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## **CHALLENGES AND STRATEGIES FOR CHEMICAL/INDUSTRIAL PARKS IN EUROPE**

Stephan von Delft

## **INTER-INDUSTRY INNOVATIONS IN TERMS OF ELECTRIC MOBILITY: SHOULD FIRMS TAKE A LOOK OUTSIDE THEIR INDUSTRY?**

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# Letter from the Editor

## Chemical Parks – Forthcoming challenges

The chemical industry is characterized by one specific phenomenon that no other industry pursues in such an efficient way, i.e. the organization of several companies within joint locations – the so called ‘chemical parks’. One main factor explaining the unique efficiency and competitiveness of such chemical parks is the occurrence of synergies effects, e.g. ensured by site operators providing an appropriate infrastructure, supplying energy and water, and being responsible for care and security aspects. Nevertheless, especially European chemical parks may be confronted with serious challenges in the forthcoming years. For instance, emerging chemical parks in Asia may outperform the historically grown European chemical parks as the latter ones often lack a comparably tailor-made construction design and therefore cannot provide for the same efficiency. Consequently, operators of European chemical parks need to be prepared and continuously develop new ways of increasing their competitiveness. Thus, we are pleased to welcome Gunter Festel and Martin Würmseher who present detailed insights into the challenges and strategies for chemistry parks in Europe. In their commentary, the authors outline an overview of the current situation and future development of chemical parks in Europe. Here, they specifically refer to success factors, strategic positioning, restructuring, consolidation and subsequent performance improvement. Regarding the latter one Gunter Festel and Martin Würmseher provides you with examples illustrating cost saving potentials by means of optimizing the supply of electricity, steam and water.

Additionally, Christoph Behrendt also refers to the present topic of chemical parks. In his article “How to secure sustainable competitiveness of Chemical Industry Parks: Global competitive challenges and a systematic, customer-centric response”, the author addresses the highly relevant question of how operators of chemical parks should consider external investors’ perspective into their strategic decision making. Thus, the author illustrates insights from an international competitiveness study of leading chemical parks and, in so doing, provide a guideline of how operators of chemical parks may implement a customer-oriented focus in their business model and stay competitive on a global scale.

In their article “Are you still comparing or already learning? Experience report of a Facility Management benchmarking for laboratory buildings”, Jörg Petri and Andreas Kühne highlight the advantages of identifying the most efficient concepts of designing and operating laboratory and office buildings by applying benchmarking studies (based on selected key figures). Exchanging and learning about the conditions and causes of deviations across participants during Best Practice Workshops are central in order to develop guidelines, i.e. Good Operating Practices, to improve processes in consideration of firm-specific characteristics and enhance their performance.

The research paper of this issue “Inter-industry innovations in terms of electric mobility: Should firms take a look outside their industry?” written by Stephan von Delft aims to make companies aware of the increasing necessity to collaborate with (new) actors showing additional knowledge and capabilities in order to generate and capture value in new configured value chains, for instance deriving within convergence processes. Technological challenges, changing industry structures, the formation of alliances and business model innovations are topics that are not only arising in the field of electric mobility as the anticipation and response to changes within firms’ environments are crucial for all businesses.

Now, please enjoy reading the second issue of the tenth volume of the Journal of Business Chemistry. We would like to thank all authors and reviewers who have contributed to this new issue. If you have any comments or suggestions, please do not hesitate to send us an email to: [contact@businesschemistry.org](mailto:contact@businesschemistry.org).

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# Commentary

## Challenges and strategies for chemical/industrial parks in Europe

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### 1 Introduction

Starting in the United States, chemical/industrial parks have been used since the 1950s to foster economic development and to support the change of industry structures (Griefen, 1979; Reisdorph, 1991). In Europe, the shifting of new investments to locations outside of Europe led to a dissatisfying degree of utilisation of industrial sites and the emergence of industrial parks (Badri et al., 1995). Especially in the chemical and related industries, the last 15 years have seen an increasing trend towards chemical/industrial parks with dedicated infrastructure companies as site operators. After transforming traditional chemical sites into chemical/industrial parks, the whole landscape has been, for many years, in a phase of restructuring and consolidation (Festel, 2007; Festel, 2009). This was the basis for the increasing competitiveness of the chemical industry on a global scale in some European countries, like Germany or the Netherlands.

This commentary gives an overview of the current situation and outlook of chemical/industrial parks in Europe with the focus on success factors and strategic positioning as well as restructuring, consolidation and performance improvement. Some examples of performance improvement opportunities will be given showing cost saving potentials within the supply with electricity, steam and water as well as fire brigades and security services.

### 2 Positioning and specialisation

The correct positioning based on the specific success factors and strengths of an industrial park is still a major challenge for chemical/industrial parks. This is especially difficult as most of the industrial sites were historically grown with a very broad portfolio of chemical activities. The result being in that we have seen many redundant operations in parks close together. Many of the modern

chemical/industrial parks are positioning themselves through product oriented specialisation or by focusing on production strengths in the sense of the existing integrated production networks of the companies that operate at the site. Good examples are the Chempark/Germany (chemical sites of Bayer in Leverkusen, Dormagen and Uerdingen), InfraLeuna/Germany or Chemelot in Geleen/The Netherlands (chemical site of DSM). One key aspect of this focus are the cost advantages of an efficient network structure (for example with regard to the logistics of dangerous or hard-to-transport substances). Chemical/industrial parks also establish an end user or industry oriented specialisation aligned to customers located near the site. The main goal of this type of positioning is to achieve as many scaling and networking effects on the production site as possible, in order to strengthen the network structure. An example for this positioning strategy is the ValuePark in Schkopau/Germany. Size is an important factor for the success of this positioning strategy: the larger the industrial park, the easier it is to strengthen the network structure. To ensure their future existence, smaller chemical/industrial parks have to make themselves attractive through partnerships or specialisation.

In the future, chemical parks will continue to specialise as pure chemical parks (with pure chemical companies as users), chemical/industrial parks with focus on the chemical industry (with chemical companies and related operations as users), and mixed trade parks (with only chemical related operations as users). The drivers for specialisation are the high overhead costs in pure chemical parks (cost intensive infrastructure), legal requirements (licenses, environmental issues) and acceptance by the local community. Only certain chemical companies will be able to carry the overhead costs associated with a chemical park over the long term. Those are mainly companies that have a complex infrastructure by virtue of their production

processes or that have to provide certain services because of legal requirements.

Some industrial park operators whose sites are positioned based on the production network will exclude companies that do not fit into the network from the outset. On the other hand, to fulfil their growth targets, which were defined for thinning out fixed costs and the realisation of scaling and network synergies, some chemical/industrial parks are increasingly acquiring customers outside their traditional sphere of activities. A good example for this strategy is the industrial park Oberbruch/Germany, which was able to win a furniture factory and fuel cell producer as new customers for the industrial park. These operations that do not need a special chemical industry infrastructure are normally located on the periphery outside the park premises.

### 3 Service offerings and customer requirements

Chemical/industrial park operators offer ser-

vices specific to the site (on-site services) and services independent of the site, i.e. independent of the existing infrastructure (off-site services) (Figure 1). The respective classification is dependent on as to what extent cost benefits, specific to the site, can be implemented through the proximity to the site users as customers of the services or synergies (e.g. between operation and maintenance of the facilities or infrastructure). An infrastructure network typically has synergies that are generated through the existing infrastructure and the services available for the companies located there.

For some customers, it is important that the services can be bundled by the infrastructure company to form complete packages (full-service) so that producers have only one main contact partner. Combining services reduces interfaces and management costs for the customer, which is especially important, as the decisive factor for the long term success of chemical/industrial parks is a competitive price level (Figure 2). Competitive prices are necessary, because the chemical/industrial park operators compete with other locations and exter-

**Table 1** Key performance indicators for the supply with energy, steam and water (the numbers in brackets are under the regression line standing for "negative" cost saving potentials).

		P1	P2	P3	P4	P5	P6	P7	P8	P9
<b>Electric energy</b>										
Maintenance rates	[Euro/m]	17.6	1.0	5.5	7.4	9.4	4.8	31.8	10.0	20.9
Cost saving potentials	[Euro/m]	0.5	(2.2)	2.7	(2.2)	0.5	(0.7)	na	1.4	na
<b>Steam</b>										
Maintenance rates	[Euro/m]	22.4	13.2	11.4	24.5					
Cost saving potentials	[Euro/m]	5.4	(6.6)	(3.1)	4.1					
<b>Industrial water</b>										
Maintenance rates	[Euro/m]	40.6	8.3	4.2	21.9	13.5	20.0	6.4	23.7	26.2
Cost saving potentials	[Euro/m]		(4.7)	(2.2)	1.7	5.1				
Electric energy costs	[Euro/1000 m <sup>3</sup> ]	19.9	2.5	42.6	21.5	16.7				
Cost saving potentials	[Euro/1000 m <sup>3</sup> ]	0.3	(3.5)		(2.1)	4.9				
<b>Drinking water</b>										
Maintenance rates	[Euro/m]	38.2	1.9	0.1	10.1		9.4	6.4	3.0	2.5
Cost saving potentials	[Euro/m]	8.0	4.5	(0.2)	(10.8)					

nal service providers in many of their services, and are intending to increasingly make business outside of their chemical/industrial park (Festel, 2008).

Besides prices, the decisive factor for the attractiveness of chemical/industrial parks, in the park users' view, is customer orientation, i.e. flexibility and speed, professional expertise (qualification of the employees and quality of the services offered), as well as the existing service range (type and scope of services). The companies within chemical/industrial parks expect a site operator to realize the greatest possible synergies from the integrated network (integrated product or infrastructure network), and pass these on to his customers. Examples are the management of peak demand of energy and media supply (steam, water, compressed air), the individual regulation of security of supply for customers (with fair billing according to consumption), and management systems for energy data.

#### 4 Benchmarking and performance improvement

Performance improvement is a key success factor for chemical/industrial parks. Between 2006 and 2007, a benchmarking study with 9 chemical parks and chemical related industrial parks in Europe was conducted (Festel, 2008; Festel, 2011). The size of the industrial parks was between 30 and 230 hectare (ha). The organisational structures ranged from infrastructure divisions, still integrated in the parent company, over infrastructure divisions own legal entity to independent infrastructure companies. The main focus of this study was on operational and maintenance costs of selected services within chemical/industrial parks. More than 50 key performance indicators were defined and calculated. Conceptual questions, such as operating and maintenance budgets and costs, as well as performance and pricing models were also discussed during workshops to give the participants the chance to share their experiences and to learn from each other. The goal was to obtain an overview regar-

Table 2 Key performance indicators for fire and security services.

		P1	P2	P3	P4	P5
<b>Fire brigade</b>						
Costs per fire brigade employee	[Euro/employee]	64,080	52,685	75,000	60,555	46,133
Costs per ha of site area	[Euro/ha]	16,020	10,926	6,667	22,947	24,912
Costs per person on site per day	[Euro/person]	1,001	551	550	1,148	1,205
Costs per million Euro replacement value	[Euro/mn Euro]		1,381	1,176	2,462	2,057
Share of directly invoiced fire brigade costs	[%]	7	78	100	15	5
<b>Security services</b>						
Costs per security employee	[Euro/employee]	7,920	11,726	37,500	28,346	18,467
Costs per ha of site area	[Euro/ha]	1,980	2,432	3,333	10,742	9,972
Costs per person on site per day	[Euro/person]	124	131	275	537	482
Costs per million Euro replacement value	[Euro/mn Euro]		307	588	1,152	823
Share of directly invoiced security costs	[%]		66	100	13	7



ding the operational competitiveness of the participants and to find first indications for improvement and cost saving potentials.

