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Knowledge Management and Knowledge-based Marketing

Yoosuf Cader

Engineering an Instrument to Evaluate Safety Critical Manning Arrangements in Chemical Industrial Areas

G.L.L. Reniers, W. Dullaert, B.J.M. Ale, F. Verschueren, K. Soudan

Technology to Clean Up Coal for the Post-oil Era

Joseph Auer

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Letter from the Editor

Tackling present and future challenges of the chemical industry

In times of globalized markets and rapid technological change, the chemical industry faces several challenges. Increasing pricing pressure, especially from Asia, forces chemical companies to elevate production efficiency to a maximum level and simultaneously develop innovative products and processes to open up new markets. At the same time, firms need to face the inescapable depletion of the earth's oil reserves and prepare for a change in the raw material as well as energy supply. This issue's articles address these challenges and point out possibilities to tackle them.

First, the article "Knowledge Management and Knowledge-based Marketing" stresses the importance of knowledge management for innovation. Using examples from the biotechnology and engineering industries, the article shows how knowledge management systems can be used to foster innovation.

This issue's second article "Engineering an Instrument to Evaluate Safety Critical Manning Arrangements in Chemical Industrial Areas" deals with the safety problems that can arise out of the pressure to reduce the size of operational teams in the chemical process industry. The authors present an instrument that allows for an evaluation of safety critical staffing levels required to meet performance specifications for safety critical activities.

Our last article "Technology to Clean Up Coal for the Post-oil Era" highlights the importance of coal as an energy source in the transition period to the solar age. Often thought of as a climate killer or not even considered at all when talking about energy options of the future, the author presents an interesting and intriguing point of view regarding the future of coal.

We would like to thank all authors and reviewers for their contribution to this selection of interesting themes. Now enjoy reading the second issue of the *Journal of Business Chemistry* in 2007. If you have any comments or suggestions, please send us an e-mail at contact@businesschemistry.org.

Benjamin Niedergassel

Commentary

Australian Cooperative Business

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The fine chemicals industry including the pharmaceutical industry relies on academic university research as the driver to discover new methodology and reactions that can be transformed into industrial processes. Whilst in Australia industrial support for research remains scarce, the Cooperative Research Centres (CRC) Programme that was established in 1990 was designed by the Federal government to improve the effectiveness of Australia's research and development output. The sum of $11.1 billion (cash and in-kind) was contributed by all parties. The challenge and objective is to connect researchers with business to focus R & D with innovative outcomes that can progress towards utilisation and commercialisation of research at an incremental and new industry level.

The CRCs are funded for up to 7 years to promote long-term strategic links and collaborations between industry, universities and government with the purpose to target the needs and requirements of industries to deliver benefits for Australian business. There are currently some 57 CRCs in operation, spanning manufacturing technology, information and communication technology, agriculture and rural based manufacturing, environment and medical science technology. New CRCs are being established so opportunities for business involvement are ongoing. Some of the benefits that the Programme can offer business are:

- Output of higher quality products, services and industrial processes leading to increased profits
- Collaborations and associations with leading researchers in Australia and the world
- Securing excellent scientific support to attract investors

- Opportunities to integrate with industry experts
- Employment of excellent graduates to develop business requirements and
- Professional development courses to sustain industry skill levels

A recent economic impact study of the CRC Programme that measured the net economic benefits for the economy between 1991 and 2010 calculated that the return to Gross Domestic Product (GDP) for every dollar invested in the Programme produced $2.16. The Department of Education, Science and Training minister announced that the consequences of the research, training and commercialisation activities of the CRCs had resulted in an increase in the Australian GDP of around $2.7 billion. The report has also revealed a number of other significant features of CRC operations:

- It is clear that successful CRC proposals must be genuinely end user driven.
- The last funding round (round 9) trend was to promote funding a smaller number of CRCs that were better resourced.
- The benefits delivered to the end user application of research were most significant even if it did not realise in the production of a direct commercialisation process.
- The time lag between commencement of a CRC and the delivery of measurable outcomes are around 5 to 10 years. Outside of CRC activities, research to market can take up to 20 years and this is one of the major impediments to attracting investors.
- It has been claimed that for every million dollars the Federal Government provides for research, the CRCs efforts produced at least twice as many inventions, patents and licences

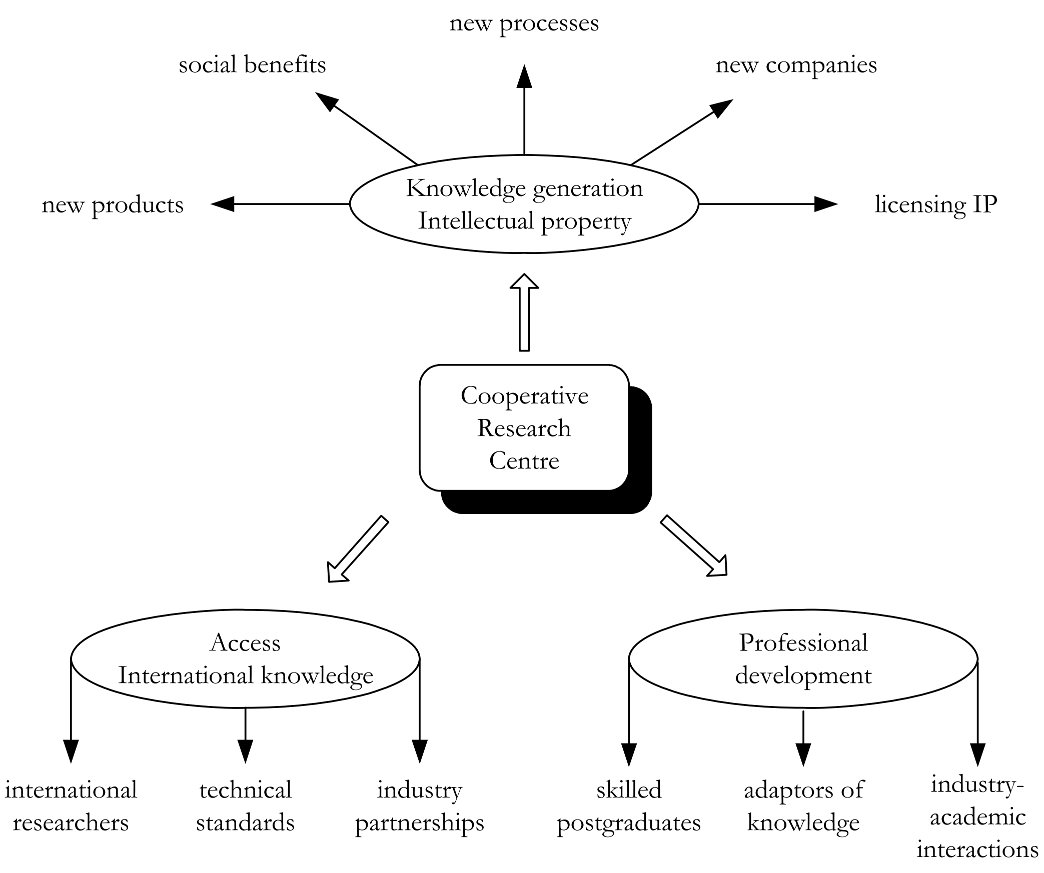

Figure 1: Different directions, pathways and spheres of influence of CRCs are presented

as the overall university sector.

- The CRC brings focus to research work and in so doing generates 'industry ready' postgraduates to provide the skills necessary to sustain scientific industrial processes

Areas that CRCs have generated direct commercialisation of knowledge include: Capital markets surveillance services; CRC for Sensor Signal and Information Processing; CRC for Tropical Plant Protection: developing 'super fodders'; CRC for Advanced Composite Structures: maintaining Australia's stake in aerospace; Cotton Catchment communities CRC: managing pests and improving water efficiency; CRC for Welded Structures: cast reductions for industry; Australian Sheep Industry CRC: parasite management and precision production; CRC for Alloy Solidification Technology (CAST): delivering production cost reductions; CRC for Sustainable Aquaculture of Finfish: improving farming processes of Southern bluefin tuna; eWater CRC: reducing water infrastructure costs while maintaining quality; CRC for Sensor Signal and Information Processing Reduction of environmental impacts of industry and agriculture through high-tech control systems and CRC for Enterprise Distributed Systems Technology: Health IT software.

It is anticipated that in future huge economic benefits can be derived from CRCs by addressing the societal problems of the 21st century such as clean energy, biofuels, Alzheimer's disease when these are tackled not just in academia but in productive partnership with business. For such tactics and strategies to succeed the best talent/brainpower would have to be devoted to science and innovation supported by the best business brains.

Research Paper

Knowledge Management and Knowledge-based Marketing

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Abstract: Two separate qualitative research studies are designed to gain an insight into the practice of knowledge management and marketing in the engineering and biotechnology industries. The findings show that the engineering industry is practicing knowledge management to varying degrees. The biotechnology industry clearly differentiates between data, information and knowledge. With the new knowledge gained, the biotechnology industry (a rapidly growing knowledge-intensive industry, according to Donn Szaro) is able to innovate and market new products and services.

A Knowledge Management System (KMS) model has been used to show how the various components within the KMS are coordinated and integrated to best achieve organizational objectives in the engineering and biotechnology industries. The KMS model is also used to show how customer-focused organizations use knowledge to market innovative products and services.

Introduction

Most organizations are now more customer-focused and use knowledge-based strategies to reach out to their customers. This is particularly so in knowledge-intensive industries such as the biotechnology and the engineering industries. The biotechnology industry is growing at a rapid pace and is now considered as one of the fastest growing industries in almost all industrialized countries[1]. Knowledge management's overall goal is to build an organization that can 'see' the customer (customer-focused), for it is the customer that drives any business. Peter Drucker [2], the well known marketing guru, views marketing as a philosophy or way of doing business and in its importance in focusing on the customer:

"It is a customer who determines what a business is. It is the customer alone whose willingness to pay for a good or service converts economic resources into wealth and things into goods. What a business thinks it produces is not of first importance, especially not to the future of the business and to its success. What the customer thinks he is buying, what he considers value, is decisive - it determines what a business is, what it produces, and whether it will prosper. And what the customer buys and considers value is never a product. It is always utility, meaning what a product or service does for him. The customer is the foundation of a business and keeps it in existence"

Unless the customer's needs and wants are more than satisfied and their expectations are met, the customer is likely to defect to a competitor. Even satisfied customers are defecting to competitors because the competitor has differentiated and is providing a better service, or quality, or something else better that matters to the customer. Jones and Sasser [3] performed a study to find out why customers defected. They investigated more than 30 companies, in five different industries, with different competitive environments and different types of customer relationships. Their findings on reasons for a shift in customer loyalty were that customers were reasonable but they want to be completely satisfied. If they are not and have a choice, they can be lured away easily. Therefore to be competitive, it is imperative that organizations must be customer-focused. Therefore, knowledge management's overall goal is to build an organization that can 'see' the customer (customer-focused). This article presents the results of two separate qualitative studies, one in the engineering industry and the other in the biotechnology industry, both taking customer-focused approaches to achieve their organizational goals.

Literature review

In addition to being customer-focused, organizations must also practice knowledge-based marketing strategies. However, prior to practicing knowledge-based marketing strategies, organizations need to know what kind of 'marketing knowledge' is needed. There are different interpretations of what constitutes 'marketing knowledge'. Some scholars such as Huber, Morman, and Miner have defined it as 'market information', meaning this information has to progress through knowledge acquisition, information distribution, information interpretation, and organizational memory [4, 5, 6]. However, other marketing scholars such as Jaworski and Khol, Slater and Narver have defined it as "market orientation" depicting the generation and dissemination of market information [7, 8]. Srinivasta et al. [9] defined it as a phenomenon that involves three different core marketing processes: Product Development Management (PDM), Supply Chain Management (SCM), and Customer Relationship Management (CRM). However, according to knowledge management protagonists Davenport et al. [10] , customer relationships are built by customizing the needs of each of their customers and serving them profitably and to do this 'customer knowledge' needs to be managed. Knowledge management however, involves managing customer knowledge and all other available knowledge within an organization to achieve the common goal of increasing organizational productivity.

What then are knowledge-based marketing practices? These are marketing strategies that have been based on the greater understanding gained from the existing marketing knowledge. It is this understanding that is critical in gaining competitive advantage. In other words, for example two marketing managers (human capital) could be looking at the same marketing knowledge but could arrive at different levels of understanding (managerial judgment or cognitive capacity) based on their own intuition and experience. The organization with the marketing manager who has the greater understanding of the marketing knowledge will gain the competitive advantage, assuming other activities being equal. Similarly the organization that has the appropriate systems in place and has the relevant and updated knowledge embedded in databases also gains the competitive advantage. More importantly, if the three (human capital, systems, and databases) are integrated in an organization, then that provides this organization with the best opportunity to gain competitive advantage.

Product Development Management (PDM), SCM (Supply Chain Management), Customer Relationship Management (CRM), and Marketing Information Systems (MkIS) are useful core marketing processes and each on its own will produce the intended outcomes. However, what is needed is a system that can coordinate and integrate the outcomes of each of these disparate processes to generate the best and most up-to-date marketing knowledge. Such a system is called a Knowledge Management System (KMS) which will help in developing knowledge-based strategies to gain sustainable competitive advantage. Described below is a model (Figure 1) of a KMS which was designed by the author and can be applied to any industry [11]. In this model, the knowledge creating organization integrates the various components responsible for the productivity in an organization. The knowledge creating organization has four important components: Organizational mission; Knowledge inputs (marketing and other); Organizational outputs or objectives; Information Systems, Computing and Telecommunication Technology.

In the KMS data are gathered from ***independent*** and ***dependent*** variables from the marketing environment. The independent variables include data from the marketing mix variables (product or service, promotion, price and place – the 4Ps) and the macro- and micro-environmental factors, i.e. marketplace knowledge (Figure 1). The dependent variables include data from customer behavioral responses and expected performance measures. The behavioral responses include awareness, knowledge, liking, preference, intent-to-buy, and purchase. Performance measures (organizational objectives) include both financial (cost, profit, revenues, ROI, cash flow, earnings per share, sales value, brand value, etc.) and non-financial metrics (sales volume, market share, competitive advantage, customer satisfaction, new patents, and brand image).

The type of data that are gathered from the **micro-environment**, are product or service knowledge, knowledge of competitors, value chain knowledge, and knowledge of customers; such as knowledge of their purchasing power, income distribution, and availability of credit, debt and savings potential. An important resource of the organization is human intellectual capital. This includes marketing personnel who interpret the marketing information.

