regarding, for instance, the diffusion of cellular phones, diesel motors with direct injection, etc. Here we see a clear deviation from that rule, since at least the diffusion curves overlap.

After analysing the technology diffusion in the four countries, the question arises: Can we determine a lead market for coal-fired power plant technology today? It can be concluded from the discussion of lead market factors that currently no clear lead market exists for coal-fired power plant technology. Although the USA still has comparative advantages in terms of prices, demand and market structure, Japan has caught up in terms of transfer advantage and Germany in terms of regulation. In the near future, demand advantages will switch to China. This supports also the thesis that - apart from the demand-oriented lead market model - push factors such as R&D activity play a strong role for establishing lead markets as well. The transfer advantage of Japan stems mainly from its intensive R&D activities. Thus it can be concluded that a mix of push and pull policies is necessary in order to establish a lead market position. Against the background of increasing greenhouse gas emissions and the significance of coal resources in both industrialized and emerging economies, more efficient ways to generate electricity are currently of high political relevance. Using econometric methods we test the role of factors such as hard coal abundance, the price of hard coal, the age of the power plants and inflows of foreign investments for the degree of efficiency. For this study panel data techniques were applied to perform the analysis. It was found that higher prices for hard coal lead to higher energy efficiency in power plants, i.e. pricing pressure induces a more efficient way of electricity generation. Likewise, foreign direct investment has a positive impact on energy efficiency as it might support knowledge diffusion. The importance of coal abundance for energy efficiency depends on the measure that is chosen to represent this attribute. In general, our empirical results suggest that the more hard coal resources a country possesses, the less efficient is its electricity generation, i.e. power plant operators in countries with higher coal reserves might tend to be lavish with this resource. The estimates regarding the average age of the plants in a country imply that a high share of old facilities decreases the average degree of efficiency of the respective countries. From an environmental policy perspective it can be concluded that flexible policy instruments such as taxes that internalise the external effects caused by greenhouse gas emissions as well as support for foreign investments are important means to foster energy efficiency. However, economic efficiency – even when compared with energy efficiency – must not be neglected in the design of energy policies.

III.2 The Development of Coal Fired Power Plant Technologies in National Contexts

R&D activities of firms are conducted in a nation-specific “network of institutions in the public and private sectors whose activities and interactions initiate, import, and diffuse new technologies.” [Freeman, 1987]. The National System of Innovation approach thus claims (a) that the way innovations in various countries are developed and diffused differs and (b) the technologies and innovations successfully advanced differ also. In the course of the project the differences between Germany, the USA, Japan and China with respect to the institutional context within which coal fired power plant technologies are being developed were assessed and the different national technological portfolios were analysed. The main focus of innovative activities in the United States has been on fluidised bed combustion and IGCC. Relevant company R&D was highly subsidised and (in contrast to other technology fields) cooperation with other firms and research institutions played a crucial role. Concentration on cost effectiveness (due to liberalization), the urge to use domestic resources (cheap but impure coal) and lenient environmental regulation helped to produce only small incremental innovations. Due to resource constraints especially in Japan and high environmental standards both in Japan and Germany, the innovation activities in the energy area in these two countries strongly focus on energy efficiency. Therefore, innovation activities and successes in the power plant sector in these two countries concentrate on power plants with high steam parameters. Technology development in Japan like in other industrial sectors can be called a concerted effort, in which even radical innovations (like IGCC) where envisaged in the hope to sell new products on the world market. The development of new technology in Germany takes primarily place in state sponsored network activities in which a variety of technological options from incremental to radical innovation were experimented with. During the periods with monopolistic energy markets the big public utilities were more willing to take risks with respect to new technologies than at present. Currently there is a slowly increasing importance of the central government level in the regulation and promotion of the sector. Markets in the four systems of innovation are thus determined by different elements. These are the availability of coal resources, the dependence of coal imports and coal prices as well as the regulatory framework with respect to environmental issues. The country comparison showed that the dependence on coal imports is much higher in Germany and Japan than it is for the USA and China. Coal prices are very high in Germany and Japan; they are lower in the USA and on a very low level in China. Another implicit and important aspect is the used fuel quality, which is very high in Germany and Japan, whereas the quality used in China and the USA vary strongly. Furthermore, the environmental standards of Germany and Japan are on a high level, compared to the USA standards which are lower, and particularly in comparison with China, which is characterized by low environmental standards and an especially low standard of enforcement. As examples which show the influence of the NIS on innovation processes, the R&D activities on pressurized pulverized coal combustion, pressurized pulverized fluidized bed combustion and IGCC can be used: After decades of research in Germany the R&D activities on these technologies were significantly reduced because of underestimating the potential for efficiency increases regarding alternative technologies, unexpected high cost and changes in the framework conditions (e.g. liberalisation of the electricity market) which lead to a drop in the willingness to take risks. In other countries the R&D on these technology were still continued because other economic and political framework conditions. With the discussion on CO_2-mitagtion investors in Germany reconsidered their attitude towards IGCC and started R&D activities again.