One analysed area was the supply with electricity, steam and water. To determine the maintenance rates of electricity grids, the maintenance costs in relation to the length were taken and gave maintenance rates in the range of 1.0 to 31.8 Euros per metre (Table 1). After considering the special aspects and taking into account the complexity of the networks, a cost saving potential of up to 2.7 Euros per metre could be identified. Especially through an extension of the revision cycles of the electricity networks costs could be saved. While the average revision time span is 5 years, a yearly revision is norm at many of the participating parks. At best, the revision cycle could be extended to 10 years. The range of the maintenance rates of steam networks in relation to the length of the network was between 11.4 and 24.5 Euros per metre. The cost saving potential of a maximum of 5.4 Euros per metre is higher than that of the electricity grids.

The maintenance rates for industrial water are in the range of 4.2 to 40.6 Euros per metre showing cost saving potentials from 1.7 to 5.1 Euros per metre. Within a continual optimisation of water networks, the many weak spots and leakages, which lead to significant losses, have to be identified. Some of the participants have systematically set up a network of water metres which has led to an improvement of the identification of weak spots and a decrease in losses. Also, the installation of energy efficient pumps is becoming important, due to the ever increasing energy prices. The electricity costs for the generation and distribution of industrial water are between 2.5 and 42.6 Euros per thousand cubic metres, whereby the specific electricity costs were corrected by the discharge and production volume showing cost saving potentials from 0.3 to 4.9 Euros per thousand cubic metres. The maintenance rates for drinking water are between 0.1 and 38.2 Euros per metre with cost saving potentials from 4.5 to 8.0 Euros per metre.

Another area within this benchmarking and

Figure 1 On-site and off-site services of infrastructure service providers (Festel, 2009).

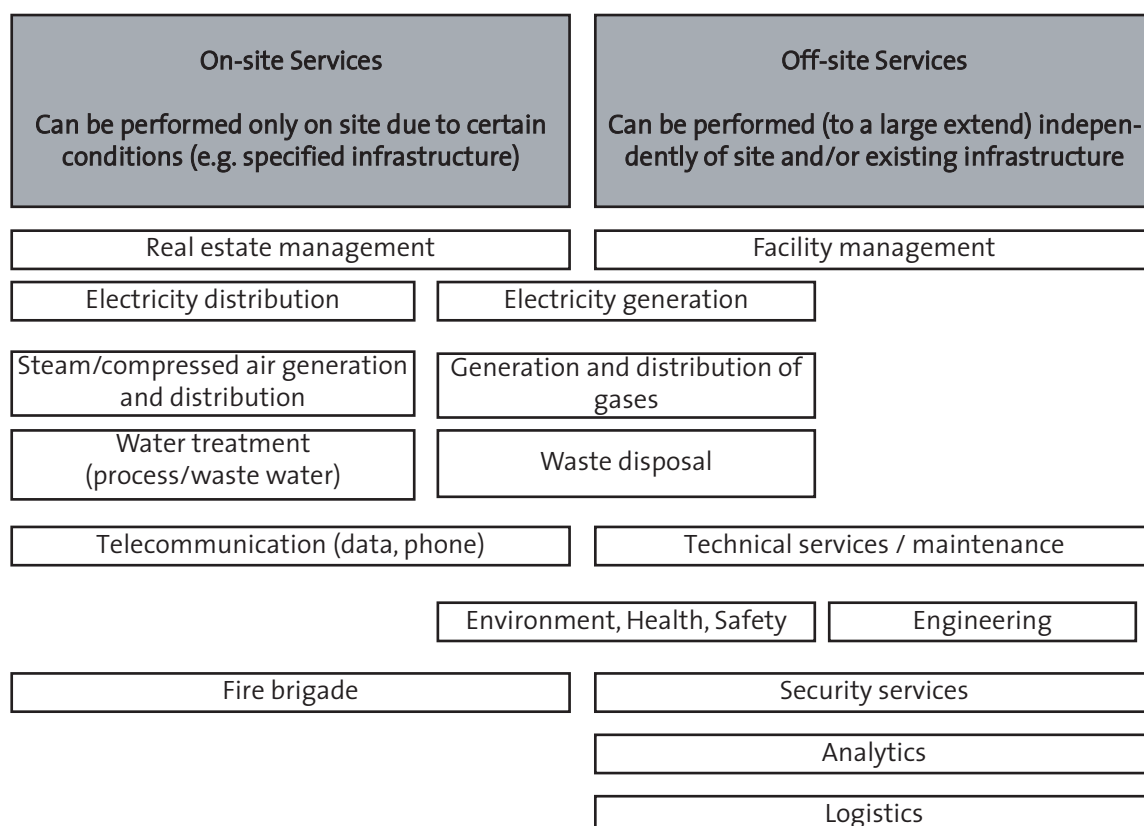


Figure 2 Success factors for chemical/industrial parks in the view of park users (Festel and Foth, 2005).

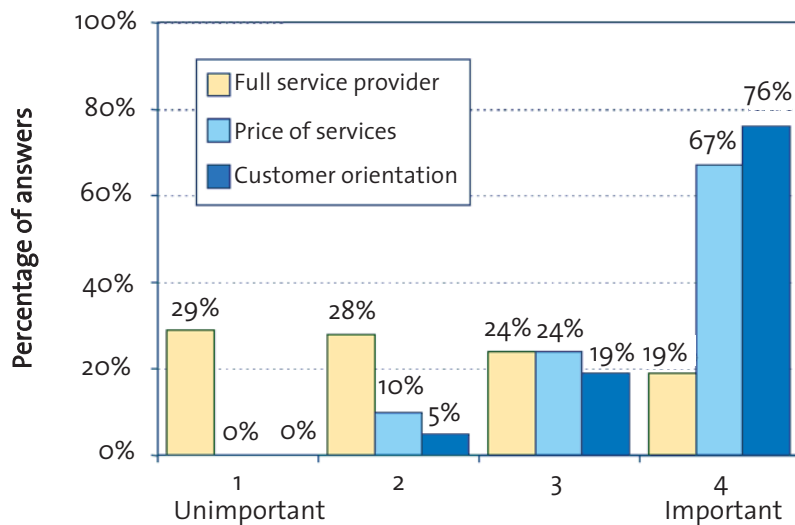


Figure 3 Activity analysis of the fire brigades.

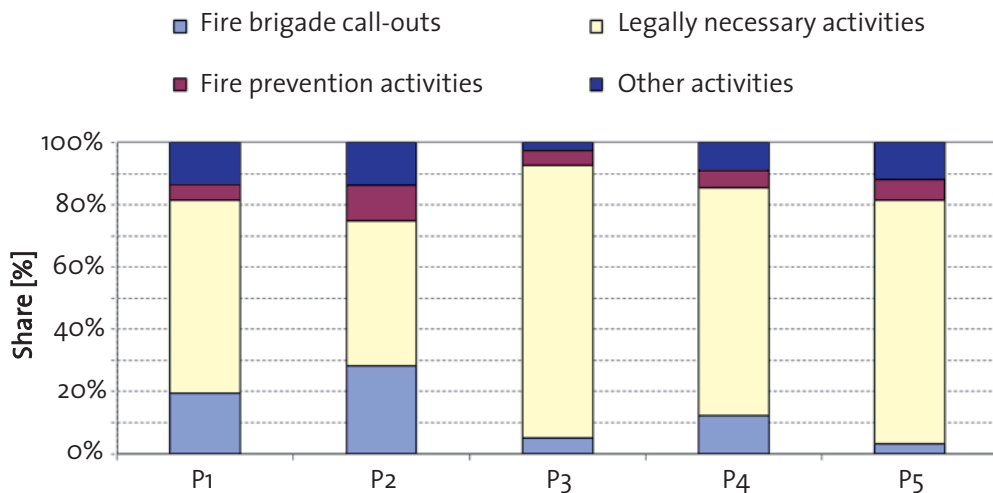
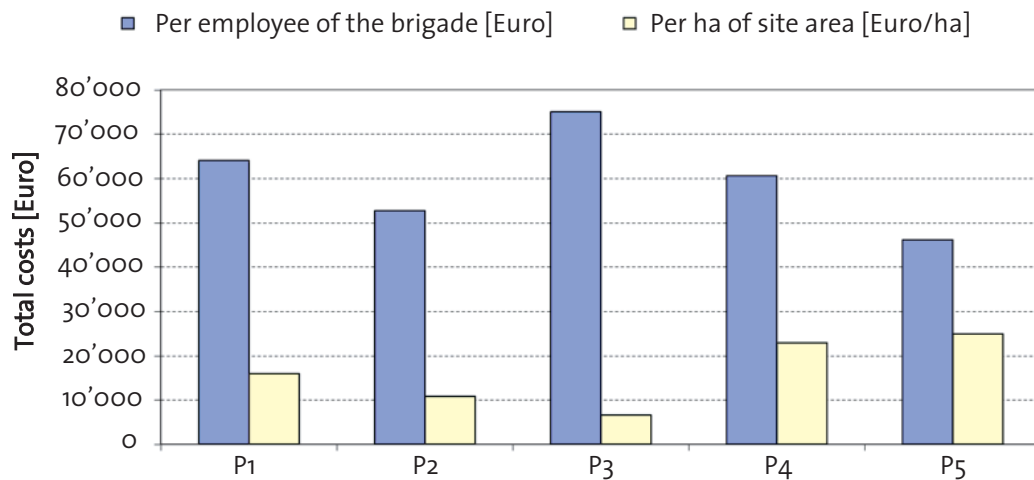


Figure 4 Key performance indicators for the brigade.



best practice initiative was the fire brigade and various security services (property and building surveillance, access control, company and contractor ID cards, reception services, visitor assistance, personal protection, event security, investigation service) with the definition of specific key indicators (Table 2).

Figure 3 shows the activities of the fire brigades based on an activity analysis within all participants. Most of the activities are fire brigade call-outs and legally necessary activities, i.e. activities which are required by law or authorities. The fact that these legally necessary activities are between approximately 60% and 90% gives a clear indication that there is a cost reduction potential in some

chemical/industrial parks. The impression is that the fire brigade still has a special position in many chemical/industrial parks with lower pressure to reduce costs compared to other functions. This statement is strengthened by analysing the key performance indicators for the fire brigade. Total costs per employee of the fire brigade and per ha of the site area are presented in Figure 4. The performance differences between the participants are large, ranging from approximately 46,000 to 75,000 Euro per employee of the fire brigade and 6,700 to 24,900 Euro per ha of the site area. Especially the per ha figure shows that some chemical/industrial parks have not done their homework regarding the realisation of cost reduction potentials. This is

Figure 5 Key performance indicators for security services.

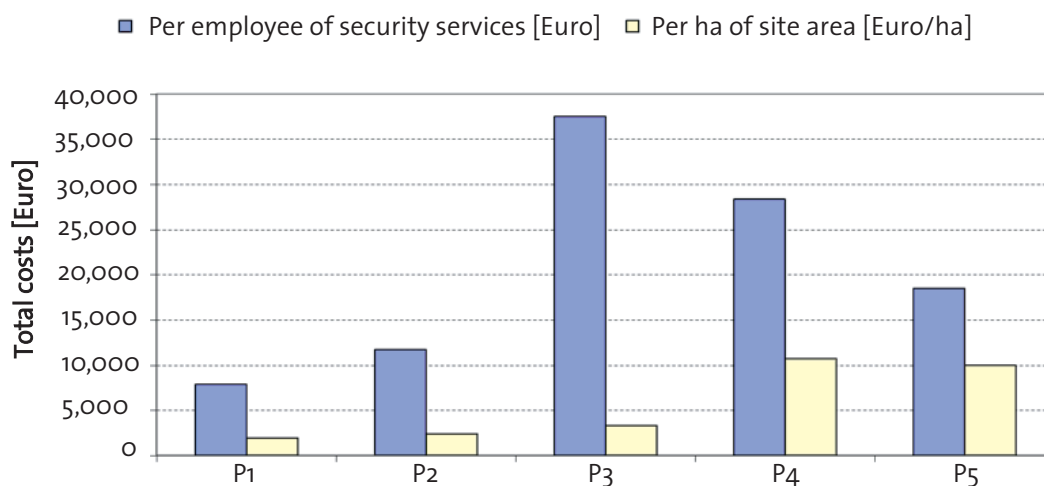
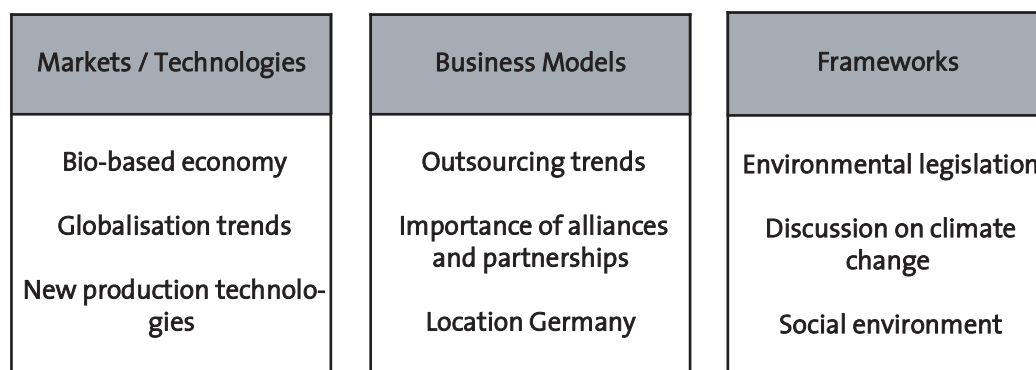


Figure 6 Examples of important and relevant trends for chemical/industrial parks.



also stated by many companies, as users, at these parks with bad performance.