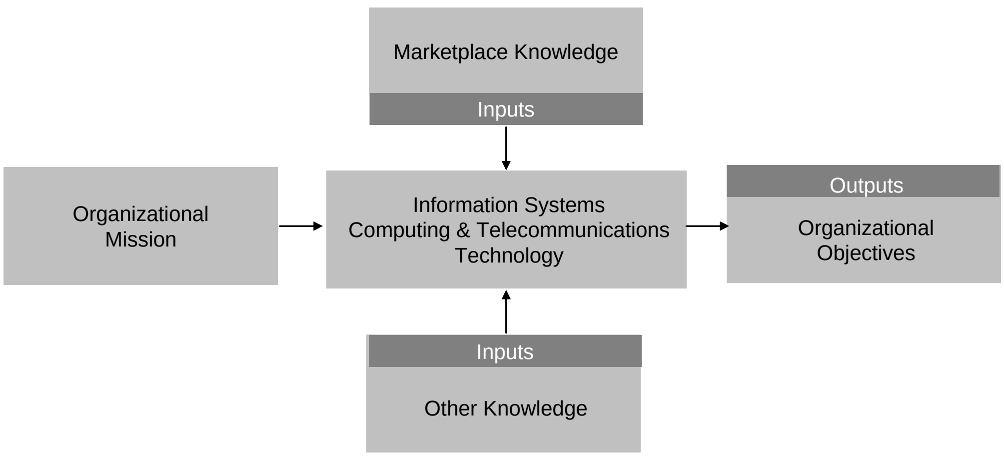

Figure 1: The flow of Knowledge Management in Organizations

In the larger **macro-environment**, the marketing functional unit must continuously monitor and update its knowledge of the changing trends such as social, legal, economic, political, cultural, technological, and demographic factors that impact on the marketing functional unit's ability to implement its marketing strategies. These and other marketplace data lie embedded inside databases within the organization's Marketing Information System (MkIS). These databases must be mined for information using data mining procedures. This enables the organization to effectively implement knowledge-based marketing strategies. Interpreting the output (information) as a result of the transformation of the micro- and macro-environment data in the databases within the Marketing Information System (which is a part of the Knowledge Management System) helps in developing knowledge-based marketing strategies.

In summary, the data from the independent and dependent variables are fed into the databases in the Marketing Information System (MkIS), which is an integral part of the Knowledge Management System (KMS). When marketing managers (human capital) interpret the outputs generated by the systems and if all three - the databases, systems and human capital - are integrated, then this provides the organization to focus on knowledge-based strategies with the best opportunity to gain competitive advantage.

Hypothesis development in the marketing unit of a biotechnology organization

Using this model many hypotheses can be developed for the marketing unit of a biotechnology organization where the 'Marketplace Knowledge Inputs' are the independent variable and the marketing objectives (or outputs) are the dependent variables. Listed below are some hypotheses:

1. Marketplace knowledge inputs lead to an increase in market share
2. Marketplace knowledge inputs lead to an increase in sales
3. Marketplace knowledge inputs lead to an increase in customer satisfaction
4. Marketplace knowledge inputs lead to an increase in profits
5. Marketplace knowledge inputs lead to an increase in brand awareness

These hypotheses can be tested for a biotechnology organization by designing experiments to study the influence of any of the marketplace variables and measuring marketing objectives such as market share, brand awareness, sales, and customer satisfaction.

Knowledge-based marketing

What is knowledge-based marketing? It is marketing which makes use of the macro- and micro-environmental knowledge that is available to the marketing functional unit in an organization. It is not a case of "knowing what you know" but "what you need to know" in a changing micro- and macro-environment.

When marketing theory such as the importance of continuously scanning the environment and looking for trends is not put into practice it can result in product failures. Tupperware's failure to continuously scan and monitor the demographic trends resulted in loss of market share. Tupperware markets air-tight, easy-to-use plastic food storage containers using the party concept method of distribution according to Grossmann. In the 1960s and 1970s company sales were doubling every five years. However, the environment started changing in the 1980s when the incidence of divorce and women entering the work force increased. As a consequence the North American sales started declining from 60% to 40% of the market. At the same time a competitor's (Rubbermaid) sales shot up from 5% to 40% of the market [12]. Rubbermaid adapted to the changes in the environment and used the new knowledge to market similar products in grocery and discount stores, while Tupperware did not respond to these environmental changes. Tupperware markets household consumer products (not engineering or biotechnology products). However, this example has been mentioned to stress the importance of scanning any marketplace environment rather than restrict it to the biotechnology or engineering environment.

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Many organizations, large or small are practicing knowledge-based marketing. Kotler and Keller have described the practices in a knowledge-based organization. Procter and Gamble (P&G), one of the largest global consumer organizations has a marketing research unit called Consumer and Market Knowledge (CMK) [13]. Its goals are to gain knowledge of consumers, sustain long-term brand equity, to use local market expertise and establish retail partnership. It also has a Corporate CMK group whose functions are to manage a proprietary research methods department, to use expert application of and acquire cross-business learning from core research competencies, share services and infrastructure, leveraging traditional research basics e.g. brand tracking; experiential consumer contacts; proprietary modeling methods; and scenario planning or knowledge synthesis events. On the other hand, a small organization such as Okmulgee Plumbing (Oklahoma) practices knowledge-based marketing in a less sophisticated but yet effective way. They make a deliberate attempt to capture and maintain knowledge about every customer they serve. They do this with knowledge exchanges with their target market. This involves analyzing customer databases, listening to customers, conducting market research including surveys and studying the micro- and macro-environmental trends which includes the competitors. A Knowledge Management System is vital in any organization that intends to practice knowledge-based marketing and the model of the Knowledge Management System (KMS) described above can be applied to any industry including the engineering and biotechnology industries.

Knowledge management system (KMS)

Knowledge management is a way of doing business just like marketing or Six Sigma is. However, the understanding of the concept of knowledge management by different individuals within the same organization may be incoherent. This very much depends on the functional unit to which the individual is attached in the organization. For example, information technologists would consider the information technology infrastructure of the organization as the most critical knowledge asset, whereas operations managers would consider continuous improvement and operational techniques as its most critical knowledge asset, while marketing professionals consider knowledge-based marketing as its most critical asset, and so on. In the KMS designed by the author (described above) the model represents how the effectiveness of the 'whole' is greater than the effectiveness of the 'disparate parts' in terms of organizations becoming more productive by leveraging all of its knowledge assets in an integrated and coordinated manner.

In the KMS model, the knowledge creating organization brings together the various components responsible for the productivity in an organization including the innovation of new products or services (see figure 1). As mentioned earlier, the knowledge creating organization has four important components: Organizational mission; Organizational outputs or objectives; Knowledge inputs (marketing and other); and Information systems, computing and telecommunication technology.

According to this model, the organizational mission of the knowledge creating organization must have a clear purpose which should be carefully crafted and successfully implemented. More importantly the organization must be faithful to the mission in every sense of the word. This is why organizations as diverse as British Petroleum and SENCO (a US-based nails manufacturer) consider themselves as being in the knowledge management business. As a consequence they are effectively leveraging knowledge to create wealth for their organization and value for their stakeholders. They are doing this more effectively than their competitors.

Anything that an organization does is focused on achieving its outputs or objectives. Organizational objectives such as market share, knowledge-based innovative products or services, customer and stakeholder delight, knowledge that benefits human welfare, and profits, to name a few, are derived from the carefully crafted mission statement.

In the KMS model various marketplace knowledge inputs are required before the strategies are developed. As mentioned earlier these include macro- and micro-environmental knowledge, product or service knowledge, knowledge of competitors, knowledge of customers, and value chain knowledge, etc. Other non-marketplace knowledge includes research and development knowledge, knowledge of automation, knowledge of operational techniques, and contribution by knowledge workers, etc. (see figure 1). In the KMS model the core of any organization today is its information systems, computing and telecommunication technology resources. These technologies enable the organization to capture, create and share knowledge. No organization will survive without this critical resource that would enable it to deal with a rapidly changing environment. All these knowledge components within an organization should be integrated and coordinated in order to achieve its overall objectives.

Customization and personalization

Mass customization involves obtaining market knowledge and dynamically organizing resources leading to customization. This process enhancement creates a quality product and a body of **architectural knowledge** (human, technological and processes). Burger King practices the concept of mass customization by giving the customer the option to choose the ingredients in a hamburger. To make customers aware of this concept they advertised the now famous slogan “Have it your way”.

According to Sasser, Jones, and Klein the Ritz-Carlton Hotel chain uses both its customer and architectural knowledge to offer highly personalised services to it’s customers in a timely manner [14]. From the time a customer checks in to a Ritz Carlton Hotel, customer intelligence gathering begins in an unobtrusive way by the hotel employees, who store and disseminate the information using the networked knowledge management system. The customer’s preferences are captured and recorded in a database. When the customer checks in to a Ritz Carlton the next time, all his/her needs will be met, including the bed size, the number of pillows required, room preferences, and also ensuring the checking-in process is smooth.

Levi’s Jeans also practices the concept of mass customization. When a customer enters a store to purchase a pair of jeans, measurements and specific needs are entered into Levi’s knowledge management system. The information is dynamically sent to a central production capability, which produces the customized product for shipment to the customer faster than its competitors as time is also considered an important element of mass customization. Although the above three examples are not from the engineering or biotechnology industry the same principles of knowledge management will apply to these two industries as well.

Knowledge management officers

Apart from technology and processes, the human factor is one of the most important factors involved in implementing knowledge management. These three factors constitute what is called architectural knowledge. If the human factor is missing, then all you have is the information in databases. These databases alone do nothing for an organization unless the information contained within it is analysed and interpreted correctly by a knowledge worker and the knowledge produced is quickly shared within the organization. Unfortunately when organizations started de-layering the organizational structure, many knowledge creating employees left, taking with them the important tacit knowledge which had not been captured by the organization. Organizations should employ knowledge management officers or a ‘knowledge champion’ to capture this tacit knowledge, integrate and coordinate all the other knowledge assets within the organization and make sure knowledge is shared quickly with the appropriate people.

Capturing and transferring knowledge

It is important to capture the knowledge embedded in organizations. This is because employees not staying long enough in organizations results in a loss of ‘knowledge creating employees’ [15], the terminology used by Nonaka and Takenchi. When the ‘knowledge creating employees’ leave, they take with them what is called ‘tacit knowledge’, which is knowledge inside the head of an individual. Ninety per cent of the knowledge in an organization is tacit knowledge according to the website Libsuite KM [16]. What is important is to capture this tacit knowledge by transferring it to ‘explicit knowledge’, which is organizational knowledge in systems within the organization which can be rapidly communicated to people and processes that are connected to the Internet.

Nonaka and Takeuchi have described a good example of capturing tacit knowledge and successfully transferring this (knowledge transfer) to explicit knowledge and as a consequence leveraging it to make profits for an organization. This can be best demonstrated in Matsushita’s marketing of the home bread-making machine [15]. The Matsushita Electric Company is one of the largest corporations in the world and is well known for brand names such as Panasonic, National and Technics. In 1985, the product development team was developing a new home bread-making machine at their headquarters in Osaka. When the machine was developed they found that the outer crust of the bread was overcooked while the inside was still uncooked. After much experimentation including comparing dough mixed by this machine and by professional bakers, they could not identify the problem. A software developer, Ikoko Tanaka, volunteered to observe how the Osaka International Hotel’s chief bread maker made the best bread in the region. After about a years observation of his craft, especially the kneading techniques, and subsequent trials she realized that the hotel’s bread maker’s skills (tacit knowledge) was in the stretching and kneading of the dough. The bread maker himself could not articulate how he did this. Tanaka introduced special ribs in the machine to imitate the stretching and kneading of the dough. This product called ‘twist dough’ became a marketing success for Matsushita. Thus tacit knowledge – the baker’s skill of special stretching and kneading – was transformed into explicit knowledge by writing product specifications which included the special ribs inside the machine imitating the chief baker’s stretching and kneading skills.

According to Lord John Browne (former chairman of British Petroleum) in an interview with Harvard Business Review [17], “the wonderful thing about knowledge is that it is relatively inexpensive to replicate if you can capture it. Most activities or tasks are not one time events. Knowledge should be replicated throughout the company so that each unit is not learning in isolation and re-inventing the wheel again and again. Our challenge has been getting people to systematically capture the information the company needs, to be able to use both explicit and implicit knowledge repeatedly”. BP does this by transferring the knowledge gained in an oilfield in the North Sea to the start-up of a new field and thereby saving substantial costs in drilling at the new field. Another company, Dow Chemical, in an entirely different industry generated over $125 million in revenues and savings by actively leveraging one of its key knowledge assets, its patent portfolio.

According to Schwartz, Bruce Power, a nuclear power generator company in Canada has a good knowledge capturing system [18]. The power plant was built in the 1970s. It has 3700 employees, most of them engineers. In three years time, one-third of its workforce will retire (as most baby boomers will do) taking with them their tacit knowledge. In order to capture their tacit knowledge before they left, Bruce Power implemented a Knowledge Management System called Kana IQ, which allows engineers to document how they tackled problems. New engineers joining the company can now search Kana IQ using decision trees and case-based reasoning.

While there are formal processes developed to capture knowledge there are also informal processes that are quite effective in capturing knowledge. Socialization and story-telling are effective informal processes in organizations which help in capturing and sharing knowledge. Here the socialization and story telling can take place at lunch, or in the corridors in offices or even by the office water cooler. Sales representatives usually meet up with other sales representatives while travelling and usually engage in socializing during meal times. Oftentimes solutions to problems in this informal setting among colleagues can be very quickly resolved. Many have reported the benefits of informal socializing and story telling including Nonaka, Takeuchi [15], Brown, and Duguid [19]. Thus capturing knowledge requires organizations to do a number of things. There should be Knowledge Management Systems with databases, processes, technology and most importantly a culture that encourages employees to use the opportunity to informally socialize and exchange stories (tacit knowledge) of how they solved difficult problems.

Knowledge cultures

This is the hardest to achieve. You can have the knowledge infrastructure in place, but you may not have the right culture in place. Building the right culture in an organization is quite difficult especially so when employees are still unsure of the nature of the new knowledge asset and what leveraging that means to them. Others such as Carla O'Dell from the American Productivity & Quality Centre [20] have also confirmed that "Fewer than 10% have succeeded in making it (knowledge management) part of their culture". It appears that capturing knowledge is the hardest to achieve in any organization.

Knowledge communities

Knowledge communities help to build a knowledge culture within an organization. A knowledge community is one in which a group of people come together to share knowledge of interest to them. They could be office colleagues, people with similar interests who have formed an informal group and could be boundary less spanning the globe. Many organizations encourage employees to become members of a knowledge community sharing knowledge among them. Even part of World Bank's knowledge strategy is to build knowledge communities.

Knowledge sharing

A good example of an organization sharing knowledge is INTEC, which has revenues of over $80 million. It is a project management company based in Houston with 500 employees in the global oil and gas industry with expertise in marine pipelines, terminals, and facilities. A group of INTEC engineers formed a 'knowledge community' to capture knowledge and share it among them. They integrated INTEC's web-based software and search engines with a repository that included 75,000 technical documents, staff's existing skills and certification databases, lightweight Directory Access Protocol files of employees' names, titles, locations, e-mail addresses, and photographs. Engineers with questions can now search for relevant documents or send e-mail queries to company expatriates. The system was designed to incorporate all queries into INTEC's knowledge base. The benefit of this integrated system to INTEC was its speedy resolution to problems (saving three weeks on average), improved sales processes and also offering these benefits to its customers.

McDermott and O'Dell suggested the following strategies can contribute to creating knowledge sharing cultures [21]: Make a visible link between sharing knowledge and business objectives; provide a reward and recognition system; provide adequate resources to encourage human networks of knowledge sharing; link knowledge sharing with widely and deeply held core values; encourage 'boundary-spanning' individuals who can translate knowledge and experiences from one group to another, and support a committed project champion.

Overall research goals

1. To gain an insight into the extent of knowledge management practiced in the engineering industry in the United Arab Emirates (UAE).
2. To gain an insight into the innovative products or services launched by biotechnology organizations.