III.3 Multinational Enterprises in the Field of Coal Fired Power Plants

The field of coal fired power plant construction is dominated by a relatively small number of internationally active companies. The literature on globalisation claims that the activities of multinational enterprises reduce the importance of the characteristics of national markets and the influence of national institutions. In a second step therefore we analysed the activities of MNEs and the thesis, that MNEs are leading actors on the path towards true globalisation. The definition of what globalisation actually means and how it can be measured is disputed in the literature. On the basis of Archibugi's and Michie's analytical differentiation of three meanings of "techno-globalism", we evaluated the activities of relevant MNEs with respect to the global exploitation of technologies, global technological collaborations and the global generation of technology. Only the last term denotes genuine globalisation, which would finally lead to the disappearance of country-specific technological differences. Our analysis of MNE activities in the power plant sector of Germany, Japan, the United States and China showed that the predominant form still is the global exploitation of technologies. Global technological collaborations are particularly common in the EU context or in the rather new research field of CCS technologies. Finally the analysis could show that global generation of technologies does not yet prevail, early signs are visible, however, such as mergers and acquisitions and an increased global orientation of R&D-activities. But in spite of mergers and acquisitions and the existence of global innovation centres, country specific technological differences and an orientation towards the requirements of the home markets of the MNEs remain. For this reason, the MNEs strategy is to maintain several R&D-units in different innovation centres (i.e. in different countries) in order to catch up with varying technological competences and national requirements.

IV Ex-ante Analysis

The sub-project addressed the question, whether and under what conditions internationalization strategies of multinational enterprises (MNE) may weaken Germany's leading position as an R&D-site for coal fired power plant construction until 2020/25 relative to newly industrializing countries with large markets. In general, issues concerning the long term evolution of systems which are simultaneously influenced by political, social, economic and technological developments as well as their mutual interdependencies are difficult to handle by empirical or prognostic methods alone. For this reason the project used a Delphi-method and recruited a number of experts in the fields of innovation research and power plant construction. In a second step scenarios were constructed on the basis of a cross-impact analysis. In order to limit the work load the object of investigation had to be confined. It was agreed that focusing on two countries and their respective MNE activities is an appropriate procedure. Due to the eminent importance of the Chinese market for coal fired power plant technologies and its assumed continuing dynamic to become a leading technology site, the eventual investigation focused on the comparison and interdependencies of Germany, China, and their respective MNEs. The analysis started with a review on the state of the art in the innovation literature. Based on this review 36 primary influencing factors were extracted. These factors were evaluated by experts with respect to their sector specific relevance with regard to the internationalization strategies of German and Chinese MNE using the Delphi method. During the first expert workshop, the experts selected 19 influencing factors as being the most relevant. In an additional step, the whole scope of alternative future developments of the discussed factors was qualitatively evaluated. For eight factors a foreseeable development could be established. Eleven contingent influencing factors along with two target variables (the internationalization strategies of German/Chinese MNE) subsequently remained. These 13 variables (descriptors) now described a system of influence to evaluate Germany's future as a site for coal fired power plant construction and R&D.

Table 1: Selected descriptors and their development options with regard to internationalizing R&D in the power plant sector.

Variant descriptors Germany		**Variant descriptors China**	
[Politics] Coal policy	Coal critical	[Politics] Coal	Neutral
	Coal tolerant (coupled with CCS)		Coal friendly
[Politics] Environmental standards	Rigid	[Politics] Environment. standards/enforcement	Low
	Very rigid (close BAT)		Rising
[Politics] Promotion of innovation	Resear. funds+netw. Policy	[Sector] Domestic demand	Declining
	Resear. funds+netw. policy+demo plants		New dynamic (coupled with CCS)
[Sector] Domestic demand	Stable	[R&D] Innovation centre	No innovation centre in the sector
	New dynamic (coupled with CCS)		Emerging innovation centre in the sector
[Sector] Technology	CCS: single application	[MNE] Targeted market	Domestic market
	CCS: early market introduction		Germany
[R&D] R&D activities	Decreasing	[MNE] MNE strategies	Technology seeking
	Stable		Asset augmenting (not in Germany)
[MNE] MNE-strategy	Only asset exploiting		Asset augmenting (in Germany)
	Early indications for develop. of asset aug.		