The correlating key performance indicators for security services are shown in Figure 5. The performance differences between the participants are even more significant ranging from approximately 7,900 to 37,500 Euro per employee and 2,000 to 10,700 Euro per ha of the site. This is especially surprising as the salary level and the activity portfolio between the chemical/industrial parks is not so different which was also shown by an activity analysis within the security services. The more detailed analysis and discussion of these differences gave the clear picture that the workload is the decisive factor. Then it was possible to define first indications for cost saving potentials, like modified processes to reduce idle time.

## 5 Restructuring and consolidation

Besides performance improvements, also restructuring as the adapting of capacities to the actual requirement, and consolidation as the formation of larger entities based on existing structures, are important. An interesting trend during the last years is the consolidation in certain services sectors as a consequence of focusing on core activities and the sale of non-core areas. This consolidation process, which does not reduce the number of independent chemical/industrial parks, is especially seen in off-site services, such as maintenance. One example is the sale of the technical services of the chemical/industrial parks Höchst and Griesheim to the Munich based industrial service provider Rheinhold & Mahla in 2005. It is expected that this consolidation trend within off-site services will continue in the future.

## 6 Conclusions

There are many fundamental trends, which are important for industrial parks and, e.g., can be assigned to the areas markets/technologies, business models and frameworks (Figure 6). For instance, the transition to a bio-based economy will make a lasting change to production structures, as new supply chains, based on a changed raw material base, will make other demands to infrastructures. Further important trends are related to business models, e.g., outsourcing trends and the importance of alliances and partnerships as well as frameworks, e.g., environmental legislation and the discussion on climate change.

The relevant trends important to chemical/industrial parks should be recognised and evaluated in the scope of the strategy development process. Based on a fundamental under-

standing of the trends, the evaluation of these should result in the identification of strategic options. A sensible linking with own strengths together with the necessary resources to realise the developed strategy supplies the unique selling point, in order to achieve "first choice" status with new settling companies. It has been shown that without clear unique selling points the competition for new settling companies is toilsome and does not usually promise success. There are various types of unique selling points, which can be defined on the basis of different strengths, such as composite structures (production, product, infrastructure), the specialisation on certain companies and value chains or the positioning through the geographical location. Most chemical/industrial parks have been successful in realising their strategic goals and are showing real unique selling points.

Most of the chemical/industrial parks in Europe were also successful with performance improvement and restructuring. Nevertheless, benchmarking evaluations and best practice discussions show large differences in performance levels. This is a clear indication that there are still significant cost saving potentials in chemical/industrial parks. It is necessary for each industrial park to understand the individual performance level and adapt best practice in all areas. It is the performance level which makes a clear difference between high performance industrial sites and sites which have to be more consequent in their restructuring and cost saving efforts. The environment for chemical/industrial parks in Europe has worsened during the current financial and economic crisis. Some chemical companies, like Dow Chemical, have postponed investments in Europe until the economic situation improves again (Kaskey, 2012). Those chemical/industrial parks which, in the past, have not done their homework will have a difficult time ahead of them and are going to have to take some painful cuts. On the whole, the situation of most of the chemical/industrial parks in Europe is not so bad and they provide a good basis for sustainable growth in the future taking into account the major trends, like transition to a bio-based economy.

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## References

- Badri, M.A., Davis, D.L., Davis, D. (1995): Decision support models for the location of firms in industrial sites, *International Journal of Operations & Production Management*, **15** (1), p. 50-62.
- Festel, G., Foth, O. (2005): Marktstudie zu den Zukunftsaussichten von Industrieparks / Infrastrukturdienstleistern, FESTEL CAPITAL, Hünenberg, p. 68-70.
- Festel, G. (2007): Chemical/industrial parks in Germany –

- current situation and outlook, *Chemische Rundschau - Industrial Sites Supplement*, **60** (5), p. 44-45.
- Festel, G. (2008): The performance level makes the difference, *Chemische Rundschau - Industrial Sites Supplement*, **61** (4), p. 16-18.
- Festel, G. (2009): Chemical/industrial parks within the economic crisis, *Chemische Rundschau - Industrial Sites Supplement*, **62** (4), p. 18-19.
- Festel, G. (2011): Infrastruktur-spezifische Aspekte beim Benchmarking, *Chemie Plus*, **20** (11), p. 10-11.
- Griefen, R.J. (1979): The Impact of the Industrial Park, *Appraisal Journal*, **38** (1), p. 83-91.
- Kaskey, J. (2012): Dow Chemical to Close Five Plants on Slower European Economy, available at <http://www.bloomberg.com/news/2012-04-02/dow-chemical-to-close-five-plants-on-slower-european-economy-2-.html>, accessed 9 January 2013.
- Reisdorph, D.H. (1991): Chemical/industrial parks as an economic development asset, *Economic Development Review*, **9** (4), p. 29-30.
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## Research Paper

# Inter-industry innovations in terms of electric mobility: Should firms take a look outside their industry?

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The beginning electrification of the automotive powertrain is supposed to have a major impact on the automobile value chain - reshaping it significantly and bringing up new alliances, business models and knowledge bases. Such a transformation of the value chain might fade boundaries between hitherto distinct knowledge bases, technologies, or industries. Over the past decades, the blurring of industry boundaries – the phenomenon of industry convergence – has gained attention from researchers and practitioners. The anticipation of a convergence process plays an important role for strategic and innovation management decisions, e.g. for new business development, mergers and acquisitions or strategic partnerships. However, despite the relevance of convergence, it is often challenging for incumbent firms to (1) foresee such a transformation of their environment, and (2) respond strategically to it. Hence, this study presents a tool to anticipate convergence and strategic implications are discussed.

## 1 Introduction

Technological change is known as a key driver of economic growth and prosperity (Schumpeter, 1947; Abernathy and Utterback, 1978; Kondratieff, 1979). From the first steam engine to the latest developments in nano- and biotechnology, companies have constantly benefited from and proactively promoted the development of new technologies and scientific research. A special phenomenon of technological change is known as industry convergence. Traditionally, it has been associated with the fading of industry boundaries between information technologies, consumer electronics and telecommunication (ICT) (Duysters and Hagedorn, 1998; Pennings and Puranam, 2001). Recently, convergence has also been observed in other industries, e.g. the chemical, pharmaceutical, and food industry (Bröring *et al.*, 2006; Curran and Leker, 2009a). When hitherto distinct industries converge, the emergence of technological innovations at the borderline of these industries brings up new applications and combinations, resulting in a situation where “established paradigms will be replaced by new ones [...] and thereby disrupt and sub-

stitute rules of conducting business” (Hacklin *et al.*, 2009, p. 723). Firms facing such a situation, thus have to adapt to new knowledge bases and new technologies which do not belong to their former core competences or their traditional expertise (Curran and Leker, 2011). Scholars reason that this assimilation of knowledge and technology is a key factor for successful innovation management in converging industries (Bierly and Chakrabarti, 2001). Hence, the anticipation of convergence plays an important role for management decisions, like new business development, mergers and acquisitions, or strategic research and development (R&D) partnerships. But how can firms anticipate the blurring of industry boundaries and, thus know if they should take a look outside their industry? And what consequences do blurring industry boundaries have for firm’s strategic and innovation management?

Taking the current trend of battery electric vehicles as an example, I used a bibliometric analysis of patents and scientific publication as an indicator for a beginning convergence process between the automotive industry, producing electric vehicles, and the chemical industry, producing batteries and battery components for those vehicles.

Based on this quantitative analysis, I deduce basic implications for strategic and innovation management in the field of electric vehicles. Recent examples from the automotive and chemical industry are used to support the concept of this study.

The remainder of this paper is organized as follows. In the next two sections the ongoing debate on battery electric vehicles and theoretical developments relating to industry convergence are summarized. Section 4 explains the methodology applied in research; and section 5 presents the results of the analysis. The paper concludes with a discussion of the findings and future research opportunities.

## 2 Electric mobility

The automotive industry has a long-standing history and denotes one of the most important pillars of our economy. However, global trends, such as emerging markets, increasing political regulation, climate change and increasing oil prices have forced automotive companies to combine their traditional businesses with innovative ways of energy supply (Drapcho *et al.*, 2008; Nag, 2008; Booz & Company, 2009; Deutsche Bank, 2009). The result is an increasing degree of electrification in the automotive industry called electric mobility<sup>1</sup> and captured by the catchphrase “e-mobility”. Some scholars focus on the electric engine of a vehicle and the electric energy source when they refer to electric mobility (Möller, 2010), while others like the IEA (2009), Canzler and Knie (2010) and Karg and Reinhardt (2010) have a broader understanding of electric mobility. Instead of solely focusing on the change from internal combustion to electric power supply, they define electric mobility as a new traffic system, with new infrastructure, so called “smart” electric grids, as well as new business models. Others again, like Schill (2010) argue that there is no clear definition of electric mobility. In this work, I focus on battery electric vehicles. The importance of the vehicle-grid-connection and the potential impact of other electric vehicles types, e.g. fuel cell electric vehicles, should thereby not be reduced.

The electrification of the powertrain is considered to be one of the most fundamental technological changes for the automotive industry. The consulting company McKinsey for example observes a “dramatic shift in the value chain, affecting market fundamentals and required competences” (McKinsey, 2011, p. 9), while Boston Consulting identifies the emergence of new business models, e.g. business models that are built around leasing concepts (BCG, 2010). Roland Berger concludes that

new players will appear along the value chain, intensifying competition, and reshaping the business landscape (Roland Berger, 2009). This reshape of the entire automobile value chain is estimated to include skill shifts from mechanics to battery chemistry and electronics (McKinsey, 2011), as well as an intensified competition (McKinsey, 2009). This transition calls for the development of a new knowledge base which can only be achieved through strategic partnerships and innovation alliances (Cappgemini, 2009), as the required competences, e.g. in battery chemistry, would “overburden the R&D departments of a single carmaker” (McKinsey, 2011, p. 14) in terms of fundamental research and financial risks. While consulting companies have been very active in this field, it is remarkably that academia has neglected many managerial aspects of the ongoing debate on electric mobility.

Besides a few exceptions (Mikkola, 2001; Pohl and Yarime, 2012) scientific studies have so far focused on life-cycle costs of electric vehicles (Werber *et al.*, 2009), the dynamics of the interdependencies between car manufacturers and consumers (van Bree *et al.*, 2010; Zhang *et al.*, 2011), or the possible penetration of electric vehicles in specific countries (Weinert *et al.*, 2008; Duke *et al.*, 2009). Based on a patent and publication analysis, I will address this gap and discuss several management challenges, as well as possible strategies to respond to the electrification of the automotive powertrain. To better understand those challenges, I will first give a brief overview of the value chain of battery electric vehicles.