Methods used

Valuable insights can be obtained from the qualitative studies in both industries. While these qualitative studies alone cannot lead to conclusive findings due to the specific exigencies of the situation, they nevertheless provide some insight. More research needs to be done to arrive at conclusive findings.

Engineering industry

The sample represented engineers, managers, and consultants of global and local engineering firms such as Hyder Consulting Middle East, Al-Futaim Carillion, Etisalat, Anabeeb Hobas Gulf, Wilber Smith Associates, Capita Symonds, ARENCO Environmental Construction and Consultants, Meinhardt Engineering Advisory and

Consulting services, CEGELEC Solutions and Services. The sample size consisted of twenty two respondents from thirteen organizations surveyed. The sample was selected because they had knowledge of the engineering industry in which they worked.

First, an understanding of the various types of knowledge was given during a presentation. They were knowledge transfer, knowledge sharing, knowledge capture, tacit knowledge, explicit knowledge, knowledge creation, knowledge exchanges, knowledge-based marketing, etc. The audience was asked to complete the survey while the presentation was in progress explaining each type of knowledge using examples of knowledge management practiced in the engineering industry in other countries.

Biotechnology industry

In-depth interviews were conducted with ten senior managers employed in ten biotechnology organizations who were attending the XIX International Congress of Genetics held in Melbourne (6-11 July, 2003). Their responses were analyzed to identify the innovative products or services recently marketed and planned for launch in the future to researchers and other users in the biotechnology industry. These managers were selected because of their knowledge of the industry in which they were employed.

Results

Engineering industry results

A Knowledge sharing systems

The results indicate 72% of the organizations have knowledge sharing systems in place (see figure 2). These include web-based systems (internet/intranet), attending best practice seminars, web access to databases, management information systems and knowledge forums. All of these - while helpful in sharing knowledge - are not as effective when compared to the coordinated and integrated efforts of organizations such as INTEC (not a respondent of this survey). INTEC's engineers in the knowledge community were connected with web-based software and search engines with a repository of organizational information. Engineers with questions can search for relevant documents or send e-mail queries to company expatriates. The system was designed to incorporate all queries into INTEC's knowledge base. What is most important in knowledge sharing is the coordinated and integrated effort of organizations and making a connection between knowledge sharing and practical business goals.

B Knowledge cultures

In the organizations surveyed in this study, 59% have implemented a knowledge culture within their organization. This figure appears to be too high since it is well known that achieving a knowledge culture is a most difficult task. However, most of the respondents found only a minimal level of knowledge capture had been achieved. Interestingly, one organization with its head-office in the UK, has already invested one million pounds sterling this year on a trial basis and funding will continue if it turns out to be a success.

C Knowledge capturing systems

41% of the organizations surveyed had already implemented knowledge capturing systems. However, most respondents did not describe their knowledge capturing systems. One mentioned the use of databases to capture project statistics and experience, another organization mentioned the use of 'Share Points' (preference plane and or application to help share any directory in Mac OS X). It is unclear as to what other systems were used to capture knowledge.

A good reason to capture knowledge is because employees do not stay long enough in organizations, resulting in a loss of 'knowledge creating employees'. When the 'knowledge creating employees' leave, they take with them what is called "tacit knowledge". As mentioned earlier in the literature review, 90% of the knowledge in an organization is tacit knowledge.

Databases, artificial intelligence, neural networks, incentives to employees to produce high quality content, periodical quality reviews of content, encouraging employee socializing, etc. are some of the methods and tools used to capture knowledge.

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Engineering organizations use a combination of knowledge management systems, enabling technology, informal socializing, and non-threatening observation of knowledge workers in order to transfer tacit knowledge to explicit knowledge.

D Employment of knowledge management officers (KMOs)

Only 23% employed KMOs. This is a reasonable percentage within this industry and is likely to grow. It is important to support a committed project champion who can enthuse and motivate employees with the knowledge sharing initiative and bring together people in the organization who already share ideas and knowledge. This project champion is one of the key human factors involved in implementing knowledge management in organizations. The other two factors are technology and processes and all three constitute what is called architectural knowledge.

E Knowledge communities

Only 23% of the respondent organizations are part of a knowledge community. It is important to build knowledge communities similar to that practiced by INTEC, mentioned above. They connected their engineers with web-based software and search engines with a repository of organizational information.

F Knowledge-based marketing

Only 23% of the respondent organizations practice knowledge-based marketing. This is not surprising as many organizations are not customer focused. If an organization cannot “see” the customer (is not customer-focused) then all that

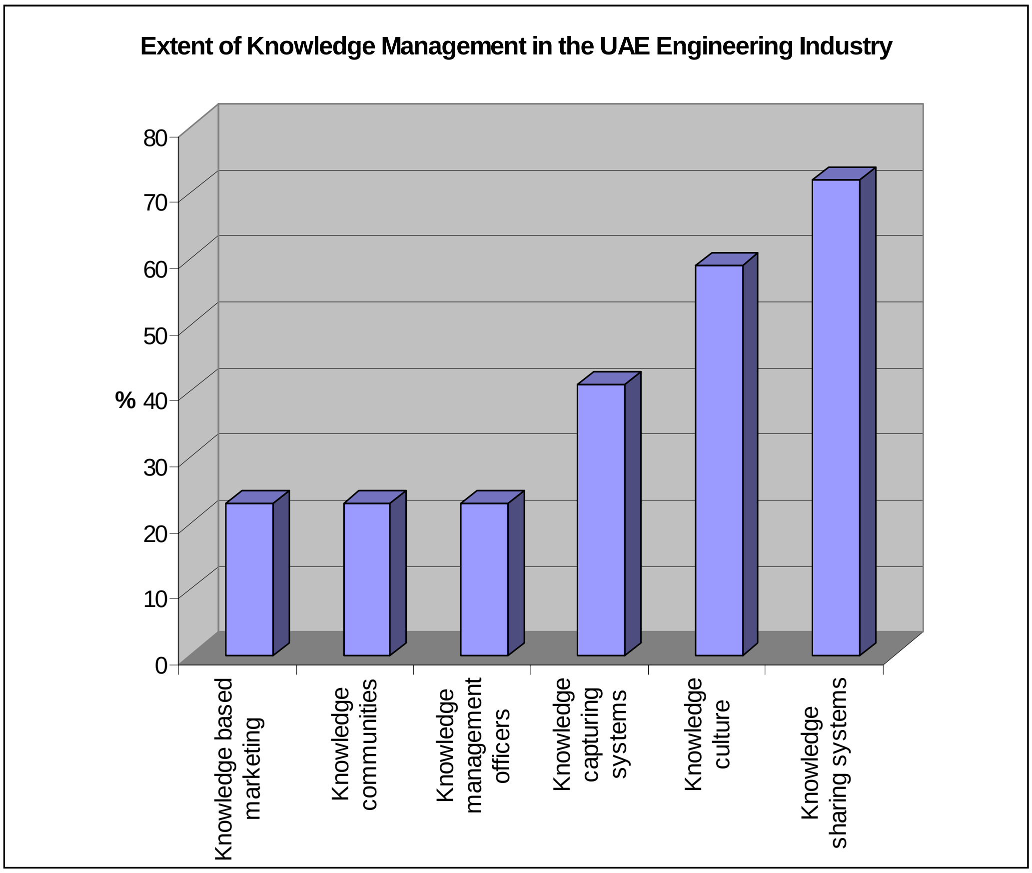

Figure 2: Extent of Knowledge Management Practiced in the UAE Engineering Industry

they do is of no use, for without customers, there is no business. They must capture knowledge and use that to become better equipped to bring out innovative and creative products and services that are needed by their customers. Every organization should have a good Knowledge Management System, similar to that described by the author (in the introduction) to capture marketing knowledge and to use that knowledge wisely.

Biotechnology industry results

The results from the interviews demonstrated the conceptualization of the flow of data, information, knowledge and products/services in the biotechnology industry and were identified as shown in figure 3. A summary of the range of new products and services being marketed to meet the biotechnology industry needs are shown below:

- Computerized drug design and innovative drugs;
- Large computer storage systems; software and hardware packages; operating systems; and database management systems;
- Microarray slides, radio-immunoassay kits, and research tools;
- Tools for analysis of genetic sequence data, text mining and natural language tools;
- Bioinformatics and other training courses;
- Organic chemistry products, mass spectrometry, chromatography;
- Cell culture;
- Statistical tools and algorithms.

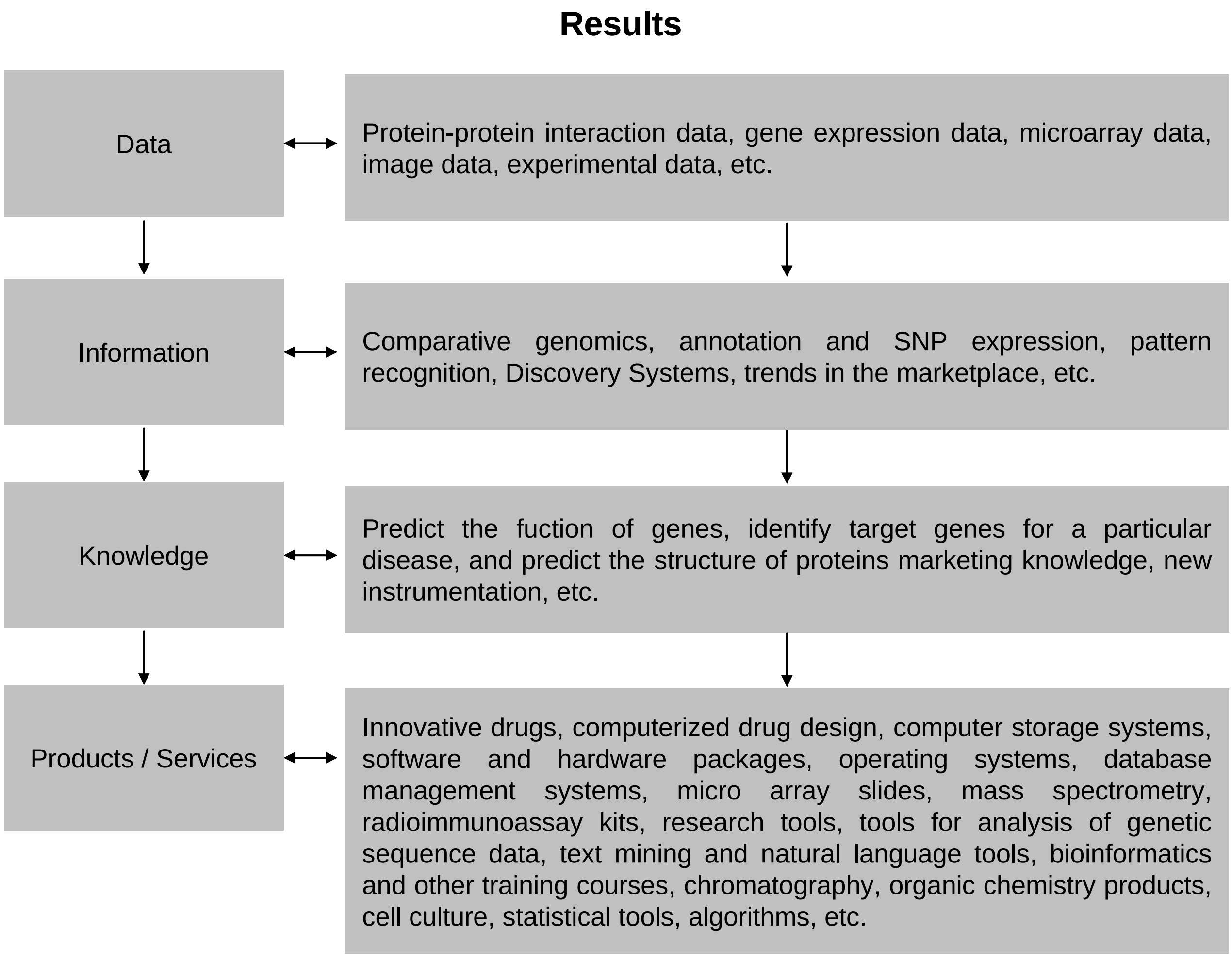

Figure 3: The flow of data, information, knowledge, and products/services

Discussion

Engineering industry

Despite the small sample size, the insights gained from surveying the engineering industry in the UAE is very valuable. The findings show that the engineering industry is implementing the various components of knowledge management to varying degrees. For example, they share knowledge and attempt to implement a knowledge culture. However, most engineering organizations do not have a knowledge Champion (Knowledge Management Officer) nor do they practice knowledge-based marketing. They have not formed knowledge communities. More importantly the various knowledge components are not integrated or coordinated. Knowledge management must be incorporated in all the sub units or functional departments – not an easy task due to interdepartmental conflict – of the organization in to an integrated whole, thereby promoting congruence where the effectiveness of the 'whole' is greater than the effectiveness of the 'disparate' functional units.

Biotechnology industry

In the biotechnology industry, several new products and services were marketed. The industry is also able to clearly differentiate between data, information, and knowledge. With the new knowledge gained (such as a target gene for a specific disease), the industry is able to come up with innovative new products and services.

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Practitioner's Section

Engineering an Instrument to Evaluate Safety Critical Manning Arrangements in Chemical Industrial Areas

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Abstract: Due to the higher workload it produces, reducing the size of operational teams in the chemical process industry can have a negative effect on the ability to control abnormal situations, fatigue, etc. A lack of qualified operational personnel in unusual conditions and the resulting lack of process control can trigger a series of internal or external accidents, eventually leading to a major accident. This paper suggests a practical method to evaluate the safety critical staffing levels required to meet performance specifications for safety critical activities. For single plants as well as for clusters of chemical plants, the method also enables consultants and inspectors to consequently apply principles to assess those manning levels representing the last but one line of defense in the prevention of major accidents.

Introduction

The organizational structure, responsibilities, practices and procedures which comprise a chemical prevention policy are all fixed in the so-called Safety Management System (SMS). One of the key points of such a SMS concerns organization and personnel issues. Guidelines give recommendations to streamline personnel tasks and responsibilities as well as recommendations to establish organizational procedures (such as education and training programmes) with respect to safety.

To date, there have been no directives on safety critical staffing levels. Neither has a best practice been established for the required quantity and/or quality of plant employees needed to monitor certain safety critical tasks which prevent a Loss of Containment (LOC). However, sufficient capable personnel on the job are needed to guarantee safety critical activities to be performed safely. Since there is a large diversity of safety cultures within the chemical process industry, the means of dealing with the Safety Critical Staffing Level issue is highly dependent on individual companies. To the best of the authors' knowledge, a harmonized guideline document for evaluating personnel occupancy in chemical installations does not exist. Nevertheless, evaluating the quality and quantity of operating team staffing levels is a topic of increasing interest to both the Government and industrial area safety management. At present, the matter is subject to discussion and debate among companies as well as between the industry and the authorities. A reason for the growing concern is illustrated in Figure 1.