Quelle: ZIRN 2009 ZIRN 2009

Subsequently a cross-impact analysis has been conducted. During two expert panels evaluations were made regarding the mutual interdependencies between the descriptors. The result was a qualitative systems model. On its basis, a system-grid was created in order to determine the systemic roles of the respective factors of influence and strategies. It could be determined, that neither German nor Chinese MNE-strategies will be the drivers of internationalization in the investigated sector in the near future. Instead, the developments in the power plant technologies sector seem to be influenced to an extraordinarily high degree by political framework conditions. An interpretation of this analysis suggests that especially German and Chinese environmental standards as well as the Chinese coal policy possess the best potential for influencing the system. Furthermore, in the system-grid the German coal policy, the German state of technology and the German concept for the promotion of innovation seem to be of vital importance for the self-regulation of the system. Additionally the cross-impact analysis was used to establish which scenarios can be interpreted as the most consistent based on the specified interdependencies. The result being that the assumed relations of interdependence allow only for one single scenario. This scenario describes a development until 2020/25 which is based on the idea that the CCS-technology will be available on the world market, the German power plant R&D retains its lead over China (opposite to developments in many other sectors) and in spite of the beginning technological progresses made in China, no – possibly not yet – turning away of MNE from Germany as their principal R&D site is foreseeable. The described scenario has a very low sensitivity in the face of evaluation uncertainties and is highly robust faced with disturbances, as long as fundamental assumptions of the analysis are not questioned. Nevertheless, according to the general concept of the scenario technique, this scenario does not present a forecast, but represents a consistently formulated, possible future option. In order to discuss alternative developments, which from today's point of view seem to be unlikely, the experts identified 14 critical incidents, having fundamental consequences for the scenario and hence allowing for fundamentally alternative developments.

Table 2: Scenario based on the expert evaluations of factor interdependencies

Framework conditions			**Framework conditions**		
	[Politics] Patent governance	Regulations and enforcement rigid		[Politics] Patent governance	Regulation rigid/Enforcement poor
	[Sector] Sector structure	Components + Plants + R&D		[Politics] Globalization policy	Market openness
	[R&D] Network type innov. centre	„Virtual" innov. cent. in the sector exists			
	[Site] Density of regulations	High			
	[MNE] Targeted market	Global market			
	[MNE] Characteristics of knowledge	Context sensitive + implicit			
Variant descriptors			**Variant descriptors**		
	[Politics] Coal policy	Coal tolerant (coupled with CCS)		[Politics] Coal policy	Coal friendly
	[Politics] Environmental	Very rigid (close BAT)		[Politics] Environment. standards/enforcement	Rising
	[Politics] Promotion of innovation	Resear. funds+netw. policy+demo plants			
	[Sector] Domestic demand	New dynamic (coupled with CCS)		[Sector] Domestic demand	New dynamic (coupled with CCS)
	[Sector] Technology	CCS: early market introduction		[R&D] Innovation centre	Emerging innovation centre in the sector
	[R&D] R&D activties	Stable		[MNE] Targeted market	Domestic market
	[MNE] MNE-strategies	Only asset exploiting		[MNE] MNE strategies	Technology seeking

Quelle: ZIRN 2009 ZIRN 2009

The expert panel discussed these critical incidents and qualitatively evaluated their impacts. One of these critical incidents, a crisis of acceptance of the CCS-technology, was investigated in more detail. Such an incident would disrupt the development on which the main scenario was based and could possibly lead to more unfavorable prospects for Germany as a leading R&D site. (Tab.3)

Table 3: Possible development in the case of a crisis of acceptance of CCS.

	[Politics] Coal policy	Coal critical		[Politics] Coal policy	Coal friendly
	[Politics] Environmental standards	Very rigid (close BAT)		[Politics] Environment. standards/enforcement	Rising
	[Politics] Promotion of innovation	Resear. funds+netw. policy+demo plants			
	[Sector] Domestic demand	Stable		[Sector] Domestic demand	Declining
	[Sector] Technology	CCS: no applications		[R&D] Innovation centre	Emerging innovation centre in the sector
	[R&D] R&D activities	Stable		[MNE] Targeted market	Germany
	[MNE] MNE-strategies	Open		[MNE] MNE strategies	Technology seeking

Remarks: The framework factors are consistent with the scenario shown in fig. 3. The consequences of the critical incident are highlighted.