All types of battery electric vehicles use a more or less powerful battery for energy storage, whereby the lithium technology, e.g. lithium-ion- or lithium-air-battery, is a promising candidate (Winter and Besenhard, 1999; Thielmann *et al.*, 2010). This technology is therefore used in the analysis. The simplified value chain of electric vehicles, shown in figure 1, is compared to the traditional automotive powertrain value chain characterized by a significant “chemical part”.

The design of lithium batteries for electric vehicles requires advanced chemical know-how, e.g. in chemical engineering and physical chemistry, because all components are specifically designed for usage in electric vehicles. Therefore, tier-3 and tier-2 firms (raw materials and cell components) are basically chemical companies. Automotive suppliers are positioned on tier-1 (battery integration/assembly) or tier-2 level (electronics for batteries). However, cell electronics must meet the specific requirements of the battery design,

<sup>1</sup>) Sometimes also framed “electromobility”.

which implies a strong connection between automotive suppliers and chemical companies at this level. Since the battery is one of the core elements of national e-mobility strategies, the improvement of the battery in terms of chemical performance and costs is considered to be a critical factor (Blesl *et al.*, 2009). Battery costs are estimated to decline with increasing production numbers (economies of scale) (Becks *et al.*, 2010), yet the absolute cost reduction remains unclear, underlining the uncertainty in this field. National governments have therefore initiated several programs to reduce this uncertainty by supporting market penetration, R&D, as well as the formation of national platforms of interaction between involved actors (automotive and chemical firms, industry associations, unions, universities & research institutions, politicians, and others), e.g. the so called National Platform Electromobility that has been formed by the German government (German Federal Government, 2009). Hence, research and development on lithium batteries for electric vehicles is in the focus of practitioners as well as university scientists. Examples for this attention are newly public-founded battery research programs like TUM CREATE, a joint research program between the Technical University of Munich and Nanyang Technological University (TUM, 2013), industry joint ventures like Li-Tec Battery by the automotive company Daimler and the chemical company Evonik (Li-Tec, 2013), and corporate spin-offs like Maxell Energy by Hitachi Maxell (Hitachi Maxell, 2011). According to McKinsey, companies aim to achieve a first-mover-advantage with those actions.

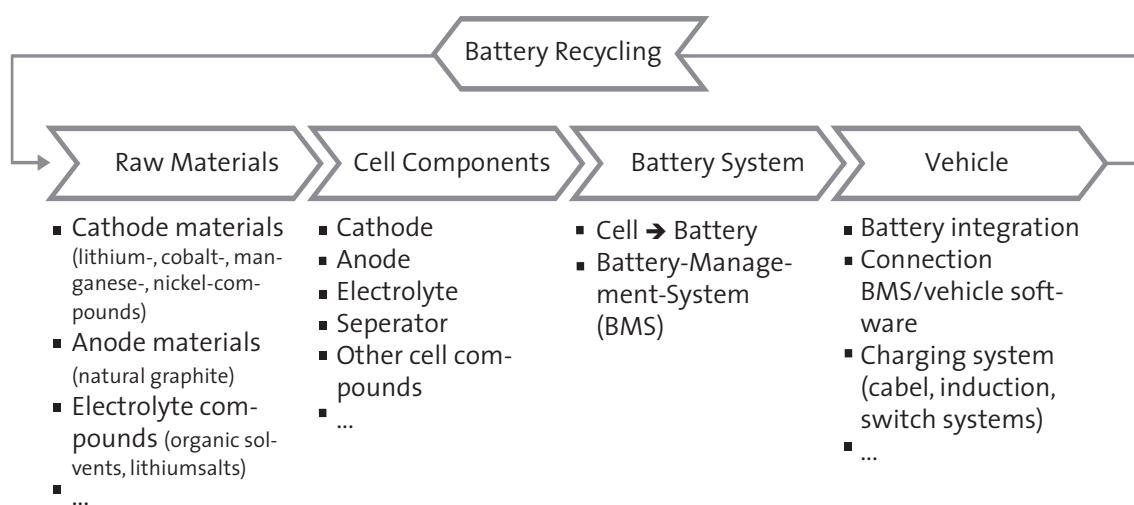
### 3 Industry convergence

#### 3.1 Definition and drivers

Several definitions of the term “convergence” exist. However, a clear *ex ante* definition of “convergence” and a conceptual delineation from the term “industry convergence” has started only in the late 1990s. Scholars argue that due to this late clarification, convergence has rather become a buzzword, especially in ICT, than a scientific term (Lind, 2004; Curran and Leker, 2011).

Rosenberg was one of the first who used the term convergence to describe technological changes between machinery and metal-using sectors (Rosenberg, 1963). A well-known definition was later given by the OECD defining convergence as “the blurring of technical and regulatory boundaries between sectors of the economy” (OECD, 1992, p. 13). Following this definition, Choi and Välikangas describe convergence as the blurring of “boundaries between industries by converging value propositions, technologies, and markets” (Choi and Välikangas, 2001), while Pennings and Puranam define convergence as “the erosion of boundaries that define and isolate industry-specific knowledge” (Pennings and Puranam, 2001, p. 3). These definitions do not clearly distinguish between convergence in general and industry convergence in specific. In this study convergence is therefore defined as a generic term for a *process characterized by blurring boundaries between objects*. In the case of industry convergence, objects are industries (in figure 2 overlapping circles are used to illustrate this phenome-

Figure 1 Simplified value chain of lithium-ion-battery electric vehicles.





non). Other loci of convergence can be scientific disciplines, technologies or markets. Distinguishing between these different levels of convergence implies to view convergence as a process, rather than as a single event.

Before I will give a more detailed description of this process-view, I will briefly describe what triggers and drivers of convergence have been identified in the literature.

Similar to the drivers of electric mobility, socio-economic factors, e.g. demographic change, new customer value propositions and globalization, have

been mentioned as drivers of convergence (Choi and Välikangas, 2001; Hacklin, 2008; Nyström, 2008). Furthermore political factors, like regulation and liberalization, as well as technological factors, like digitalization and the growing importance of the internet in case of ICT, are known as drivers of the convergence process (Katz, 1996; Theilen, 2004; Bröring, 2005). Scholars also highlight the role of management decisions as individual business actions, framed “managerial creativity” (Yoffie, 1997, p. 9) or evolutionary “business thinking” (Katz, 1996, p. 1083) resulting in new business models, may ini-

Figure 2 Illustration of the phenomenon of industry convergence at two points in time, adapted from: Curran and Leker (2011), p. 258.

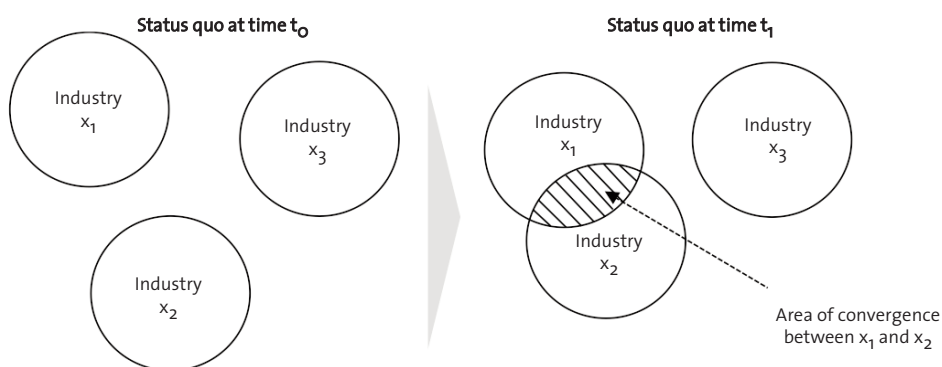


Figure 3 Drivers of convergence.

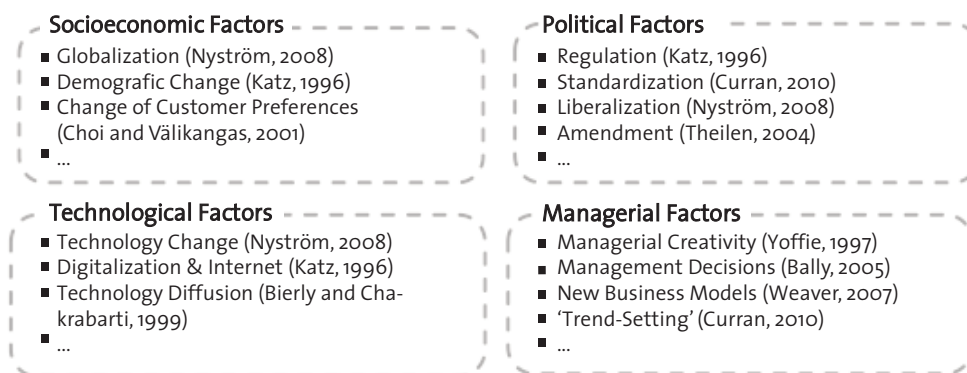
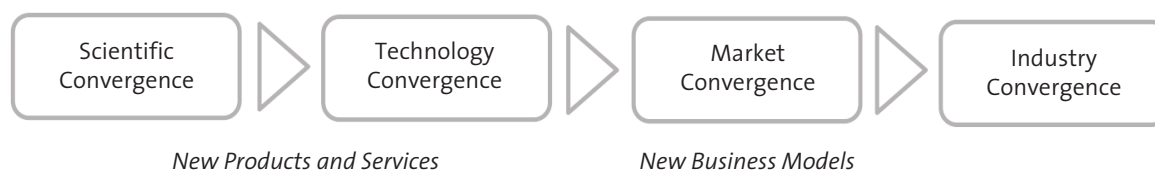


Figure 4 Process of convergence, adapted from: Curran and Leker (2011), p. 259.



tiate the convergence of markets or industries. Introducing the iPhone with its new design and functionality, and the combination to the established iPod/iTunes business model, is an example for how new products in combination with attractive business models can drive convergence (Johnson *et al.*, 2008; Curran and Leker, 2009b). Figure 3 gives an overview of drivers of convergence.

### 3.2 Convergence as a process

The process-based view of convergence was first introduced by Hacklin. Based on several case studies, he uses an “evolutionary and sequential perspective” to divide the process of convergence into four steps: (1) knowledge convergence, described as a spill-over between industrial knowledge bases that were previously unassociated, (2) technological convergence, i.e. the transition of converged industrial knowledge into industrial technologies, (3) applicational convergence, a phase where “opportunities for new value creation” emerge, and (4) industrial convergence, described as a situation of cross-industrial competition and “collision of business models” (Hacklin, 2008). The erosion of industry specific knowledge in phase (1) is characterized as an “autonomous and serendipitous” external effect for firms. However, this does not mean that firms have no options to response to knowledge convergence: the formation of cross-organizational and multidisciplinary teams is for example a way to respond to the blurring of knowledge boundaries. If this blurring leads to new technologies, the level of technology convergence has been reached. New ways of value creation are formed if these new technologies can be applied to solve customer problems that have previously been unsolved, or if they solve existing problems in a better way. Management decisions in this phase of applicational convergence can be seen as the foundation pillars of economic success in the future, because new technologies have to be integrated and existing competences have to be extended. This development can finally result in a new competitive environment, since a new industry structure with new rules of doing business, e.g. new distribution channels, occurs. While Hacklin’s view offers new insights, the focus on firms and industries in the phases of knowledge and technological convergence excludes developments outside industry, e.g. in academia. Furthermore the difference of industrial knowledge and industrial technology remains unclear. Therefore, a broader definition of knowledge and technology has been introduced by Curran (2010). Because convergen-

ce has mainly been observed and associated with knowledge- and technology-intensive industries, he argues, that convergence can first be observed in the blurring of the boundaries between different scientific disciplines, therefore called science convergence. This “coming together” of hitherto distinct scientific disciplines can be seen in interdisciplinary research collaborations. For instance, chemists, physicist, and engineers work jointly together at the Helmholtz Institute Ulm for electrochemical energy storage or the Münster Electrochemical Energy Technology battery research center (MEET, 2009; HUI, 2011). Following the innovation value chain, areas of basic research converge first, followed by applied and industrial research. The converging of science areas may then result in new technologies, which can be turned into new product-market combinations using new business models (market convergence). If entire industries or industry segments converge the stage of industry convergence has been reached.