The index figures make it easy to compare the evolution of productivity and employment over time. Figure 1 illustrates that the Production Index, i.e. a business cycle indicator expressing the volume of output and business activity of the industry, increased by 15 index points over a period of eight years. At the same time, the Employment Index measuring the changes in employment at regular intervals decreased by 9 index points between 1996 and 2004. The steep rise in productivity, combined with the gradual decrease in employment in the chemical industry, could increase the likelihood of having to resort to the last but one line of defense to prevent a LOC, should insufficient staff be allocated to perform safety critical activities. An immediate result would be the increased probability of an accident entailing damage. Making the choice of the required safety critical manning levels in a chemical industrial area more transparent could prove to be a new challenge to safety and risk management. Of course, living with risks remains essentially a management question [2].

To enhance safety by optimizing staffing arrangements within the chemical industry, a safety critical staffing evaluation methodology is needed to offer practical and usable results to inspectors and to plant and cluster management.

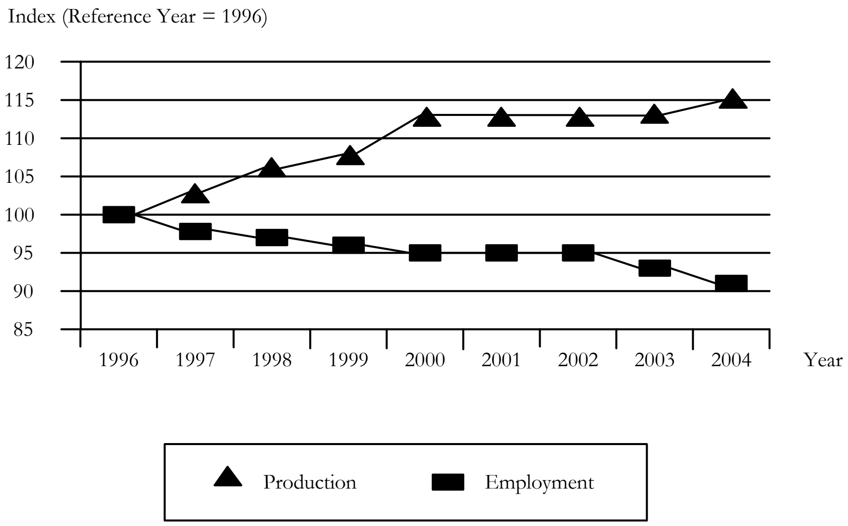

Figure 1: Production index and Employment index in the European chemical Industry (1996 - 2004), Source: based on figures available at [1]

Research objectives

This paper aims at providing support to the chemical industry by objectively evaluating the completeness, the soundness and the quality of safety critical production manning levels with a view to tackling abnormal safety critical circumstances. A real-life example would be the 4-day siege in November 2003 during which the management of a Belgian paint factory were held hostage by unsatisfied employees [3]. Other circumstances (the list is non-exhaustive) which satisfy the term "abnormal" and in which the size of operational teams can be necessarily restricted, are for example a strike (e.g. internal: the next team will not go to work and prevents access to production level, making a shift team change impossible; external: a truck drivers' strike), serious terrorist threat (e.g. hindering or preventing access to an industrial area), a major accident in the neighbourhood of a production installation or at an installation of an adjacent company, a general power supply failure, etc.

Safety managers need guidance on the various requirements for safety critical manning arrangements. A user-friendly document could offer an indication about the issues that have to be improved in terms of staffing levels by suggesting a variety of recommendations depending on the particular problem identified, e.g. improving the safety critical documentation, improving the alarm-management, enhancing communication between different control rooms, increasing the number of manning levels, etc.

Approach

The literature on the subject of staffing levels is limited, indicating that little research has been done in this area. Even in renowned reference works, e.g. "Loss Prevention in the Process Industries" [4], methods, studies, or accident reports investigating the relationship between incidents and staffing levels are not discussed.

The HSE document by Brabazon and Conlin [5] is the most important work on the topic, offering a method for assessing the manning levels in the control room (CR) of one or several chemical installations. The extensive instrument has two parts: a "physical assessment" and a "ladder assessment". The first type uses assessment trees to scan the CR manning levels with respect to six fundamental principles. Organizational factors such as training and development are evaluated with the help of ladder assessments. Using the document, bottle-necks in CR personnel arrangements can be pro-actively detected and handled. Unfortunately, this rather complicated instrument fails to evaluate field operators and its results are not specifically targeted at assessing the staffing levels in safety critical circumstances. Therefore, the document does not meet the final objectives of this examination, i.e., a user-friendly ad-hoc review of all manning levels (including CR operators and field operators) of a cluster/plant to prepare for specific abnormal situations.

Since there is diversity in chemical plant safety cultures, every company has built up its own method to satisfy its specific needs regarding safety and employment. Therefore, it is not likely to use a harmonized instrument with merely quantitative information to compare safety employment structures of different companies. A qualitative procedure [6] allows for the fact that two completely different methods used for addressing a specific manning level problem can be equivalent in their effectiveness.

Empirical results

The study thus far identified theoretical methods to assess staffing arrangements. However, these documents are based on ideas and abstract principles rather than on practical aspects or case studies. In order, therefore, to become acquainted with common practices in the industry as regards manning levels, safety engineers and production managers at 2 multinational chemical companies as well as 2 consultants specialized in determining staffing levels were interviewed. Current practices concerning staffing levels and safety activities were mapped.

Safety activities

The activities designed to ensure safe operations at chemical installations can be divided in terms of the different situations in which they must be executed. A distinction is made between "Standard Safety Activities", "Safety Critical Activities" and "Emergency Activities".

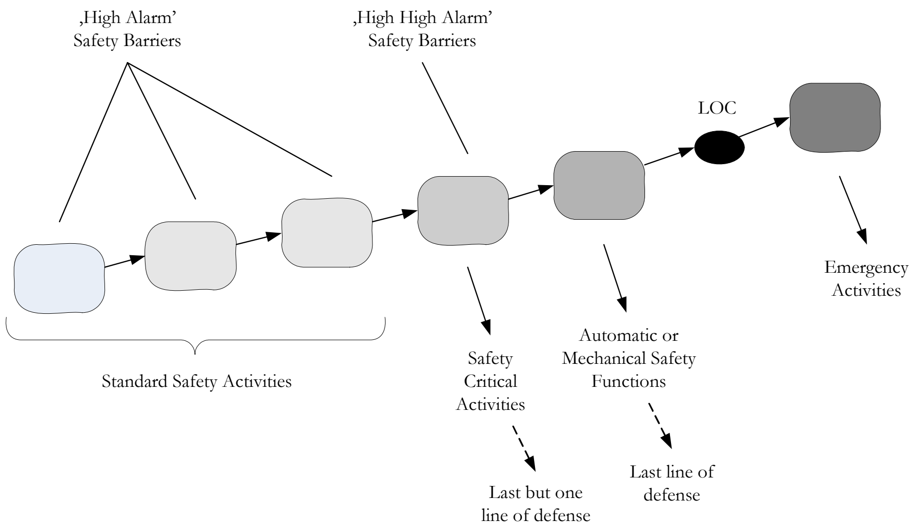

Figure 2: Types of Safety Activities

Standard Safety Activities are activated in the case of so-called "High Alarms". If these interventions are not performed, an unsafe/dangerous situation can occur, possibly leading to the disturbance of process safety, but not yet leading to an accident. The second type of activities, i.e. Safety Critical Activities, is activated in situations characterized in the industry as being "High High Alarms". If the necessary interventions do not take place in such circumstances, this might lead either to an activation of the final line of defense, i.e. an automatic or a mechanical safety function, or directly to a Loss of Containment (LOC). Whatever the case, the probability of a resultant accident with damage substantially increases if no Safety Critical Activities can be supported by the available staff. The final type of activities becomes activated in emergency situations resulting from a LOC. This type is called Emergency Activities and consists of mitigation measures to control the damage. Figure 2 depicts the different types of safety activities. Figure 3 illustrates the different lines of defense in controlling a chemical process.

The last line of defense makes use of Automatic or Mechanical Safety Functions. Automatic Safety Functions act in three stages: first they measure critical chemical process

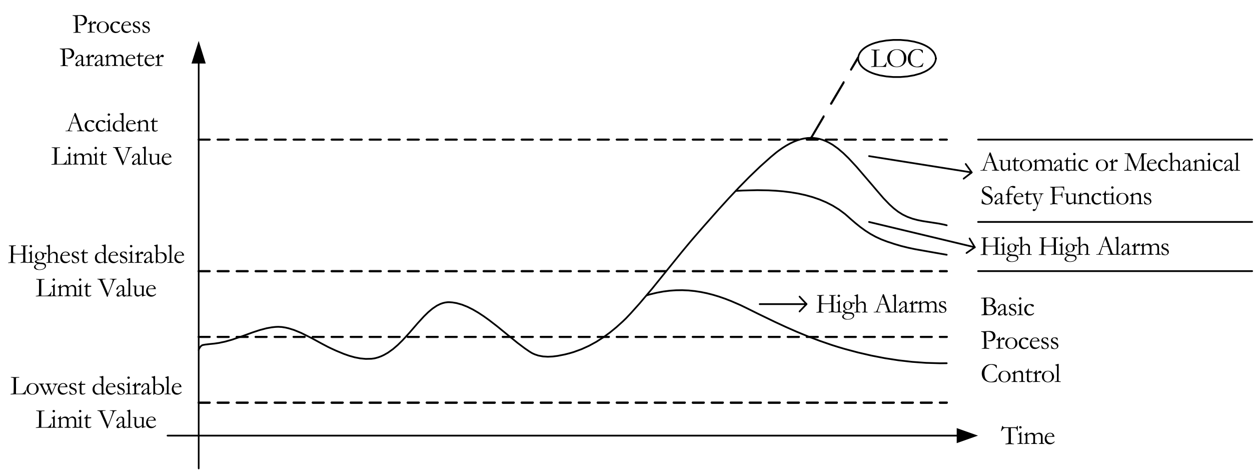

Figure 3: Control and safety of the chemical process, Source: based on [7]

Full Staffing Levels (highest manning)	The number of personnel required (taking task rotation into consideration) in a production team (a production team is composed of field operators, control room operators and all personnel required in the production process of a chemical installation.), accounting for illness, holidays, etc. to guarantee production (safety is guaranteed as well).
Standard Safety Staffing Levels	The minimum number of personnel required in a production team to fulfil all necessary activities (safety critical tasks and standard tasks – *not* emergency tasks). Determined from the productivity viewpoint, i.e. production is guaranteed (safety is guaranteed as well).
Safety Critical Staffing Levels	The minimum number of personnel required in a production team to fulfil all safety critical tasks. If the quality or quantity of personnel falls below this level, personnel substitution must be arranged to prevent having to use the last line of defense or to prevent a LOC.
Minimum Staffing Levels	The minimum number of personnel required in a production team determined from the safety viewpoint, i.e. safety is guaranteed (the last line of defense may be used; production does not need to be guaranteed).
Emergency Staffing Levels (lowest manning)	The minimum number of personnel required in a production team to take care of all emergency tasks.

Table 1: Definitions of staffing levels in decreasing order of manning

parameters, second they decide upon the need for action and finally they work automatically if required. These functions require electricity to be activated. Mechanical Safety Functions (e.g. a safety valve) are self-sustainable and do not require electricity for their performance. An extreme deviating process condi-tion suffices to activate these functions.

To minimize the probability of having to use the last line of defense when handling chemical installations is essential for obtaining sustainable safety. The safety dependency on the last line of defense goes hand in hand with the following drawbacks. On the one hand, Automatic Safety Functions require electricity for solid and reliable functioning and thus installation safety depends on electricity availability. On the other hand, mechanical safety functions can in fact be seen as controllers of small Loss Of Containments preventing a large LOC.

Staffing levels

Table 1 offers an overview of definitions of the different possible types of manning levels in the industry, ranking them in decreasing order. An attempt is made to position the Safety Critical Staffing Levels on this scale.

To determine minimum staffing arrangements for process operations, two main types of methods are used in the industry. One option is to determine staffing levels aimed at guaranteeing production at all times. This leads to the implementation of Standard Safety Staffing Levels. Another option is to establish staffing levels in accordance with safety considerations, resulting in Minimum Staffing Levels. The latter choice obviously requires less manning than the first option.

Methods used by consultants to minimize staffing levels in the CPI emanate from considering worst-case scenarios, e.g. the shutdown of chemical installations as a result of an electrical power supply failure. In case tasks which have to be fulfilled are listed, providing insights into the need of all sorts of functions and their numbers under these abnormal conditions in order to guar-antee the performance of Safety Critical Activities. To further optimize staffing levels, the sequence of activities can be examined to evaluate the necessity of parallel execution. If activities can be performed in a serial manner, manning can be reduced even further. Although at first sight appealing, this approach has some disadvantages. Under abnormal circumstances, operators are already under a great deal of pressure increasing even more the likelihood of them committing errors. Furthermore, cutting the manning levels leads to a lack of back-up operators, which can be of crucial importance should there be a situation in which abnormal circumstances combine (e.g. when a domino accident occurs).

To determine Safety Critical Staffing Levels and thus optimize the last but one line of defense to prevent major accidents at a chemical installation, a trade-off between the activities ensured by Minimum Staffing Levels and those ensured by Standard Safety Staffing Levels should be made by industrial area management. On the one hand, production does not have to be guaranteed under every circumstance if activities ensuring the prevention of major accidents are not affected, which implies that Standard Safety Staffing Levels can be regarded as the maximum of the "safety critical manning". On the other hand, safety has to be guaranteed under every circumstance with a certain degree of back-up, suggesting that Minimum Staffing Levels should be taken as a minimum for "safety critical staffing". Therefore, the optimal Safety Critical Staffing Levels are situated in between the two types of staffing levels currently used in industrial practice.

Methodology

The principles

Reniers et al. [8] point out that the use of checklist analysis is very widespread and well-known in the chemical process industry. Moreover, checklist reviews are very user-friendly and can be applied to diverse subjects [9, 10]. Therefore, an evaluation instrument is elaborated in the form of a checklist to consider safety critical tasks in the control room as well as in the field. Each company has its own trade-offs between the number of personnel and the technology present, automatisation, communication structures, team structure, etc. Given that there is thus no generally accepted definition of a "best safety manning level" regarded as valid for all industrial areas, technological, human and organizational factors have to be kept in mind while making a staffing level assessment. Therefore, the method is developed to cope with different possible physical configurations within the staffing level arrangements in an industrial area. The possible configurations are:

- One or more operators with all-round competence are responsible for the activities in the control room and in the field;
- One or more CR operators who permanently staff the control room and one or more field operators working only in the field. Eventually, within both groups, competences can be arranged in such a way that operators are interchangeable;
- Field operators who are not permanently present, but who may be summoned from elsewhere within the plant/cluster to assist one or more permanent CR operators under safety critical situations;
- Control room operators and field operators not constantly present, but who may be summoned from elsewhere within the plant/cluster to ensure a safe situation under safety critical circumstances.

Safety Problem Parameter	Principle	Interpretation
Safety Problem Detection	**1. Supervision/ intervention possibility**	There should be continuous supervision of the process by skilled field- and CR operators and the possibility to intervene whenever needed.
	2. Distractions	Distractions such as answering the phone, talking to people, performing administrative tasks and acting upon nuisance alarms should be minimized to reduce the possibility of missing/overseeing/responding too late to alarms.
Safety Problem Diagnosis	**3. Information**	Sufficient information required for diagnosis and recovery should be easily accessible, correct and intelligible.
	4. Communication links	Communication links at single plant level as well as at cluster level between the control room and the field as well as between different control rooms should be reliable.
Safety Problem Recovery	**5. Assisting personnel**	Staff required for assisting in diagnosis and recovery should be available in time and with sufficient time to attend when required.
	6. Recovery operations	Operating staff should be allowed to concentrate on recovering the plant to a safe state. Necessary but time-consuming activities should therefore be allocated to others, e.g. summoning emergency services or communicating with adjacent plant safety management. Moreover, all recovery operations should be executed in time.