Quelle: ZIRN 2009 ZIRN 2009

V Conclusions

Principally innovation processes are influenced by a lot of different economic, political, social and technological factors which can vary from country to country. Especially in the power plant sector multinational enterprises (MNE) occupy a central position for innovation processes as an information carrier. In this study selected approaches have been used to highlight influences of different factors on innovation processes using the example of coal-fired power plant technologies. Thus the dynamics of selection and co-evolution processes can be analysed in an interdisciplinary way. The results show that countries can lose their position as lead market if they do not strengthen their advantages by investing in further R&D more or less continuously. Despite increasing globalisation, significant differences in the national innovation systems (NIS) of Germany, the USA, Japan and China can be identified. Because of the differences country specific technology portfolios have evolved. Most of the MNEs which were regarded in this study maintain R&D-units in different countries to adapt their products to the local markets. However, the orientation towards their home countries remains. With the increasing number of new manufacturing facilities in low-cost countries established by MNE (or by companies with technological partnerships with MNE) the risk that Germany becomes a less important manufacturing site for power plant technologies rises. On the other hand there are tried and tested / trusted networks and a lot of ongoing R&D projects in Germany. So it can be expected that Germany will still remain an important R&D site. Because the German market for power plants is very small, it is essential to focus the German R&D activities not only on the national but also on the world market.

VI References

FREEMAN, C. (1987) *Technology Policy and Economic Performance: Lessons from Japan* London, Frances Pinter.

IEA CLEAN COAL CENTRE (Ed.) (2008) *CoalPower.* London.

Preprints 2009

01/2009 Fischer, W., Holtrup-Mostert, P., Schenk, O.: Die Klimaschutzpolitik der USA unter Präsident Obama.

02/2009 Birnbaum, U., Linssen, L., Markewitz, P., Martinsen, D., Vögele, S., Froeschle, P., Wind, P.: Elektromobilität - Auswirkungen auf die elektrische Energieversorgung.

03/2009 Kronenberg, T., Kühntopf, S. Tivig, T.: The Effects of Regional Demographic Trends on the Environmental Dimension of Sustainable Development.

04/2009 Schumann, D., Pietzner, K., Fischedick, M., Esken, A.: Social acceptance of carbon capture and storage in Germany.

05/2009 Schumann, D., Simon, A.: Communication of CO2 capture and storage (CCS): Simulating the impact on knowledge and public acceptance.

06/2009 Engel, K.: Zur Energienachfrage von Haushalten - Welche Rolle spielt der demografische Wandel?

07/2009 Kronenberg, T.: Energy Conservation, Unemployment and the Direction of Technical Change.

08/2009 Kronenberg, T.: The Impact of Demographic Change on Energy Use and Greenhouse Gas Emissions in Germany.

09/2009 Kronenberg, T.: Demografieinduzierte strukturelle Veränderungen von Konsumausgaben und Infrastrukturnutzung.

10/2009 Markewitz, P., Schreiber, A., Zapp, P., Vögele. S.: Kohlekraftwerke mit CO2-Abscheidung: Strategien, Rahmenbedingungen und umweltseitige Auswirkungen.

11/2009 Hansen, P.: Welchen effektiven Beitrag kann der Wohngebäudesektor zu den Emissionseinsparungen bis 2020 leisten.

12/2009 Schlör, H., Fischer, W., Hake, J.-F.: Measuring Sustainability in the Energy Sector – Analogies from Individual Welfare Measurement.

13/2009 Linssen, J., Markewitz, P., Vögele, S.: Energietransport und –verteilung.

14/2009 Schlör, H. Fischer, W., Hake, J.-F.: Is the German Energy System Sustainable? An Analysis Based on the German Sustainability Strategy.

15/2009 Hansen, P., Kronenberg, T., Kuckshinrichs, W., Müller, M.: Effekte des CO2-Gebäudesanierungsprogramms der KfW

16/2009 Fischer, W., Holtrup-Mostert, P.: US-Klimaschutzpolitik im Vorfeld von Kopenhagen.

17/2009 Schumann, D.: Public Acceptance of Carbon Dioxide Capture and Storage. Research Approaches for Investigating the Impact of Communication.

18/2009 Kronenberg, T.: Finding Common Ground between Ecological Economics and Post-Keynesian Economics

19/2009 Hansen, P., Kronenberg, T., Kuckshinrichs, W.: The Social Return on Investment in the Energy Efficiency of Buildings: A Case Study of Germany.

20/2009 Wagner, H.-J., Kuckshinrichs, W., Groß, C.: Globale Energie- und CO_2-Szenarien.

21/2009 Schlör, H., Fischer, W., Hake, J.-F.: Is the German Energy System Sustainable? An Analysis Based on the UNCSD theme based sustainability approach.