In this paper, Curran’s approach is applied. At this point, it is important to understand that the described process of convergence (1. science convergence, 2. technology convergence, 3. market convergence, 4. industry convergence) is not necessarily linear; it is more a simplified and idealized time series of events (see figure 4).

Curran’s model of the convergence process explains many of the effects that can be observed in convergence, e.g. forming of new knowledge bases or new product-market combinations, but it does not describe how the change of industry boundaries is taking place at the industry-level. Such models of change are not new (e.g. Anderson and Tushman, 1990), but Hacklin *et al.* (2009) were the first who adapted such a model to explain the process of convergence as an idealized sequence of events at the industry-level. Hacklin (2008) originally introduced a cyclic model of convergence, however, for this study a simplified linear model will be used to illustrate the managerial challenges during industry convergence<sup>2</sup>. As illustrated in figure 5 the linear model consist of four sequential phases: (I) initialization, (II) diffusion, (III) consolidation, and (IV) maturation.

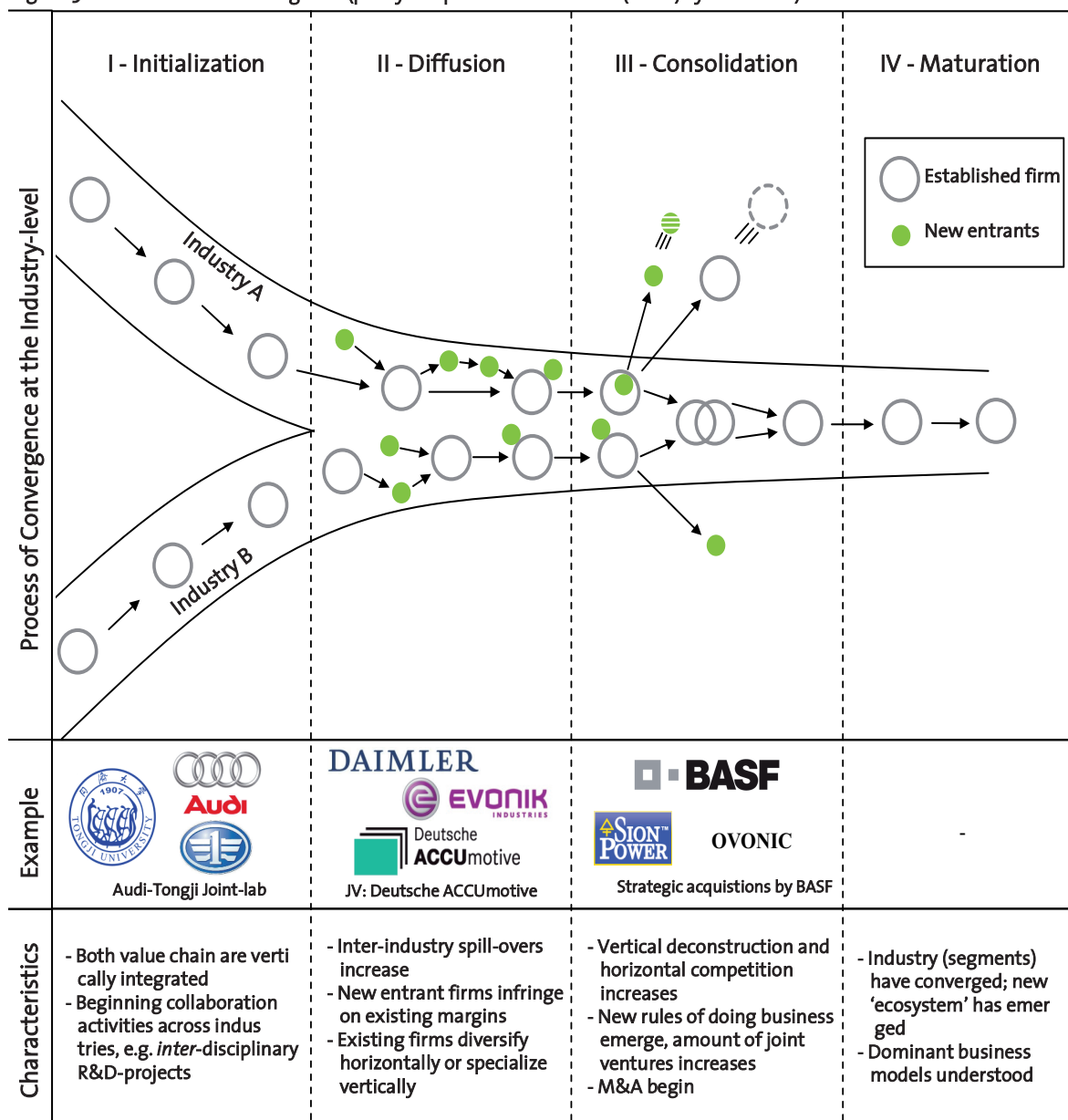
In the initial state, different vertical integrated industries (or industry segments) undergo structural changes, e.g. driven by new technologies or new regulations, independently. Industries may react differently to external influences, e.g. by forming *intra*-industrial collaborations or research partnerships with academia. For instance, the German car manufacturer Audi, the Chinese car manufacturer FAW, and the Tongji University have established a

<sup>2</sup> Based on previous work with practitioners and the discussion with researchers, adjusting Hacklin’s cyclic model to a more simplified, linear model proves to be suitable for the context of this study.

joint-lab for electric mobility in Shanghai (Tongji University, 2010). According to Audi chairman Rupert Stadler, the company co-founded this lab because “China is an important driver for electromobility. That is why we are investing locally...” (CER, 2010). The next stage is characterized by *inter*-industrial transitions, diffusing industrial boundaries. Established firms start to diversify horizontally or specialize vertically, while new firms enter the market and start to compete with incumbents. The previously unconnected industries “move closer together”. Joint ventures between companies from the

previously distinct industries can be observed during this diffusion. In 2009, the Deutsche ACCUmotive was for example formed as a joint venture between the car manufacturer Daimler and the chemical company Evonik Industries to develop and produce battery systems for electric vehicles (Deutsche ACCUmotive, 2013). The situation of intensified competition as well as *inter*-industry collaboration then results in a phase of consolidation where mergers and acquisitions take place or firms may be phased out of the market, i.e. they undergo a reorientation to other markets (or segments) or they went

Figure 5 Linear model of convergence (partly adapted from Hacklin's (2008) cyclic model).



bankrupt. The chemical company BASF has for instance acquired an equity ownership position for \$50 million in the US battery company SION Power and acquired the US company Ovonic Battery for \$58 million (BASF, 2012a; BASF, 2012b). According to Frank Bozich, President of BASF's global catalysts division, the acquisition aims to support BASF's strategy to become the "leading provider of functional materials and components to serve cell and battery manufacturers worldwide" (BASF, 2012a). Another example reflecting this phase is this year's acquisition of all non-government business assets of the financially stricken US battery company A123 Systems by Wanxiang America Corp. (A123, 2013). Previously, Johnson Controls acquired A123's automotive business assets, including all of its automotive technology, products, and customer contracts in a transaction valued at \$125 million (A123, 2012). After the phase of consolidation, in phase IV, a new industry structure (or industry segment structure) emerges and the convergence process is completed.

### 3.3 Anticipation of convergence

Market and industrial change is considered to be a key source of innovation (Drucker, 1998). Hence, it is especially relevant for incumbent firms to monitor a potential convergence process in their industry and prepare as early as possible for such a radical change of their environment. However, according to Cohen and Levinthal (1990) and Trott (1998), only a few firms are able to scan their environment. It is therefore useful to provide the management of firms with a "scanning-tool" that allows firms to anticipate a possible convergence process in their industry. Such an anticipation method for science and technology convergence has been developed by Curran *et al.* (2010) on the basis of publicly available data. As mentioned in the previous section, science convergence can be observed by means of interdisciplinary research collaborations. When researchers from different science areas collaborate, research results are jointly published in scientific journals. Co-citations and co-authorships can indicate science convergence, as researchers conduct research interdisciplinary and start to cite publications from other science disciplines. When the process of convergence proceeds, signs of technology convergence have to be examined. Patents have a stronger technological focus than other publications and are considered to be a key competitive advantage in technology intense industries (Hall, 1993; Newbert, 2008). When technology-areas converge and new technology-bases emerge, firms start to patent outside their traditional

expertise. Therefore the analysis of patent-activities outside the knowledge-base of a firm, co-authorships and co-classifications (international patent classifications for example) are a suitable way to identify signs of technology convergence.

## 4 Methods

To detect signs of a beginning convergence process between the automotive and the chemical industry in the field of electric cars, a bibliometric search-term-based-analysis of scientific publications and patents was used in this study. "Lithium-ion battery/batteries" (covering existing lithium battery technologies), and "lithium battery/batteries" (covering future lithium-based technologies, like lithium-air- or lithium-sulfur-batteries) were used as search terms in SciFinder® and PatBase® in the period from 1990 to 2009. SciFinder® is a web-program provided by the Chemical Abstract Service (CAS) that has access to more than 33 million scientific publications in over 10,000 journals, and patent documents from 63 patent authorities. For providing a high quality of analysis, only reviewed journal articles were analyzed; excluding letters, commentaries, and reports. Because SciFinder® is not designed for extensive statistical patent-analysis<sup>3</sup>, a program designated for patent analysis was additionally used. PatBase® is a patent-analysis-tool provided by Minesoft Ltd and RWS Group that has access to more than 45 million patent-families from 95 patent authorities. Patent families are "a group of patents which, like a family, are all related to each other, in this case by way of the priority or priorities of a particular patent" (EPO, 2011).

For the analysis, two industry-samples were formed: The first sample ('A-sample') includes the 25 largest automotive manufacturing firms (based on the number of produced cars in 2008), as well as the 25 largest automotive suppliers (based on the worldwide revenue of 2008). It is assumed that those 50 companies can play a leading role in the future car market. The chemical industry sample ('C-sample') includes 70 companies that have been identified by Lowe *et al.* (2010) to be the most active companies in the field of lithium batteries for electric cars; starting with raw material suppliers and ending with major battery cell producers. An overview of the firms can be found in appendix 1.

## 5 Results

### 5.1 SciFinder®

The first published scientific articles and patent-

<sup>3</sup>) SciFinder® includes granted patents as well as patent applications that only be analyzed together as so called patent documents.

Figure 6 Development of scientific articles and patent documents on lithium batteries in the period of 1990-2009.