Table 2: Parameters and principles to deal with occurring problems, Source: based on [5]

During the staffing level arrangement assessment, the safety and the lay-out of the industrial area is subject to evaluation. The lay-out of the company/cluster and of the control room is investigated in terms of whether operators are able to move from one point to another within certain time limits, the consequences resulting when operators are not able to be in a particular place within a given time are identified and the reliability of the supporting equipment and the supporting documentation is questioned.

In summary, the evaluation verifies whether Safety Critical Staffing Levels in an industrial area affect the reliability and timeliness of detecting safety critical problems, diagnosing them, and lifting recovery to a safe state. Therefore, conditions such as the number of people required, the means necessary and the competences needed to be able to guarantee safety in the case of calamity is checked against six principles (see Table 2).

The instrument is conceived to identify the possible bottle-necks of personnel organization and to find a solution for a problem under abnormal circumstances. To do this, four questions for every principle are addressed:

- Can the principle be violated?
- In what way has the principle been/could the principle be violated?
- What are the measures to counter the violation?
- Are these measures reliable and effective?

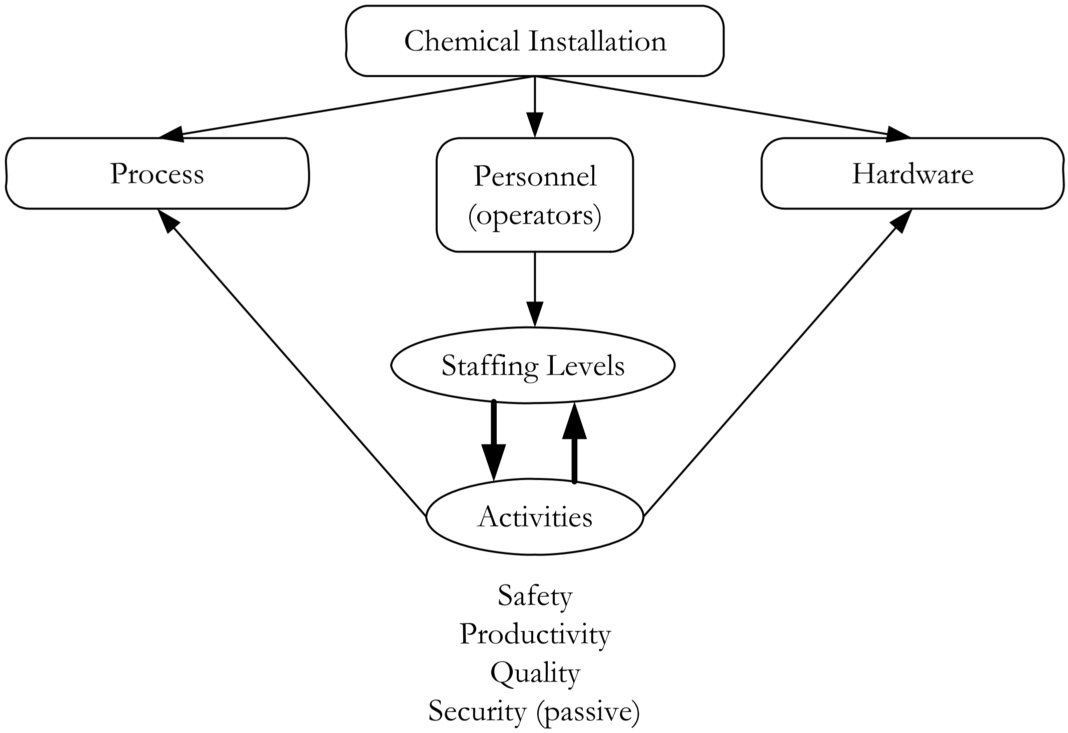

Figure 4: A chemical installation and its operational requirements

Failing on one of the above questions indicates a gap in the industrial area's personnel organization and implies that actions are required to deal with this failure. Because each "failure" is different a gradation is added to the different assessments, e.g. A is considered "best practice", D "worst practice". If an industrial area fails to be situated in the A or B category, the staffing level safety in the area is insufficient and some measures are needed. Directives for such measures are given in the evaluation instrument itself. For example, to be able to improve from category C to category B, a back-up alarm warning system might be installed.

It is also important first of all to check whether operators have the knowledge and the skills to perform their tasks as required and secondly to check whether the safety policy within the company/cluster meets all the requirements.

Personnel to be interviewed

Generally speaking, it is not possible to interview every person who might be involved in a possible sudden abnormal situation concerning safety staffing levels. Nevertheless, it is important to interview as many different people as possible concerned in practice with the problem(s) at hand. Whatever the circumstances, safety management, production management and supervisors are interviewed. If possible, other stakeholders to be interviewed include:

- CR operators and field operators. The recommendation is to interview experienced and inexperienced operators as well as operators belonging to different shift teams;
- Assisting personnel offering support during safety critical circumstances, e.g. by giving technical advice or answering telephones;
- Management and administrative personnel with knowledge of operational procedures and reliability of materials and systems.

To enhance the objectivity of staffing level evaluation, certain documents are required to verify the answers when filling in the checklist. When evaluating an answer from the questionnaire, the final judgement depends on the evidence given by the people answering the checklist. If the answers accompanied by the necessary documents are con-

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sidered insufficient to underwrite staffing level safety on a specific topic, the area fails for this topic. Extra documents which might be needed include estimation calculations or experiments (simulations) regarding the amount of time needed to react to incidents, data of previous accidents and/or observations of exercises, reliability studies of critical equipment, etc.

Safety critical activities

To determine Safety Critical Staffing Levels, the relationship needs to be identified between the activities to be executed in abnormal circumstances and the corresponding staffing levels. Figure 4 presents an overview of operating a chemical installation.

The reciprocal relationship between activities performed on an installation and the different possible staffing levels of the same installation needs to be investigated to guarantee that Safety Critical Activities can be performed in unusual circumstances. Figure 5 illustrates the different paths leading to an accident if the last but one line of defense fails and offers suggestions to determine the activities that have to be taken into account in the checklist.

In Figure 6, a decision chart is given to distinguish between activities which select the activities to be catalogued as "Safety Critical Activities" in the evaluation.

The tasks emerging from Figure 6 are those which define the Safety Critical Staffing Levels in this research. Once the Safety Critical Activities are identified, the evaluation document as developed in the next section can be used.

The safety critical staffing evaluation instrument

The instrument, which amounts to a checklist, puts forward a number of binary (yes/no) questions related to the six principles of Table 2. All questions lead to an indirect evaluation of the possibility of performing the Safety Critical Activities (listed as a result of executing the Figure 6 decision chart) in an industrial area. The checklist answers should provide a clear insight into the ability of an industrial area to handle safety critical problems in the field and in the control room(s). To verify whether the interviewees interpret the questions in the right

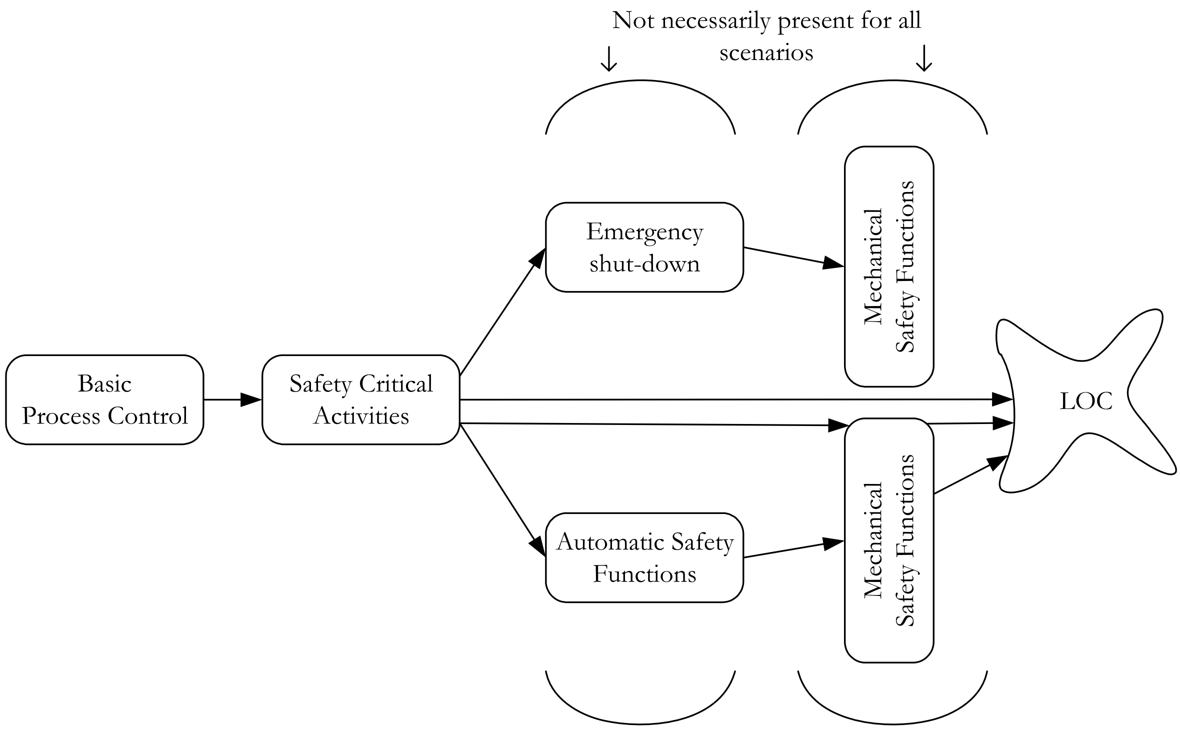

Figure 5: From Basic Process Control to Loss of Containment

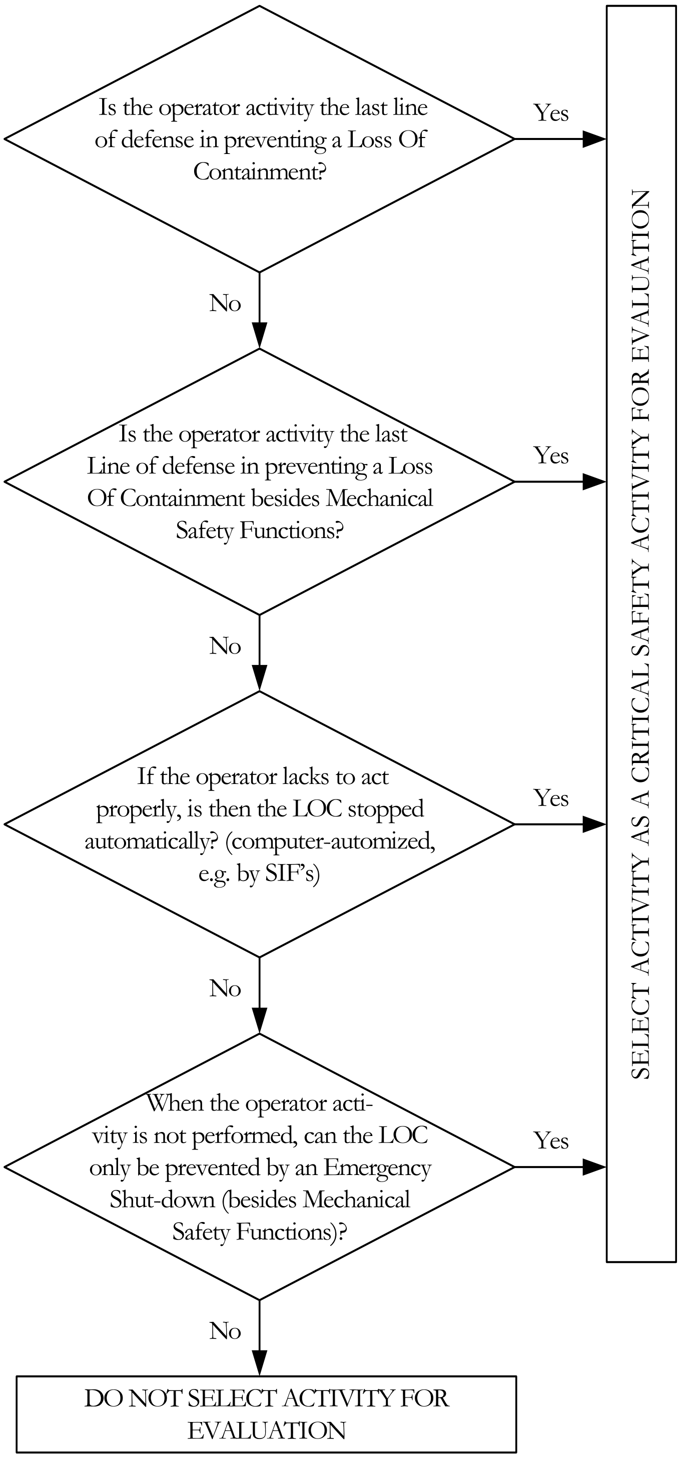

Figure 6: Decision chart to select safety critical activities

way, a control question (indicated "C.Q.") is inserted for each yes/no question. This C.Q. is an open question asking for evidence, information and documentation to support the "yes" or "no" rating on the binary question. The complete instrument is shown in the appendix.

Evaluating the checklist results

As indicated before, three parameters are important for monitoring process installation safety, i.e. detection, diagnosis and recovery of problems.

Problem Parameter	Ranking	A	B	C	D	Total Ranking
Detection	**Principle 1**	1A	1B	1C	1D	
	Principle 2	2A	2B	2C	2D	
Diagnosis	**Principle 3**	3A	3B	3C	3D	
	Principle 4	4A	4B	4C	4D	
Recovery	**Principle 5**	5A	5B	5C	5D	
	Principle 6	6A	6B	6C	6D	

Table 3: Safety critical staffing evaluation tabulation to be filled in

Degree	Description
A	The parameter of the safety critical problems is **guaranteed** by the **inherent** presence of a sufficient quality and quantity of **staffing level.** The organization of the industrial area personnel guarantees safety in safety critical circumstances.
B	The parameter of the problem is **guaranteed**. There is no need for any kind of back-up system to solve the safety critical problem. However, there is one disadvantage: the quality and/or the quantity of the staffing level is not sufficient to guarantee the inherent presence of competent personnel, information and/or communication in the case of safety critical circumstances. The **problem can be tackled promptly addressing the qualitative and/or quantitative staffing level required**.
C	The quality and/or the quantity of the staffing level **suffice** to solve safety critical situations thanks to the presence of **back-up systems**. To be able to cover highly unlikely circumstances, actions should be taken. **Measures are needed** to ameliorate the response rate with which the staffing level is recovered and/or to ameliorate the quality and/or the quantity of the staffing level.
D	The **organisation of personnel fails.** For this problem parameter, the staffing level should ameliorate in a qualitative and/or quantitative manner. The industrial area is not capable of guaranteeing safety and preventing incidents in the case of abnormal circumstances.