22/2009 Hencke, E.-G., Martinsen, D., Riedle, K., Weber, K., Wagner, H.-J.: Sustainability and Greenhouse Gas Reduction.

23/2009 Arens, M., Wietschel, M., Markewitz, P., Dötsch, C., Herkel, S., Krewitt, W., Möst, D., Scheufen, M.: Energietechnologien 2050.

24/2009 Schlör, H., Fischer, Wo., Hake, J.-F.: Index of Sustainable Development - Measuring sustainability in the energy sector in absolute and relative terms.

25/2009 Sander, M., Baumann, F.: Österreich – Kleines Land ganz groß? Energieunternehmen als Akteure und Einflussfaktoren der österreichischen Außenpolitik.

26/2009 Kronenberg, T.: Perspectives for Ecological Post-Keynesian Economics.

27/2009 Fischer, W., Hake, J.-F., Martinsen, D., Sander, M.: Das deutsche Energiesystem im Übergang.

28/2009 Geske, J.: A theory of urban structure development.

29/2009 Kronenberg, T., Kühntopf, S., Tivig, T.: Die Effekte von regionalen demografischen Trends auf die ökologische Dimension der Nachhaltigkeit.

Research Reports 2009

01/2009 Weber, K., Martinsen, D.: IKARUS-FLP3 - Beschreibung für die Implementierung mit Beispielen.

02/2009 Kuckshinrichs, W., Hansen, P., Kronenberg, T.: Gesamtwirtschaftliche CO2-Vermeidungskosen der energetischen Gebäudesanierung und Kosten der Förderung für den Bundeshaushalt im Rahmen des CO2-Gebäudesanierungsprogramms.

03/2009 Hake, J.-F., Hansen, P., Heckler, R., Linßen, J., Markewitz, P., Martinsen, D., Weber, K.: Projektionsrechnungen bis 2050 für das Energiesystem von Deutschland im Rahmen des VDI-Projektes „Future Climate Engineering Solutions".

04/2009 Marx, J.; Schreiber, A.; Zapp, P.; Hake, J.-Fr.: Synthesis report of environmental evaluation of CCS using Life Cycle Assessment (LCA).

05/2009 Schumann, D.; Pietzner, K.: Scrutinizing the impact of CCS communication on the general and local public. Results of the comparative study of CCS communication methods in Germany.

06/2009 Schreiber, A., P. Zapp, P. Markewitz, S. Vögele: Environmental Analysis of a German Strategy for Carbon Capture and Storage of Coal Power Plants

07/2009 Hansen, P.: Analyse des Umsetzungsstands der Gebäudemaßnahmen des Integrierten Energie- und Klimaprogramms der Bundesregierung.Hansen

08/2009 Kuckshinrichs, W., Linssen, J., Markewitz, P., Zapp, P., Peters, M., Köhler, B., Müller, T.E., Leitner, W.: Weltweite Innovationen bei der Entwicklung von CCS-Technologien und Möglichkeiten der Nutzung und des Recyclings von CO2.

09/2009 Vögele, S., Markewitz, P., Weimer-Jehle, W., Fuchs, G., Wassermann, S., Rennings, K., Hoffmann, T., Moslener, U., Voigt, S.: The Significance of Germany as a Site for Power Plant Construction Against the Background of an Increasing Internationalization of Innovation Processes.

Systems Analysis and Technology Evaluation at the Research Centre Jülich

Many of the issues at the centre of public attention can only be dealt with by an interdisciplinary energy systems analysis. Technical, economic and ecological subsystems which interact with each other often have to be investigated simultaneously. The group Systems Analysis and Technology Evaluation (STE) takes up this challenge focusing on the long-term supply- and demand-side characteristics of energy systems. It follows, in particular, the idea of a holistic, interdisciplinary approach taking an inter-linkage of technical systems with economics, environment and society into account and thus looking at the security of supply, economic efficiency and environmental protection. This triple strategy is oriented here to societal / political guiding principles such as sustainable development. In these fields, STE analyses the consequences of technical developments and provides scientific aids to decision making for politics and industry. This work is based on the further methodological development of systems analysis tools and their application as well as cooperation between scientists from different institutions.

Head: Jürgen-Friedrich Hake
Forschungszentrum Jülich
Institut für Energieforschung (IEF)
Systems Analysis and Technology Evaluation (IEF-STE)
Wilhelm-Johnen-Straße
52428 Jülich
Tel.: +49-2461 61-6363
Fax: +49-2461 61-2540
Email : jfh@fz-juelich.de
Internet: www.fz-juelich.de/ief-ste