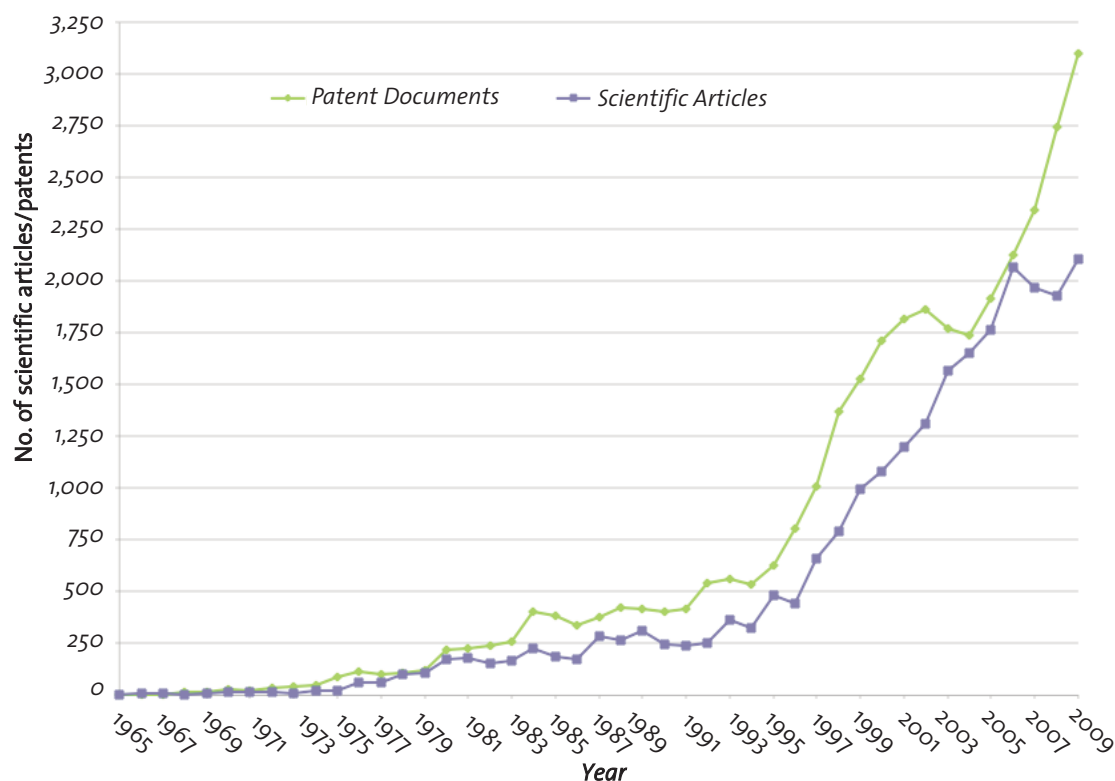


Table 1 Scientific articles published from A-sample firms 1990 and 2009 (most active firms).

Automotive manufacturers		Automotive suppliers	
Company	No. of scientific publications	Company	No. of scientific publications
Mitsubishi	68	Hitachi	48
General Motors	28	Sumitomo	17
Toyota	25	Bridgestone	3
Nissan	9	Johnson Controls	2
Honda	8	TRW Automotive	2
...	...	...	...
Others	13	Others	1
<b>Total No. of publications</b>	<b>151</b>		<b>73</b>
<b>Share on all publications in %</b>	<b>0.70</b>		<b>0.34</b>

Table 2 Scientific articles published from C-sample firms between 1990 and 2009 (most active firms).

Chemical companies			
Company	No. of scientific publications	Company	No. of scientific publications
Saft	84	Valence Technology	46
Panasonic	82	Toshiba	34
Samsung	80	Osaka Gas Chemical	33
Yardney	58	Asahi Kasei	24
Sanyo Electric	53	LG Chem	24
Others	110		
<b>Total No. of publications</b>	<b>628</b>		
<b>Share on all publications in %</b>	<b>2.93</b>		

documents covering the topic of lithium batteries can be tracked back to the year 1965. Since the early 1990s, one can observe a substantial increase in the publication, as well as patenting activity. After removing duplicate entries, the search in SciFinder® resulted in 21,451 scientific articles and 28,940 patent documents in the period from 1990 to 2009.

As expected, the field of scientific publications is dominated by universities and research institutions. Firms from the A-sample published 224 articles between 1990 and 2009, i.e. 1.04% of all scientific publications on lithium batteries in this period. All firms from the A-sample together have fewer publications in 20 years than the Central South University of China – the organization with the highest number of publications in the analysis – in 4 years. Within the sample, car manufacturers, especially Mitsubishi and Toyota, publish more (151 articles) than the automotive suppliers (73 articles). Table 1 shows the most active firms from the A-sample. Sample-firms published almost only in chemistry journals, e.g. *Journal of Power Sources*, whereas only 5% of the articles are published in automotive journals, e.g. *Journal of the Society of Automotive Engineers of Japan* (see appendix 2 for a list of journals).

The 70 firms of the C-sample published 628 scientific articles in the period from 1990 to 2009, resulting in a share of 2.93% of all scientific publications on lithium batteries in this period. How-

ever, 36 firms of the C-sample have not published any articles. The highest number of publications are mainly assigned to companies from Asia, like Panasonic or Samsung, only two US-companies (Yardney, Valence Technology) and one EU-company (Saft - Société des Accumulateurs Fixes et de Traction) are part of the top 10 (see table 2). The three firms with the highest number of research articles primarily publish in chemistry journals (83%) and belong to the tier-1-level (battery, battery-system).

The number of filed patents is, compared to scientific articles, preferably used to determine the commercialization activities in one field. Within the 50 organizations that filed most lithium battery patent documents between 2006 and 2009 are 41 companies and only 4 research institutions (Central South University, Fudan University, Tsinghua University, Korea Electro Technology Research Institute). Not one university appears among the top patent applicants before the year 2000.

Furthermore the analysis in SciFinder® shows that firms from the automotive industry have increased their patent activities in the field of lithium batteries over the past 20 years. Between 1990 and 2000, only two automotive firms are among the top-50 patent applicants, whereas nine automotive firms show high activity from 2006 to 2009. 48% of all patent documents on lithium batteries in the period from 1990 to 2009 belong to the 120

Table 3 Patent documents filed by A-sample firms between 1990 and 2009 (most active firms).

Automotive manufacturers		Automotive suppliers	
Company	No. of patent documents	Company	No. of patents documents
Mitsubishi	1,310	Hitachi	1,218
Toyota	716	Sumitomo	595
Nissan	331	Denso	192
Fuji (Subaru)	53	Bridgestone	114
Honda	45	Delphi	15
...	...	...	...
Others	40	Others	33
<b>Total No. of patent documents</b>	<b>2,493</b>		<b>2,167</b>
<b>Share on all patent documents in %</b>	<b>8.61</b>		<b>7.49</b>

Table 4 Patent documents filed by C-sample firms between 1990 and 2009 (most active firms).

Chemical companies			
Company	No. of patent documents	Company	No. of patent documents
Panasonic	2,495	Mitsui Group	407
Sanyo Electric	1,581	BYD	320
Samsung	1,443	Ube Industries	209
Toshiba	874	Toray Industries	142
LG Chem	485	Valence Technology	142
Others	1,196		
<b>Total No. of patent documents</b>	<b>9,294</b>		
<b>Share on all patent documents in %</b>	<b>32.11</b>		

Figure 7 Number of patent documents on lithium batteries in the period of 1990-2009 by C-sample-firms divided by home country of the company

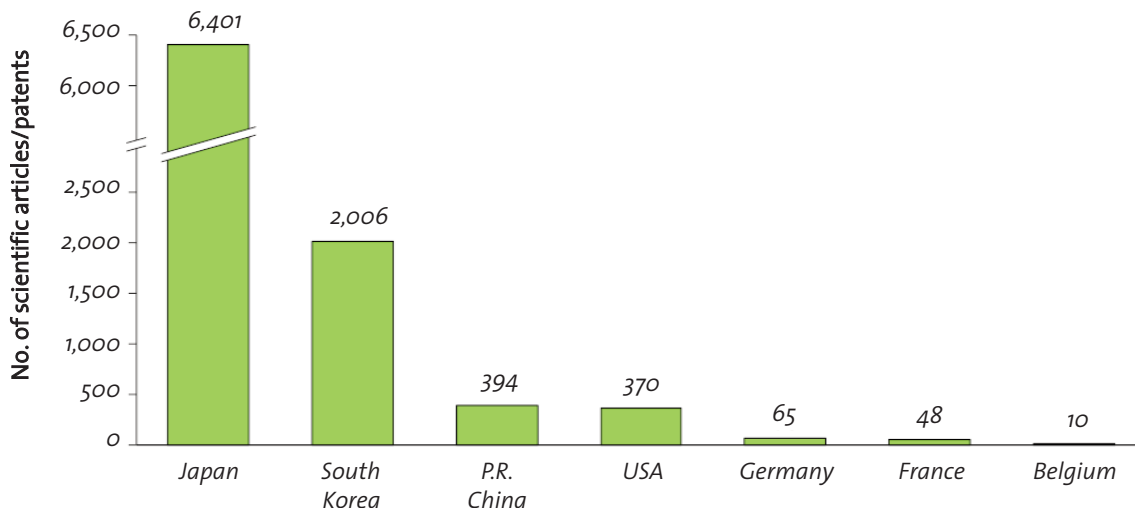
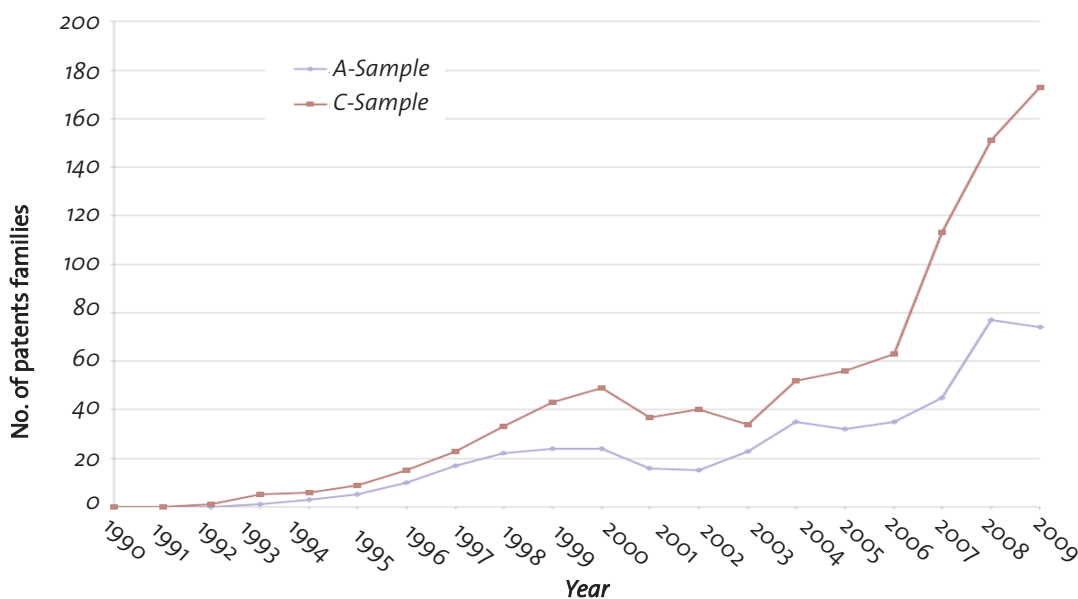


Figure 8 Number of patent families on lithium batteries in the period of 1990-2009 by sample-firms, source.



firms from the A- (16%) and C-sample (32%), indicating a high activity in patenting on battery technologies in contrast to the low share of scientific articles.

As can be seen in table 3, automotive manufacturers from Japan, like Mitsubishi, Toyota and Nissan, have a very strong position in respect to the number of filed patents on lithium battery-technologies. Other manufacturers have less than 10 or no patent documents on lithium batteries. A

similar situation can be observed on the side of automotive suppliers where a few firms from Japan have top positions in the ranking.