Table 4: Description of the different gradings for the safety critical staffing evaluation instrument

For each of these three issues, two principles are checked. The evaluation of every principle, and hence every question, leads to a safety critical staffing ranking ranging from "A" to "D". Table 3 offers an easy-to-use ranking tabulation, indicating the company Safety Critical Staffing Levels' failures.

In the "Total Ranking" boxes, the worst of the combined ranking outcomes is always assigned for each problem parameter. For example, if ranking principle 1 = 1A, and ranking principle 2 = 2C, then the total ranking for detection of problems would be "C". The implications of the ranking degrees A, B, C or D in terms of the final decision are given in Table 4.

Conclusions

An effective industrial area Safety Management System is characterized by the solid evaluation of its constituents. A very important topic for managing safety in process installations is the quality and the quantity of staffing levels required to perform safety critical activities. These activities represent the last but one line of defense for preventing accidents. This paper provides a user-friendly checklist for evaluating the manning levels in an industrial area to meet the needs of plant or cluster safety management as well as of government safety inspectors. The information required for using the checklist can vary considerably from cluster to cluster and facility to facility. Therefore, the checklist provides guidelines for collecting the right information to support the evaluation of the current staffing levels.

Acknowledgements

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Appendix

1. Supervision / Intervention possibility (Detection)	**Yes**	**No**
1.1. Is continuous supervision possible (24/7) A. in the Field (manual interventions)?	□	□
B. in the Control Room (computer operated interventions)?	□	□
C.Q.: In which way can this be guaranteed (qualitatively as well as quantitatively)? e.g. - one all-round competent operator is assigned to the Control Room and to every part of the process installation; - one operator assigned to the Control Room supported by several Field operators are responsible for certain parts of the process installation; - several operators are responsible for the Control Room and for some parts of the process installation (having an all-round competence). ***If both answers are rated "yes", ranking 1. =1A, go to 2.1; otherwise go to 1.2.***		
1.2. Does a discernable and audible alarm exist which is sent to a location (e.g. central CR of plant/cluster) where personnel is permanently (24/7) located should a safety critical problem arise? A. in the Field (manual interventions)?	□	□
B. in the Control Room (computer operated interventions)?	□	□
C.Q.: Does the possibility exist the alarm might fail? ***If both answers are rated "yes", ranking 1. =1B, go to 2.1; otherwise go to 1.3.***		
1.3. Does a back-up system exist to report a safety critical problem A. in the Field (manual interventions)?	□	□
B. in the Control Room (computer operated interventions)?	□	□
C.Q.: Does the possibility exist the system might fail? ***If both answers are rated "yes": ranking 1. =1C; otherwise ranking 1. =1D; go to 2.1.***		
Extra documents to consult in order to evaluate principle 1: shift team system, operator competence schemes, workschemes, technical information concerning the alarm, technical information concerning the back-up system, etc.		

2. Distractions (Detection)	**Yes**	**No**
2.1. Do the operators have to perform/attend to other specific tasks (e.g. answering phones, administration, production tasks, etc.) in addition to Safety Critical Activities A. in the Field (manual interventions)?	□	□
B. in the Control Room (computer related interventions)?	□	□
C.Q.: If the answer is 'no', how can this be guaranteed? ***If both answers are rated "no", ranking 2. =2A, go to 3.1; otherwise go to 2.2.***		
2.2. Does an alternative exist in case the operators miss an alarm due to other tasks A. in the Field (manual interventions)?	□	□
B. in the Control Room (computer related interventions)?	□	□
C.Q.: What is the alternative? (e.g. the alarm is sent to a third party, there is a continuous alarm on the same level, there is a new alarm at the next warning level, etc.) ***If both answers are rated "yes", go to 2.3; otherwise ranking 2. =2D, go to 3.1.***		
2.3. Is the time left sufficient to respond to the alarm? A. in the Field (manual interventions)?	□	□
B. in the Control Room (computer related interventions)?	□	□
C.Q.: On which basis is the time margin defined in the industrial area? ***If both answers are rated "yes": ranking 2. =2B if time margin exceeds 5min.; ranking 2. =2C if time margin < 5min.; otherwise ranking 2. =2D; go to 3.1.***		
Extra documents to consult in order to evaluate principle 2: listing of (other) operator tasks, technical information concerning the alternative alarm, technical information concerning the time definitions within the company, etc.		

3. Information (Diagnosis)	Yes	No
3.1. Is it necessary to consult extra information in order to diagnose and solve a possible safety critical problem		
A. in the Field (manual interventions)?	☐	☐
B. in the Control Room (computer related interventions)?	☐	☐
C.Q.: If the answer is 'no', how will the problem be diagnosed and solved? ***If both answers are rated "no", ranking 3. =3A, go to 4.1; otherwise go to 3.2.***		
3.2. Is it possible to attain this information 24/7		
A. in the Field (manual interventions)?	☐	☐
B. in the Control Room (computer related interventions)?	☐	☐
C.Q.: How can the attainability of the information be guaranteed? ***Go to 3.3.***		
3.3. Is this information (concerning every topic) always correct and intelligible?		
A. in the Field (manual interventions)?	☐	☐
B. in the Control Room (computer related interventions)?	☐	☐
C.Q.: How can this be guaranteed? ***If both questions 3.2 and 3.3 are rated "yes" for all topics, ranking 3. =3B, go to 4.1; otherwise go to 3.4.***		
3.4. Does a back-up system exist to provide information in the industrial area		
A. in the Field (manual interventions)?	☐	☐
B. in the Control Room (computer related interventions)?	☐	☐
C.Q.: Explain the back-up system. ***If both answers are rated "yes", ranking 3. =3C, go to 4.1; otherwise go to 3.5.***		
3.5. Does another possibility exist in which the problem can be diagnosed and solved		
A. in the Field (manual interventions)?	☐	☐
B. in the Control Room (computer related interventions)?	☐	☐
C.Q.: Explain the alternative solution. (e.g. cluster know-how with extra information) ***If both answers are rated "yes", ranking 3. =3C; otherwise ranking 3. =3D, go to 4.1.***		
Extra documents to consult in order to evaluate principle 3: listing of safety critical problems, technique of attainability, technical information about the system which provides back-up information, technical information concerning the alternative solution, etc.		

4. Communication links (Diagnosis)	Yes	No
4.1. To diagnose and to solve certain safety critical problems, is there some kind of communication link required A. between the Field operators?...... B. between the Field operator(s) and the Control Room operator(s)?...... ***C.Q.:*** If the answer is 'no', how can this be guaranteed? ***If both answers are rated "no", ranking 4. =4A, go to 5.1; otherwise go to 4.2.***	☐ ☐	☐ ☐
4.2. Can this communication link be guaranteed 24/7? A. between the Field operators?...... B. between the Field operator(s) and the Control Room operator(s)?...... ***C.Q.:*** How can it be guaranteed? ***If both answers are rated "yes", ranking 4. =4B, go to 5.1; otherwise go to 4.3.***	☐ ☐	☐ ☐
4.3. Does a back-up system exist concerning one or more communication links within the plant/cluster which can be guaranteed 24/7 for usage in abnormal situations (NOT emergency situations!)...... ***C.Q.:*** Explain the back-up system. ***If the answer is rated "yes", ranking 4. =4C, otherwise ranking 4. =4D, go to 5.1.***	☐	☐
Extra documents to consult in order to evaluate principle 4: listing of communication links, technical specifications concerning the communication links and their assurance, technical information concerning the back-up system, etc.		

5. Assisting personnel (Recovery)	Yes	No
5.1. To recover certain safety critical problems, is manning assistance needed A. in the Field (manual interventions)? ...... B. in the Control Room (computer related interventions)? ...... ***C.Q.:*** If the answer is 'no', how can this be guaranteed? ***If both answers are rated "no", ranking 5. =5A, go to 6.1; otherwise go to 5.2.***	☐ ☐	☐ ☐
5.2. Is this manning assistance available 24/7 A. in the Field (manual interventions)? ...... B. in the Control Room (computer related interventions)? ...... ***C.Q.:*** How can this be guaranteed? ***Go to 5.3.***	☐ ☐	☐ ☐
5.3. Can this manning assistance arrive in time A. in the Field (manual interventions)? ...... B. in the Control Room (computer related interventions)? ...... ***C.Q.:*** How is this time margin defined? Explain. ***If both questions 5.2 and 5.3 are rated "yes" for all topics, go to 5.4; otherwise ranking 5. =5D, go to 6.1.***	☐ ☐	☐ ☐
5.4. Does a back-up system exist if the call-up system for summoning the manning assistance fails A. in the Field (manual interventions)? ...... B. in the Control Room (computer related interventions)? ...... ***C.Q.:*** Explain this back-up system. ***If the answers to questions 5.2, 5.3 and 5.4 are all rated "yes": ranking 5. =5B if time in which availability is ensured is less than 5min.; ranking 5. =5C if time in which availability is ensured exceeds 5min.; otherwise ranking 5. =5D; go to 6.1.***	☐ ☐	☐ ☐
Extra documents to consult in order to evaluate principle 5: shift team system, manning assistance system, technical information about attainability of manning assistance, time margin calculations, back-up system information, etc.		

6. Recovery operations (Recovery)	Yes	No
6.1. Can recovery operations be accomplished within the minimum calculated time margin A. in the Field (manual interventions)? .... B. in the Control Room (computer related interventions)? .... ***C.Q.:*** How can this be guaranteed? (e.g. task analyses, desktop exercices, simulations, etc.) ***If both answers are rated "yes", go to 6.2.; otherwise go to 6.5.***	 ☐ ☐	 ☐ ☐
6.2. Is it possible that the operators A. are assigned extra recovery operations (e.g.: back-up activities of other operators within the plant/cluster)? ……………………………………………………………………………..…... B. are assigned extra tasks (e.g.: responsibility for site alarm, emergency phone services, responsibility for non-critical alarms? ………..…………………………………………………….… ***C.Q.:*** If the answer is 'no', how can this be guaranteed? ***If both answers are rated "no", ranking 6. =6A, stop audit; otherwise go to 6.3.***	 ☐ ☐	 ☐ ☐
6.3. Are they timely informed about the extra assignments? .... ***C.Q.:*** How can this be guaranteed? ***If the answer is rated "yes", go to 6.4; otherwise ranking 6. =6D, stop audit.***	☐	☐
6.4. Can all assigned tasks be accomplished (originally assigned recovery operations, extra assigned recovery operations and extra tasks) A. by Field operators?... B. by Control Room operators?.. ***C.Q.:*** How can this be guaranteed? ***If both answers are rated "yes", ranking 6. =6B, stop audit; otherwise go to 6.5.***	 ☐ ☐	 ☐ ☐
6.5. Does a back-up solution (at plant/cluster level) exist should it prove impossible to accomplish the tasks A. for Field operators?... B. for Control Room operators?... ***C.Q.:*** Explain the back-up system. (e.g. extra back-up operator, assistance personnel to handle the administrative tasks and technical support) ***If both answers are rated "yes", ranking 6. =6C; otherwise ranking 6. =6D; stop audit.***	 ☐ ☐	 ☐ ☐
Extra documents to consult in order to evaluate principle 6: recovery time margin calculations/simulations, technical recovery information/data, back-up system data, etc.		

Appendix 1: Instrument for evaluating safety critical staffing levels

Practitioner's Section

Technology to Clean Up Coal for the Post-oil Era

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Abstract: During the transition to the solar age an energy gap will have to be filled. In this context coal may emerge as a source of hope, particularly when oil and later also natural gas have become scarce and thus expensive. The prerequisite, though, is that efforts to engineer coal's transformation into a clean energy source with a neutral impact on the climate are successful. The transition period in which coal is indispensable could be limited, however. But this would require swift progress on renewable energies as well as on hydrogen research. Breakthroughs by backstop technologies such as nuclear fusion need much more time. Until then, coal will be of the essence.

During the transition to the solar age an energy gap will have to be filled

The thirst of populous emerging economies for energy and the industrial countries' sustained need for energy will ensure a further rise in demand. However, it looks as if the supply of oil, and later also natural gas, will not keep pace with this demand. Only by leveraging every possible means will it be possible to compensate the imbalances emerging on the horizon.

Coal offers great potential as a substitute for oil and natural gas in the medium term, but so far its versatility has been underestimated. Going forward, coal could attract more attention in all three major energy sectors – power generation, the heating market and transport – provided that the right technologies delivering higher efficiency and lower environmental burdens take root.

Environmental risks emphasise need for "clean coal"

Global warming is one of the biggest dangers facing human existence on earth, and combatting this danger is therefore one of the greatest challenges. Since coal causes 40% of global CO_2 emissions, only advanced technology can pave the way to a better future. Therefore, a "yes to coal" will always come with strings attached. The required quantum leaps in technology could, however, open the doors to the global mass markets.

Immense global potential for innovative clean coal technologies

With oil currently trading at around USD 54/bbl, coal-to-liquid technology is already an interesting alternative from a purely commercial point of view. Plans are afoot to invest USD 10 trillion in power generation plants worldwide. The need for investment is very high not only in emerging economies like China but also in Europe and particularly in Germany, where the effects of the law to phase out nuclear power will unfold fully in the years ahead. CO_2-free coal-fired power plants could become a milestone on the way to a better energy future in spite of their additional fuel consumption. However, achieving nationwide solutions will require a considerable amount of time and funding.

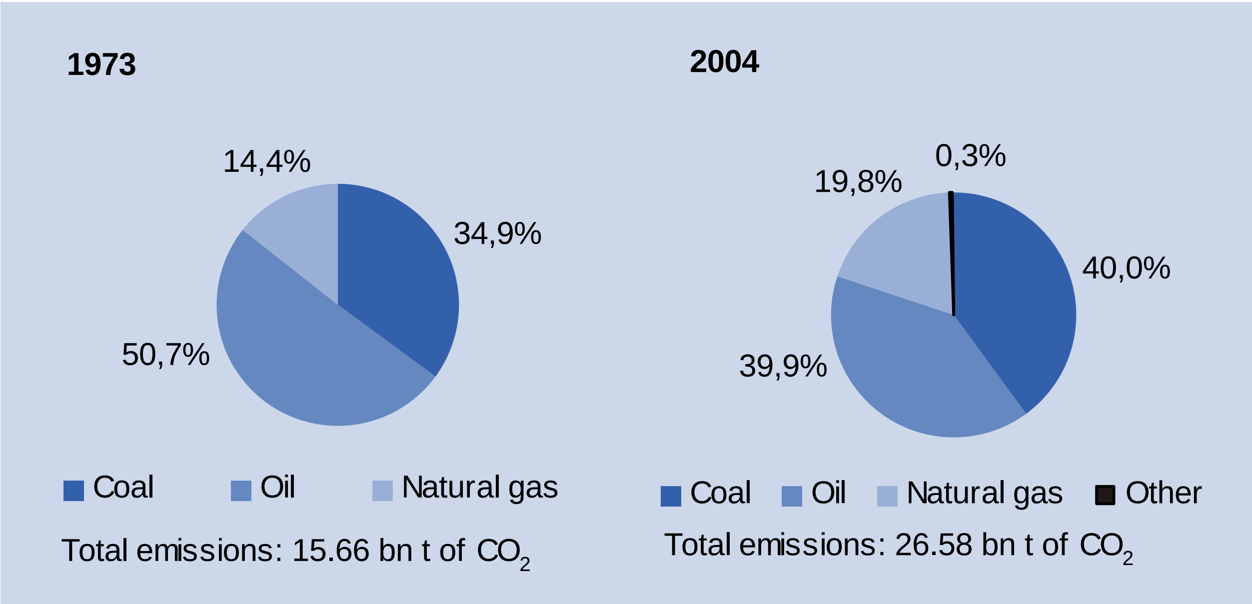

Figure 1: Coal's contribution to global CO_2 emissions has increased – Share or energy source in CO_2 emissions, Source: IEA

Coal will gain significance in the post-oil era

Nothing says that our global energy future has to be dark, depressing and hopeless. Worldwide prospects for energy after the petroleum age are actually quite good, but only if all possible levers are used [1]. These include steps – apart from urgently needed conservation and efficiency-enhancing strategies – to diversify the range of energy carriers with an even greater drive to mobilise renewable energies and to continue developing potential alternative technologies.

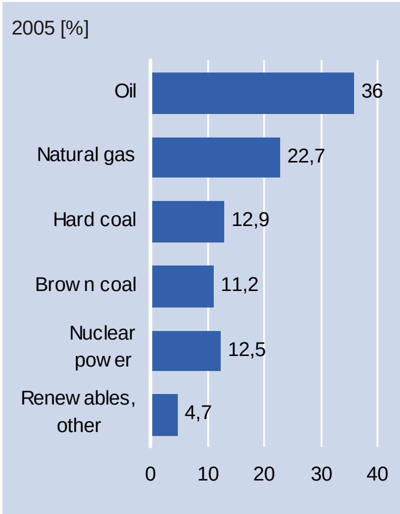

Figure 2: Coal accounts for ¼ of primary energy consumption in Germany, Source: AG-Energiebilanzen

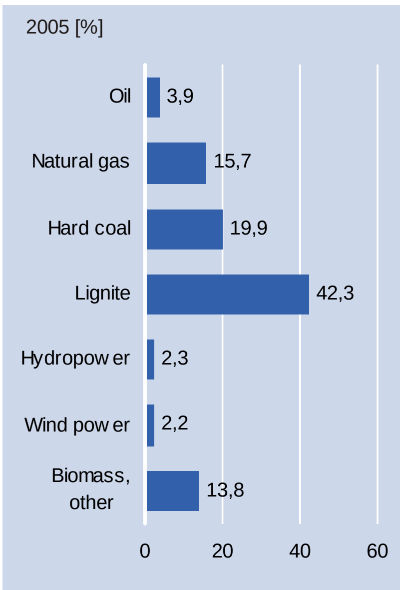

Figure 3: Lignite important for primary energy generation in Germany, Sources: AG-Energiebilanzen; GVSt, Steinkohle Jahresbericht 2006

In public debate about our energy options after the petroleum age virtually no consideration is given to coal or else it gets very bad reviews. In the developed countries, coal is usually considered synonymous with a dangerous climate killer; in the developing countries, for inhuman labour conditions in the mining industry (the talk is of "blood coal"). At best, coal is given credit for its valuable contribution to energy security during the industrialisation era.

From pariah to paragon of virtue

Today, coal is used in the industrial countries above all as a source of fuel for generating electricity, for the heating market and for metal production. In the emerging economies, coal is still used in some places to fire steam engines. Going forward, coal could attract much more attention in all three major energy sectors – power generation, heating and transport – provided that the right technologies with higher efficiency levels and a low environmental impact take root. In this sense, the versatility of coal has been underestimated.

As a substitute for the hydrocarbon fuels oil and natural gas, which will become increasingly scarce in the relatively near future, coal offers considerable potential for improving our energy structures in future – at the national, European and global levels. At heart, the main issue is the transition period during which first oil and later also natural gas will become very scarce and expensive while renewables are not yet able to shoulder the main burden. However, only advanced technologies and innovations will be able to pave the way for coal into a better future. In this respect, the "yes to coal" will always come with strings attached.

Coal is a pillar of the energy mix in Germany

Nearly 83% of Germany's primary energy consumption in 2005 was based on fossil fuels. When the contributions from hard coal and brown coal (lignite) are taken together, their combined

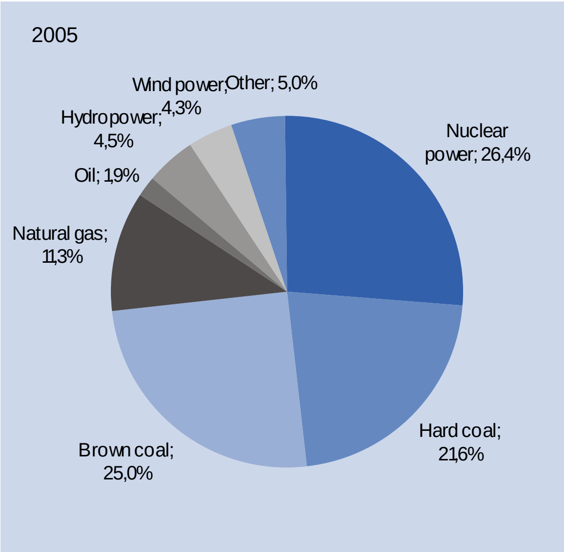

Figure 4: Energy mix for electricity generation in Germany, Sources: Energiemarkt Deutschland, DIW

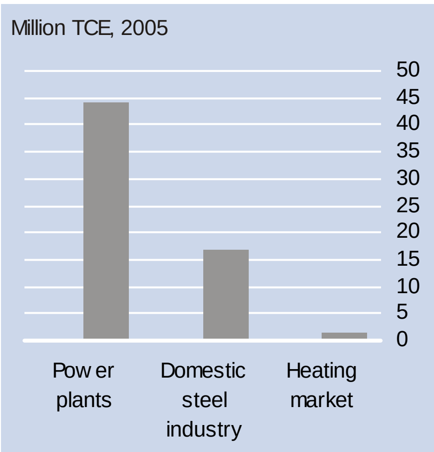

Figure 5: Main users of hard coals in Germany, Sources: Coal industry statistics; Schiffer H.-W. Deutscher Energiemarkt 2005

share (24%) is slightly higher than that of natural gas (23%). In volume terms, only oil (36%) is more significant. For generating secondary energy in the form of electricity, the contributions from hard coal and brown coal (22% and 25%, respectively) are surpassed only by that of nuclear energy (26%). Combined, though, hard coal and brown coal clearly account for the lion's share at nearly half of the total.

In terms of primary energy generation, lignite is the biggest domestic source of energy in Germany. In 2005 lignite delivered 54.8 m tonnes of coal equivalent (TCE), or 42% of the total energy generated in Germany (129.7 m TCE). Next in line were hard coal and natural gas. With lignite output of 178 m t in 2005 Germany is the world's biggest producer, accounting for nearly one-fifth (19%) of global production. The deposits are concentrated in three areas: the Rhineland, Lausitz and other parts of east Germany. Because raw brown coal has a high water content of 55% on average and a relatively low heating value, transporting it over fairly long distances is of no commercial interest. Therefore, 92% of the domestic output is used in nearby plants for generating electrical power or heat for district heating purposes. There is no import dependence for lignite whatsoever.

Unlike the lignite industry, which receives virtually no subsidies, the existence of hard coal mining in Germany has been propped up by government funding for years. Without this protection hard coal would no longer rank second for primary energy generation in Germany. Nevertheless hard coal extraction declined from 149 m t in 1957 (useable output) to 25 m t in 2005, i.e. by 83%.

The much higher energy content of hard coal vis-à-vis brown coal makes the transport of this energy carrier commercially feasible over great distances as well. International trade in hard coal benefits from the fact that this source of energy is available in abundance at relatively low cost worldwide. It is no wonder that the German import ratio has been climbing steadily for years and already reached about 60% in 2005. Hard coal consumption came to about 63 m TCE in Germany in 2005. The main users are power generating stations (70%), the steel industry (27%) and the heating market (3%).

Germany's imports of hard coal harbour no cluster risk since they come from a diverse range of countries. More than 80% of the coal imported in 2005 came from Germany's main suppliers: South Africa (25%), Poland (20%), the CIS (16%), Colombia (12%) and Australia (9%). Another 14% came in roughly equal measures from Canada, the US, China and Norway. While shipments of hard coal from Australia and China need up to three months, deliveries from Poland and Russia can

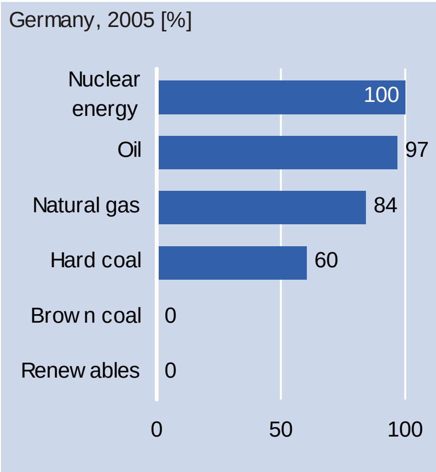

Figure 6: Nearly 2/3 of hard coal is imported (import ratio by source of energy), Source: AG-Energiebilanzen

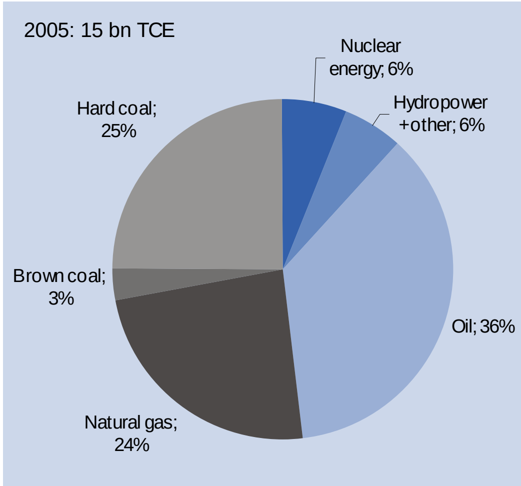

Figure 7: Oil predominant in global primary energy consumption (without biomass), Sources: BP Statistical Review of World Energy, Juni 2006, BGR, DB Research

reach the German market in two months including lead times. All in all, the coal imports are sourced from an adequately diversified variety of regions. Supply disruptions in individual countries could be compensated relatively easily – unlike with natural gas. At last reading the cost of import coal (delivery to German border) was EUR 59.75 per tonne, i.e. far less than German coal (EUR 160).

Hard coal of key importance to global energy supply

In total, coal covers 28% of world demand for energy, which ran to about 15 bn TCE in 2005. Actually, the hard coal and brown coal shares are strongly asymmetrical, as lignite contributes only 3 percentage points. Over seven-tenths of global hard coal output is used to generate electricity, meaning that it covers 35% of world electricity demand, while lignite accounts for only 4%. As with all other sources of energy, production and consumption of coal have been climbing for decades, though significant shifts are to be seen on the user side. The growing demand for iron and steel benefits the coking coal segment. Steam coal is attracting more orders from power stations but losing significance in the heating market.

The globally rising demand for hard coal has boosted growth in international trading. In 2005 around 16% of global hard coal output was marketed outside the country where it was mined. Only 10% is transported by land means, with the other 90% being transported by sea.

Versatile coal: capital intensive and fiercely competitive

Coal figures strongly in substitution competition with practically all other sources of energy. Since considerable time and expense are needed to adapt energy infrastructure, the individual sources of energy do not compete with one another directly. Coal only becomes competitive after its energy has been converted in power generating stations to the secondary energy carriers electricity and heat or in refining facilities

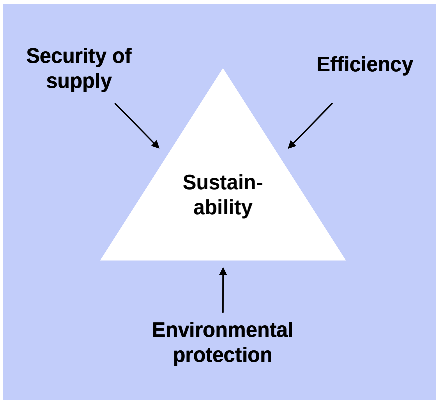

Figure 8: Triangle of objectives in energy policy, Source: DB Research

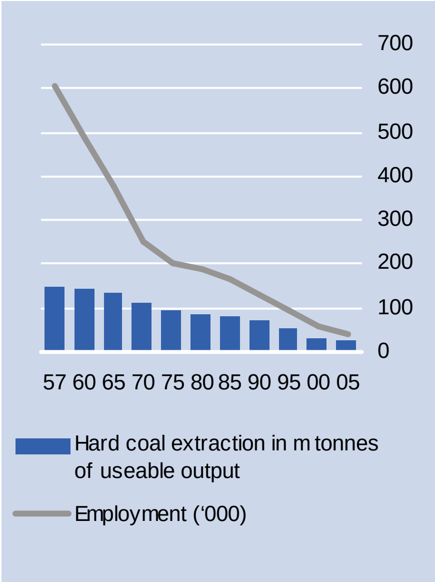

Figure 9: Germany's hard coal industry in decline, Source: GVSt, Steinkohle 2006

Reserves are deposits of raw materials used as energy sources that can be tapped in commercially feasible volumes at current prices and with current technology.

Resources are proven quantities of energy sources that for technical and/or commercial reasons are currently not yet exploitable, as are unproven quantities of energy sources which it may be geologically possible to exploit in future ("yet to find").

Figure 10: Definitions, Source: BGR

to the form of coking coal, briquettes or dust. This competition is ultimately played out at the user level, where energy is required for process heat, air conditioning, lighting, and mechanical purposes such as mobility, production processes and consumer electronics. Ultimately, the end-users of energy are industry, households, government facilities and private transport companies. For them, the initial energy plays more of a subordinate role; what is much more relevant is the price of a specific energy service.

In the medium to longer run, though, the demand for coal is also a function of the capital invested, for capital-intensive investment will determine the technology of energy conversion and thus ultimately also energy demand. For example, modern coal-fired power stations need less energy input to produce electricity than they used to thanks to technological improvements and higher efficiency.

Coal – challenge for German energy policy

Before and after the last world war, coal played an important role in energy policy. The traditional objectives of energy policy have had a varying degree of relevance over time, though.

After the war it was initially an advantage to be able to tap the locally abundant deposits of brown coal and hard coal as a source of energy. There is no denying that domestic coal did much to shore up Germany's energy supply during those first few decades. It provided employment and enabled the development of modern industrial structures to boost Germany as a production location.

The economic efficiency of supplying energy with coal raised more and more questions over the years though and was regularly the subject of bitter political conflicts – especially when it was a matter of continuing or adapting support programmes. This scarcely applies to lignite, for it can be procured in Germany at low cost. By contrast, domestic hard coal has been at the centre of controversy: deposits in geologically unfavourable locations and ever deeper mines have led to very high costs by international standards. Hard coal producers in Germany have simply been unable to match the cheap world market price. Over time, the annual subsidies have gone into the billions, sparking a political rethink. Politicians have now reduced their arguments "only" to whether it is a good idea to maintain a domestic "hard coal base" for critical supply situations or whether it would be more practical to shut down all hard coal operations altogether. The issues – besides regional, labour-market and social considerations – are future financing (federal states and/or federal government) and business strategy (floating Ruhrkohle on the market, for instance).