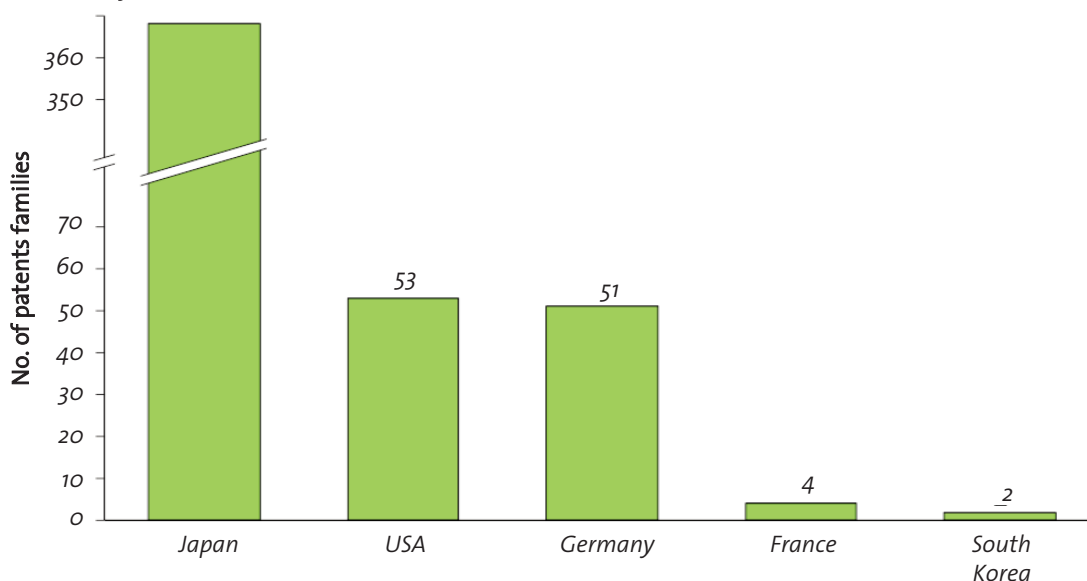
Firms from the C-sample hold 9,294 patents. Among the 20 most active companies of the C-sample are 13 from Asia (Panasonic, Sanyo Electric, Samsung, Toshiba, and LG Chem). Valence Technologies, 3M, and A123 are the firms from the US, while Saft, BASF, and Evonik Industries are the European firms with the highest number of patent docu-



Table 5 Patent families by A-sample firms between 1990 and 2009 (most active firms).

Automotive manufacturers		Automotive suppliers	
Company	No. of patent families	Company	No. of patent families
Toyota	71	Sumitomo Group	102
Mitsubishi	55	Hitachi	54
Nissan	43	Delphi	19
General Motors	16	Bosch	14
Chrysler	15	Denso	14
...	...	...	...
Others	40	Others	15
<b>Total No. of patent families</b>	<b>240</b>		<b>218</b>
<b>Share on all patent families in %</b>	<b>5.01</b>		<b>4.55</b>

Figure 9 Number of patent families on lithium batteries from A-sample firms in the period of 1990-2009 divided by country.



ments. Table 4 and figure 7 show the results of the C-sample-analysis.

## 5.2 PatBase®

The analysis in PatBase® in the period from 1990 to 2009 results in 4,789 patent families on lithium battery technologies. Within the 50 organizations

with the highest number of patent families are 47 companies and only 3 research institutions (Fudan University (P.R. China), Institute of Physics of the Chinese Academy of Science (P.R. China), and the Centre National de la Recherche Scientifique (France)).

Firms from the two industry-samples have a share of 30% (1,316) on all patent families on lithi-

Table 6 Patent families by C-sample firms between 1990 and 2009 (most active firms).

Chemical companies			
Company	No. of patent families	Company	No. of patent families
Samsung	155	LG Chem	44
BYD	147	Valence Technology	29
Lishen Battery	145	3M	24
Panasonic	65	SBS	21
Sanyo Electric	64	Evonik Industries	17
Others	192		
<b>Total No. of patent families</b>	<b>903</b>		
<b>Share on all patent families in %</b>	<b>18.86</b>		

um battery technologies. Within the A-sample, automotive manufacturers hold 240 patent families (5.01%) and automotive suppliers 218 (4.55%). The analysis of the C-sample results in 903 patent families, which corresponds to a share on all patent families of 18.86%. As can be seen in figure 8, firms from the A-, as well as from the C-sample have increased their patenting activity between 1990 and 2009.

Within the A-sample, Honda and Nissan are the car manufacturers with the highest number of patent families, while Sumitomo and Hitachi, as well as the US-company Delphi hold a main share of patent families assigned to automotive suppliers. Table 5 shows the most active firms and figure 9 a cross-country comparison.

The analysis of the C-sample in PatBase® shows – in line with the results from the analysis in SciFinder® – that firms from Asia hold the highest number of patent families on lithium battery technologies. But, compared to the results in SciFinder®, Chinese companies are more active than Japanese companies. Table 6 shows a list of the firms with the highest number of patent families on lithium battery technologies.

## 6 Discussion

The analysis in SciFinder® shows a substantial increase in the number of publications and patent documents over the last 15 years, confirming the

increasing attention of firms and research institutions on lithium battery technologies. Additionally, the number of patent documents per year is constantly higher than the number of scientific publications per year, indicating a strong tendency to commercialize lithium battery technologies.

As expected, public research institutions dominate regarding the number of scientific publications. Research organizations from China take a notably leading position in the number of scientific articles, which underlines the importance of emerging markets as mentioned in section 2. Although from this quantitative leading position one cannot *per se* deduce on qualitative knowledge leadership, the ‘national distribution’ of knowledge and expertise should, against the background of convergence, not be underestimated. The results from the analysis of the A- and C-sample show that not only chemical companies publish in chemistry journals, automotive companies do so as well – an area that does neither belong to their core competences nor their traditional knowledge base. This might be a first sign of convergence. However, the small number of discovered articles in the analysis reduces the validity of this statement. The results of the patent analysis in SciFinder® show an increasing activity of automotive firms in patenting lithium battery technologies, whereby only few large Japanese conglomerates (*keiretsu*), e.g. Mitsubishi and Sumitomo, are responsible for this trend. One should note that those firms are not only automotive

manufacturers or suppliers, but also have a chemical business like Mitsubishi Chemical in case of the Mitsubishi Group. It was not possible to separate between different business units of one company in this analysis. However, one can assume that patents from one business unit can relatively easily be used in another belonging to the same company. The mentioned assortment of different business units in those conglomerates can be seen as an advantage in the case of electric mobility as more steps of the value chain are covered by one entity.

In line with the results from SciFinder<sup>®</sup>, the analysis in PatBase<sup>®</sup> shows an increasing patent activity on lithium batteries from 1990 to 2009. Especially since 2006, automotive firms have substantially increased their activities in this field. The analyzed firms start to adapt to a new technology base. By moving to a new position, automotive firms also start to compete with established battery producers from the chemical industry. An increasing patent activity across traditional knowledge boundaries, like in the case of the analyzed sample firms, characterizes the transition from science convergence to technology convergence described by Hacklin (2008), showing technology innovations, protected by patents, become more and more important.

The findings show that firms from the automotive and chemical industry have started to increase their publication and patent activities in the segment of battery electric vehicles significantly. Especially in the case of automotive firms, one can observe that they have started to develop a new knowledge- and technology-base outside their traditional knowledge and technology boundaries. Automotive firms act outside their vertical industry boundaries. Using the described linear model of convergence, this activity shows a beginning diffusion of the vertical integrated value chains of the automotive and chemical industry. On the one side this evolution might bring up new entrants that compete with existing firms and challenge their position. And on the other side new collaborations, especially for innovation, can be formed, and new possibilities for value creation occur. The development of new business models, involving horizontal diversification between industry boundaries as well as vertical specialization, can be part of the transformation process, resulting in a period of consolidation, including mergers and acquisitions.

The methodology applied here has some limitations: (1) Search-word-based analyses have some general limitations as selected search terms may have been too broad to cover specific technology developments, or they may not cover all relevant

documents, e.g. patents that only have been published in Chinese or Japanese. However, more restrictive search terms might prevent the detection of weak signs of convergence at early stages. Moreover, the choice of the database is also a critical factor – for this study, a chemistry-related database (SciFinder<sup>®</sup>) and not an engineering-related one was used. (2) The formation of the two industry samples may not cover all relevant firms that are involved in the electrification of the automotive powertrain. For example small start-ups with an excellent knowledge or technology base might have been overlooked. (3) In the applied method only quantitative data have been analyzed whereby the quantitative number of publications or patents allows no general conclusion on the quality of these data. Additionally, there are reasons for a firm not to protect certain technologies by patents (Ernst, 1996).

Furthermore, it is important to mention that the presented tool can only indicate signs of convergence, but it cannot be used to *forecast* future markets.<sup>4</sup> Furthermore, even if, like in the case of electric mobility, signs of convergence can be detected and examples from practice can be associated with one of the phases of the convergence model, like in section 3.2, one cannot predict that industry segments will finally converge. Thus, in the context of this paper, there is no guarantee that segments of the automotive and chemical industry will really converge. It is only possible to show that signs of science and technology convergence exist, but it is not possible to forecast a future market for electric vehicles or to be sure that these industry segments will overlap at some point in the future. Only an ex-post analysis can reveal the whole convergence process; like Hacklin (2008) did in case of the ICT-industry. The dilemma of seeing industry convergence while only signs of science and technology convergence are detected is something that can be framed the “convergence trap”. Thus, companies should not trap into the perception that technology convergence leads automatically to industry convergence.

## 7 Implications

In this paper, a beginning convergence process between the automotive and the chemical industry in the segment of battery electric vehicles was investigated. Findings show first signs of science and technology convergence in this segment – firms from the automotive industry have identified the cross-sectoral application of battery technologies, which points to a certain degree of fading boundaries between automotive and chemical indus-

<sup>4</sup> As Christensen et al. explain it: “markets that do not exist cannot be analyzed” (2003: 5)

try. Based on a linear model of convergence it is possible to deduce basic managerial implications for firm's strategic and innovation management:

- Established automotive firms must search for opportunities to diversify horizontally, including collaborations for innovation with battery and cell producers, as well as possible ways to specialize vertically. This ambidextrous situation is challenging (He and Wong, 2004; Kortmann, 2011; Bauer and Leker, 2013). On the one side, firms have to focus on the exploitation of existing technologies and on the other side, firms must openly explore completely new ways of doing business, search for innovation partnerships outside their traditional expertise, and substitute existing competences. Therefore one can assume that innovation management becomes a portfolio business.
- Automotive and chemical firms from Asia, especially Japan, have a strong position with regard to patents. Firms from the United States and Europe must search for possible collaboration partners not only on an inter-industry-level, but also internationally.
- The development of non-linear thinking (Stevens et al., 1999) during the innovation process becomes more and more important. While existing industry boundaries blur, it becomes necessary to foster thinking outside firm's knowledge base. Automotive firms must reorganize their knowledge management, e.g. proactively support their engineering departments to collaborate with battery experts from academia.
- Business model innovations are part of the convergence process. Therefore it becomes even more important for incumbent firms to (continuously) re-think and reinvent their business model if necessary (von Delft and Kortmann, 2013). For instance, BASF has adapted its organizational structure in 2013 by reorganizing its functional materials business segment. Part of this segment is BASF's new battery chemistry unit. According to Kurt Bock, Chairman of BASF's Board of Executive Directors, in "the new organization, the bundling of product groups with the same business model will help management to better focus on the success factors necessary to be a market leader both in meeting customer's needs and in operational excellence." (BASF, 2012c). Understanding, working, and experimenting with a firm's business model will be essential for incumbent firms, especially in times of market convergence.
- The improvement of battery performance is still a major challenge in the development of electric cars. In collaborative innovation platforms of automotive and chemical firms, risk management becomes more important, because the

technological uncertainty in the segment of electric vehicles is still high, making abort decisions in innovation projects more difficult.

Notwithstanding the findings of the analysis, a closer look at a potential convergence of automotive and chemical industry in the segment of electric vehicles is necessary. Future research could for example analyze co-authorships and co-classifications of articles and patents in the segment of electric vehicles, or analyze collaborations between automotive and chemical firms in detail to confirm the detected signs of convergence in this work. To support the given implications and deduce further management implications case studies, similar to those applied in the development of Hacklin's model of convergence, could also contribute to this field of future research.