Environmental objectives are the Achilles' heel

The actual Achilles' heel of using coal is the negative externalities that go with it such as spoiled landscapes and – of far greater significance on a

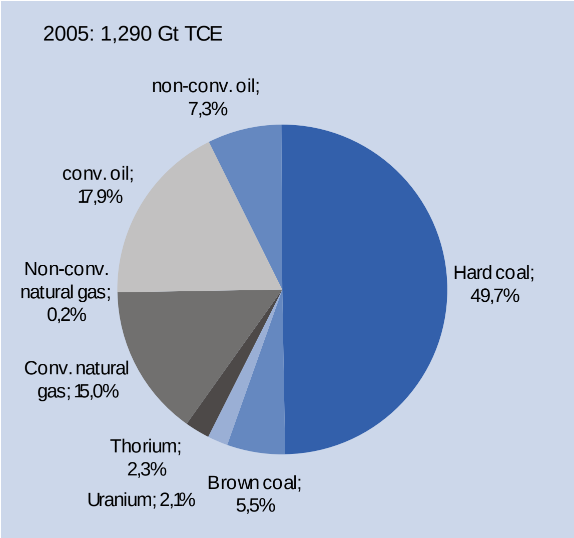

Figure 11: Dominance of coal in global energy reserves (non-renewable sources of energy), Source: BGR

world scale – the gases emitted when both types of coal are burned.

What was regarded just a few decades ago as a doomsday phobia can – in view of countless scientific studies and publications – no longer be dismissed out of hand: there is an unambiguously positive correlation between the consumption of fossil fuels, the emission of greenhouse gases and the warming of the earth's climate. Since the use of coal produces the most greenhouse gases, it receives particularly strong criticism and is opposed most vehemently. From a climate point of view, lignite gets worse marks than hard coal, but hard coal is of much greater relevance for energy supply worldwide.

Fossil fuels, especially those that pose the greatest threat to the earth's climate, will only have a future if they can be reinvented from an ecological standpoint. Coal accounts for 40% of global output of carbon dioxide (CO_2). The "bridge to the future" must therefore lead to "clean coal", which if possible has to be climate neutral and thus acceptable to the public at large. If "King Coal" [2, 3, 4], the mythical figure of the coalmining saga, stops wearing a black robe in future and instead dons an environmentally-friendly white robe, his days will not be numbered and he may go on to prosper the second time round.

Until renewable sources of energy are finally mature and established enough to shoulder the burden of the world energy supply largely on their own, the purified "clean coal" may develop into one of the biggest sources of hope for a more secure energy supply. Notwithstanding, it would help if it were possible to boost the pace at which renewables are being developed.

Large reserves and resources of coal around the globe

According to statistics from Germany's Federal Institute for Geosciences and Natural Resources (BGR), coal accounts for 55% of the global reserves of all non-renewable sources of energy, coming ahead of oil, natural gas and uranium. In terms of volume, hard coal makes up nearly 50% of the reserves, so it is much more important than lignite at 5.5%. The dominance of coal becomes even more apparent when you look at the potential resources, i.e. the volumes that are not yet commercially feasible at present. In this case, the breakdown for coal is 60% of total resources, with hard coal contributing 55% and lignite some 5%. Next in line come natural gas (including non-conventional types), oil and uranium.

One advantage of coal is that it offers the

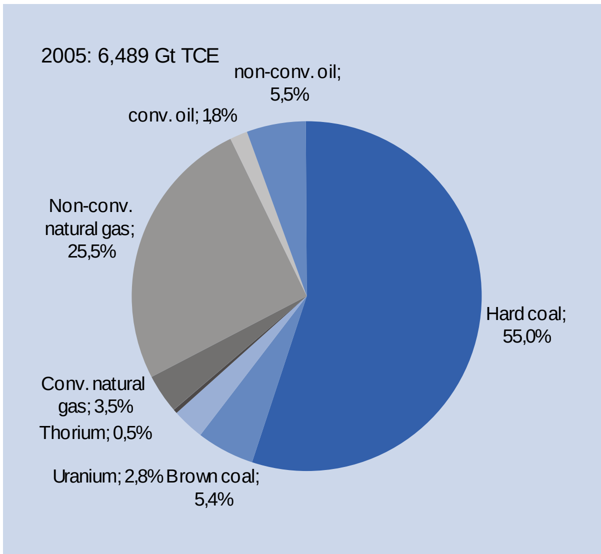

Figure 12: Coal accounts for 60 % of global energy resources (non-renewable sources of energy), Source: BGR

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greatest range of global reserves among the fossil fuels. The “static range”, i.e. the quotient of current reserves to annual output, came to over 212 years for lignite at the start of 2006, and 153 years for hard coal. By contrast, the ranges for oil (42 years) and natural gas (63 years) are much smaller. The reserves findings alone point to a relatively high performance capability for coal. Experience tells us, though, that the ranges represent only a snapshot of the situation, since the numerator and the denominator vary over time owing to technological progress, new finds, price changes and growth of global demand.

If the conventional and non-conventional resources are added to the reserves, the ranges increase. However, while this then boosts the ranges for oil and natural gas to only 120 and 200 years, respectively, the range for brown coal extends to 1,300 years and hard coal to around 1,000 years. The figures for the fossil-based hydrocarbons oil and natural gas, in particular, suggest that supply is secure when in fact it is not, for it is scarcely likely that non-conventional resources can be activated technologically and economically in the foreseeable future.

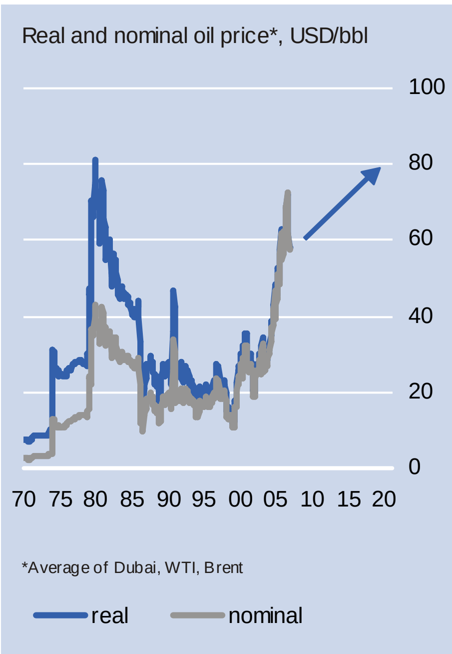

Figure 13: Rising price of oil signaling end of era, Sources: HWWA, MWV, OECD, DB Research estimates

Not only the large proven reserves and potential resources among the fossil fuels argue for an even greater role for coal in the coming decades and centuries. The generally global distribution of coal deposits is also a point in its favour.

High oil prices turn coal into an alternative fuel

The search for alternatives to conventional fuels did not seem to be an urgent task in late 1998 when a barrel of oil cost less than USD 10. Not quite 10 years later, with oil going for an annual average price of USD 65 in 2006 (i.e. an increase of more than 500%), sentiment is reminiscent of the gold rush days. The most prominent participants in the contest for the fuels of the future have long since entered the race. Mass markets are awaiting the winners:

- First-generation bio-fuels are increasing in popularity in the most diverse countries of the world, such as Brazil, the US and Germany. In Brazil, they have long since become commercially competitive. Research on the second generation, the synthetic bio-fuels (biomass-to-liquids, or BTL), is continuing briskly.
- Natural gas has been a common fuel in some countries for years. More appears to be possible if the catalytic conversion of natural gas proves able to secure the availability of a synthetic fuel, socalled GTL (gas-to-liquids), on an industrial scale. GTL and BTL will mean fewer emissions and higher efficiency.
- By means of liquefaction (coal-to-liquids, CTL), coal may directly replace oil even as a fuel. Thanks to higher reserve and resource ranges, coal as a asubstitute would clearly have and advantage over fuels based on natural gas.

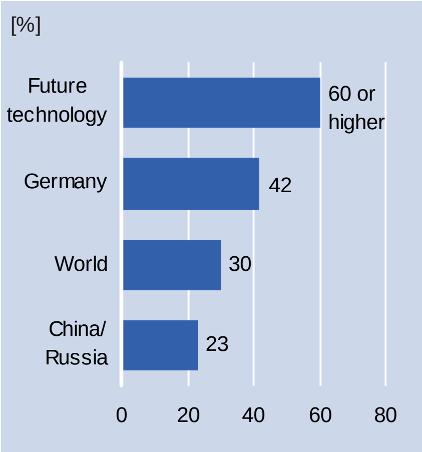

Figure 14: Efficiency of hard-coal power plants, Source: GVSt

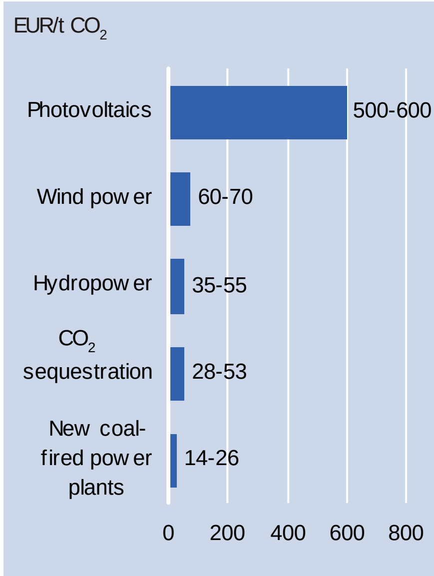

Figure 15: Specific CO_2 avoidance costs, Sources: Euracoal, RWE

What would appear to be a technological sensation for the younger generation has basically been the state of the art for years. The direct liquefaction of coal was first put into practice at the beginning of the past century. In 1925, Franz Fischer and Hans Tropsch discovered an indirect liquefaction method, one which still bears their names: Fischer-Tropsch synthesis. This means that coal can in principle be liquefied both directly and indirectly. All three basic processes – coal hydration, coal extraction and petrol synthesis – were developed in Germany.

Before the second world war, Germany sought to achieve energy autarchy. Towards the end of the war it had 27 liquefaction facilities, 9 being Fischer-Tropsch indirect plants and 18 direct liquefaction plants. They covered 90% of domestic fuel demand. After the war the technology fell out of favour in Germany as it was sidelined by a different energy policy and low oil prices.

Coal liquefaction currently plays a commercial role in South Africa, which established and fostered a CTL industry in the 1950s that covers about 60% of domestic demand. The US also uses CTL technology. As of late the world's biggest coal producer, China, is also planning to engage in CTL with the erection of its first largescale facilities. The three countries all have abundant deposits of coal that can be exploited at low cost. In the long run, though, these should only be activated if technological advances are able to keep the environmental impact in check.

The US, which has traditionally favoured technological solutions to problems, launched initial programmes for modern CTL technology in the mid-1970s. The initiatives of the US government and the Department of Energy (DOE) cover a broad range extending to the president's latest hydrogen initiative, for hydrogen can also be generated via coal liquefaction. Stimuli for CTL solutions are also coming from the Department of Defense (DOD), since they will enable the military to enjoy a secure supply of fuel and propulsion agents without being dependent on imports.

Most US programmes target CTL technologies becoming competitive at oil prices of around USD 25-30 per barrel. In the early days, though, the price of oil was much lower. With oil currently trading at around USD 54/bbl, CTL is an interesting alternative from a purely commercial point of view. The commercially feasible costs for CTL lie in a range of USD 40-50 [5]. From a macroeconomic standpoint, the result is not as good of course because of the higher costs of CO_2 emissions. But if these problems are solved, e.g. by means of sequestration, coal would be a source of hope for the fuel market in the post-oil era.

2005	Extraction	Consumption
World (Exajoules)	122.6	122.4
	%	%
Europe	4.0	8.8
CIS	8.2	6.3
Africa	4.6	3.7
Middle East	0.0	0.3
Austral-Asia	59.3	56.4
North America	22.5	22.5
Latin America	1.4	0.7
OECD	32.8	37.2
EU-25	3.6	7.7
OPEC	3.3	0.8

Figure 16: Hardcoal widespread throughout the world, Sources: BGR (2005), DB Research calculations

New power generation technology for fewer emissions.

A total of USD 10 trillion is expected to be invested in power generating plants around the globe up to 2030, with over USD 2 trillion being invested in China alone. The need for investment is very high not only in the emerging markets but also in Europe and particularly in Germany, where the effects of the law to phase out nuclear energy will become truly noticeable in the years ahead.

For investments, not only the direct costs but also the implications for the world climate will increasingly gain importance. This holds all the more so as over the past 30 years the share of CO_2 emissions from coal has risen from 35% to 40% – with total emissions rising by 70% globally. Since natural gas will grow more and more expensive in tandem with oil and since the delivery streams apparently already harbour risks, the potential for innovative clean coal technologies is immense. The efficiency of coal-fired power stations in the EU rose by one-third over the past three decades. Modern hard coal stations can achieve a score of 45%. The replacement and modernisation of old generating plants in the industrial countries and above all in the emerging markets alone would noticeably reduce the dangers for the climate. The specific CO_2 avoidance costs attainable with new power plants are lower than with many other strategies.

One much more revolutionary project is a plan to develop emissionfree coal-fired generating plants. Upstream and downstream CO_2 sequestration, for which there are several different methods, aims for climate conservation. There are diverse alternatives for subsequent CO_2 storage, e.g. disused mines, oil and natural gas caverns that have been pumped empty or special geological formations such as saline aquifers. As things stand today, such storage methods still harbour significant risks, though. This is why additional research is urgently needed. And the costs to be incurred until serial production is possible are not insignificant.

The initiatives for CO_2-free coal-fired power plants are widespread. The US is giving all-out backing to the development of a zeroemission power plant with the FutureGen project. The EU is doing much to support innovative technologies for sequestration. In Germany, RWE says it will build the first industrial-scale, CO_2-free coal-fired power plant by 2014. Furthermore, Vattenfall Europe plans to set up a CO_2-free pilot plant based on lignite.

The current investment boom in Germany for new coal-fired power plants is partly the result of the climate protection privileges that the federal government granted in the framework of the second National Allocation Plans for emission rights for the years 2008 to 2012 (NAP II). The streamlining of the NAP II as a result of recent EU criticism has done virtually nothing so far to change the environmental subsidies. Truly CO_2-free coal-fired power plants will probably not be available for serial production before 2020. If the technology can clear the hurdle, Germany's mechanical engineering and plant construction sectors stand to benefit even more than hitherto from the soaring global demand for investment. The European Commission is considering whether it should permit only CO_2-free power stations after

2020. It will take even longer than that before all the existing coal-fired power plants are emission-free.

Despite new technology the disadvantages inherent in the cost of mining hard coal in Germany will not be eliminated even during the post-oil era. The outlook for German hard coal will thus continue to hinge on the subsidies granted by politicians. By contrast, lignite will remain an efficient source of energy for domestic supply for decades following the oil boom thanks to modern technology.

Conclusion: versatile coal will be key in the interim

Coal will have good prospects if efforts to engineer its transformation into a clean energy source with a neutral impact on the climate are successful. Abundant deposits and the favourable global distribution will enable a relatively secure energy supply in Germany and the world, particularly when oil and later also natural gas have become scarce and thus expensive. The transition period in which coal may be the only answer could be limited, though. But this would require fast progress on renewable energies as well as on hydrogen research. Breakthroughs of backstop technologies such as nuclear fusion need much more time. Until then, transformed, more environmentally-friendly use of coal will be of the essence.

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