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## References

- A123 (2012): *A123 Systems reaches agreement to sell automotive business assets to Johnson Controls*, available at <http://www.a123systems.com/db09dea4-181a-43d4-9974-cc67d51bc3bc/media-room-2012-press-releases-detail.htm>, accessed 01 May 2013.
- A123 (2013): *Update: Wanxiang America Corp. acquires substantially all of A123 System, Inc.'s non-government business assets*, available at <http://www.a123systems.com/about-us-asset-purchase-agreement-and-chapter-11-filing.htm>, accessed 21 May 2013.
- Abernathy, W. J., Utterback, J. (1978): Patterns of industrial innovation, *Technology Review*, **80** (7), p. 40–47.
- Anderson, P., Tushman, M. L. (1990): Technological discontinuities and dominant designs: A cyclical model of technological change, *Administrative Science Quarterly*, **35** (4), 604–633.
- Bally, N. (2005): Deriving managerial implications from technological convergence along the innovation process: A case study on the telecommunication industry, in: MEMO-STENCIL, Preliminära Forskningsrapporter, Åbo, Finland: Åbo Akademi School of Business.
- BASF (2012a): *BASF invests \$50 million to acquire*

- equity ownership position in Sion Power, available at <http://www.basf.com/group/pressrelease/P-12-105>, accessed 01 May 2013.
- BASF (2012b): *BASF acquires Ovonic Battery Company, the global leader in NiMH battery technology*, available at <http://www.basf.com/group/pressrelease/P-12-140>, accessed 01 May 2013.
- BASF (2012c): *BASF optimizes its organizational structure*, available at <http://www.basf.com/group/pressrelease/P-12-495>, accessed 01 May 2013.
- Bauer, M., Leker, J. (2013): Exploration and exploitation in product and process innovation in the chemical industry, *R&D Management*, **43** (3), 196–212.
- Becks, T., De Doncker, R., Karg, L., Rehtanz, C., Reinhardt, A.-M., Willums, J.-O. (2010): *Wegweiser Elektromobilität*, Berlin/Offenbach, VDE.
- Bierly, P. E., Chakrabarti, A. K. (2001): Dynamic knowledge strategies and industry fusion, *International Journal of Manufacturing Technology and Management*, **3** (1/2), 31–48.
- Blesl, M., Bruchof, D., Hartmann, N., Özdemir, D., Fahl, U., Eltrop, L., Voß, A. (2009): Entwicklungsstand und Perspektiven der Elektromobilität, Institute of Energy Economics and the Rational Use of Energy of the University of Stuttgart, Stuttgart (Germany).
- Booz & Company (2009): China's automotive opportunity leading the transition to new energy vehicles.
- BCG - Boston Consulting Group (2010): Batteries for electric cars – Challenges, opportunities, and the outlook to 2020.
- Bröring, S. (2005): *The front end of innovation in converging industries: The case of nutraceuticals and functional foods*, Wiesbaden (Germany), DUV.
- Bröring, S., Cloutier, L. M., Leker, J. (2006): The front end of innovation in converging industries: Evidence from nutraceuticals and functional foods, *R&D Management*, **36** (5), 487–498.
- Canzler, W.; Knie, A. (2010): Elektromobilität: Innovationen nur in vernetzter Form, *WZBrief Arbeit*, (08.10.2010), p. 1–7.
- Capgemini (2009): Electric vehicles: A force for the future.
- CER – China Economic Review (2010): *Audi sets up joint lab with Tongji*, available at <http://www.chinaeconomicreview.com/node/45634>, accessed 01 May 2013.
- Choi, D., Välikangas, L. (2001): Patterns of strategy innovation, *European Management Journal*, **19** (4), p. 424–429.
- Christensen, C. M., Raynor, M. E., Anthony, S. D. (2003): Six keys to creating new-growth businesses, *Harvard Management Update*, **8** (1), p. 3–6.
- Cohen, W. M., Levinthal, D. A. (1990): Absorptive capacity: A new perspective on learning and innovation, *Administrative Science Quarterly*, **35** (1), 128–152.
- Curran, C. S., Leker, J. (2009a): Employing STN Analyst to forecast converging industries, *International Journal of Innovation Management*, **13** (04), p. 637–664.
- Curran, C.-S., Leker, J. (2009b): Seeing the next iPhone coming your way: How to anticipate converging industries, PICMET (Portland International Center for Management of Engineering and Technology) '09 Conference: 'Technology Management in the Age of Fundamental Change', Portland, USA, 02.-06.08.2009.
- Curran, C. S. (2010): *The anticipate of converging industries: A concept applied to nutraceuticals and functional foods*, Münster.
- Curran, C. S., Bröring, S., Leker, J. (2010): Anticipating converging industries using publicly available data, *Technological Forecasting and Social Change*, **77** (3), 385–395.
- Curran, C. S., Leker, J. (2011): Patent indicators for monitoring convergence – Examples from NFF and ICT, *Technology Forecasting and Social Change*, **78** (2), 256–273.
- Deutsche ACCUmotive (2013): Gründung, available at <http://www.accumotive.de/de/gruendung.html>, accessed 01 May 2013.
- Deutsche Bank (2009): Electric cars: Plugged in 2 – A Mega-theme gains momentum.
- Drapcho, C. M., Nhuan, N. P., Walker, T. H. (2008): *Bio-fuels engineering process technology*, New York, McGraw-Hill.
- Drucker, P. F. (1998). The discipline of innovation, *Harvard Business Review*, **76** (6), 149–157.
- Duke, M., Andrews, D., Anderson, T. (2009): The feasibility of long range battery electric cars in New Zealand, *Energy Policy*, **37**, 3455–3462.
- Duysters, G., Hagedorn, J. (1998): Technological convergence in the IT industry: The role of strategic technology alliances and technological competencies, *International Journal of the Economic of Business*, **5** (3), p. 355–368.
- EPO - European Patent Office (2011): *Patent families*, available at [http://ep.espacenet.com/help?locale=en\\_EP&method=handleHelpTopic&topic=patentfamily](http://ep.espacenet.com/help?locale=en_EP&method=handleHelpTopic&topic=patentfamily), accessed: 29. October 2011.
- Ernst, H. (1996): *Patentinformationen für die strategische Planung von Forschung und Entwicklung*, Wiesbaden (Germany), Deutscher Universitäts-Verlag.
- German Federal Government (2009): National Platform Electric Mobility.
- Hacklin, F. (2008): *Management of convergence in innovation*, Heidelberg, Springer.

- Hacklin, F., Marxt, C., Fahrni, F. (2009): Coevolutionary cycles of convergence: An extrapolation from the ICT industry, *Technology Forecasting and Social Change*, **76** (6), p. 723–736.
- Hall, R. (1993): A framework linking intangible resources and capabilities to sustainable competitive advantage, *Strategic Management Journal*, **14** (8), 607–618.
- Hitachi Maxell (2011): Plan to establish a new company in battery operations through corporate spin-off, [http://www.hitachi.eu/about/press/pdfs/20110127\\_03.pdf](http://www.hitachi.eu/about/press/pdfs/20110127_03.pdf), accessed 01. March 2013.
- He, Z. L., Wong, P. K. (2004): Exploration vs. exploitation: An empirical test of the ambidexterity hypothesis, *Organization Science*, **15** (4), 481–494.
- HUI – Helmholtz Institute Ulm (2011): Start für das Helmholtz-Institut Ulm, available at [http://www.hiu.kit.edu/83\\_152.php](http://www.hiu.kit.edu/83_152.php), accessed 01 May 2013.
- IEA – International Energy Agency (2009): Technology Roadmap – Electric and Plug-In Hybrid Electric Vehicles.
- Johnson, M. W., Christensen, C. M., Kagermann, H. (2008): Reinventing your business model, *Harvard Business Review*, **86** (12), 57–68.
- Karg, L., Reinhardt, A.-M. (2010): Zentrale Erfolgskriterien: Infrastruktur und Netzintegration, in: Becks, T. (ed.), De Doncker, R. (ed.), Karg, L. (ed.), Rehtanz, C. (ed.), Reinhardt, A.-M. (ed.), Willums, J.-O. (ed.), *Wegweiser Elektromobilität*, Berlin/Offenbach, VDE, p. 18–24.
- Katz, M. L. (1996): Remarks on the economic implications of convergence, *Industrial and Corporate Change*, **5** (4), p. 1079–1095.
- Kondratieff, N. D. (1979): The long waves in economic life, Review (Fernand Braudel Center), p. 519–562.
- Kortmann, S. (2012): *The Relationship between organizational structure and organizational ambidexterity*, Wiesbaden, Gabler.
- Lind, J. (2004): Convergence: History of term usage and lessons for firm strategists, ITS 15<sup>th</sup> Biennial Conference, Berlin, Germany.
- Li-Tec Battery (2013): *Li-Tec Battery GmbH*, available at <http://www.li-tec.de/unternehmen.html>, accessed 01. March 2013.
- Lowe, M., Tokuoka, S., Trigg, T., Gereffi, G. (2010): *Lithium-Ion batteries for electric vehicles: The U.S. value chain*, Center on Globalization, Governance & Competitiveness Duke University, Durham, USA.
- McKinsey & Company (2009): *McKinsey Quarterly - Climate Change Special Initiative: Electrifying cars: How three industries will evolve*, McKinsey & Company, p. 87–96.
- McKinsey & Company (2011). Boost! Transforming the powertrain value chain.
- MEET – Münster Electrochemical Energy Technology (2009): Ein großer Schritt in Richtung Elektromobilität, available at <http://www.uni-muenster.de/Rektorat/exec/upm.php?rubrik=Alle&neu=0&monat=200909&nummer=11987>, accessed 01 May 2013.
- Mikkola, J. H. (2001): Portfolio management of R&D projects: Implications for innovation management, *Technovation*, **21** (7), p. 423–435.
- Möller, A. (2010): *Wie Deutschland zum Leitanbieter für Elektromobilität werden kann: Status Quo – Herausforderungen - Offene Fragen*, acatech – Deutsche Akademie der Technikwissenschaften, Berlin/Heidelberg, Springer.
- Nag, A. (2008): *Biofuels Refining and Performance*, New York, McGraw-Hill.
- Newbert, S. L. (2008): Value, rareness, competitive advantage, and performance: a conceptual-level empirical investigation of the resource-based view of the firm, *Strategic Management Journal*, **29** (7), 745–768.
- Nyström, A.-G. (2008): Understanding change processes in business networks: A study of convergence in Finnish telecommunications 1985–2005, University of Turku, Turku, Finland.
- OECD (1992): Information Computer Communications Policy 29: Telecommunications and Broadcasting: Convergence or Collision?, OECD, Paris, France.
- Pennings, J. M., Puranam, P. (2001): Market convergence & firm strategy: New directions for theory and research, ECIS (Eindhoven Center for Innovation Studies) conference, The future of innovation studies, Eindhoven, Netherlands, 20.–23.09.2001.
- Pohl, H., Yarime, M. (2012): Integrating innovation system and management concepts: The development of electric and hybrid electric vehicles in Japan, *Technological Forecasting and Social Change*, **79** (8), p. 1431–1446..
- Roland Berger (2009): Powertrain 2020 – The future drives electric.
- Rosenberg, N. (1963): Technological change in the machine tool industry 1840–1910, *Journal of Economic History*, **23** (4), 414–443.
- Schill, W.-P. (2010): Elektromobilität in Deutschland – Chancen, Barrieren und Auswirkungen auf das Elektrizitätssystem, *Vierteljahrshefte zur Wirtschaftsforschung*, **79**, 139–159.
- Schumpeter, J. (1947): *Capitalism, socialism and democracy*, London, Allen and Unwin.
- Stevens, G., Burley, J., Divine, R. (1999): Creativity business discipline = higher profits faster from new product development, *Journal of Product Innovation Management*, **16** (5), 455–468.
- Theilen, F. (2004): *Geschäftsmodellbasiertes Konvergenzmanagement auf dem Markt für mobile Finanzservices*, Wien (Austria), Springer.
- Thielmann, A., Isenmann, R., Wietschel, M. (2010):

- Technologie-Roadmap Lithium-Ionen-Batterien 2030, Fraunhofer Institute for Systems and Innovation Research ISI, Karlsruhe (Germany).
- Tongji University (2010): "Audi-Tongji Joint Lab" founded in Tongji, available at <http://www.tongji.edu.cn/english/classid-61-newsid-33244-t-show.html>, accessed 12 December 2011.
- Trott, P. (1998): Growing businesses by generating genuine business opportunities, *Journal of Applied Management Studies*, **7** (4), 211–222.
- TUM – Technical University of Munich (2013): TUM CREATE opens new battery lab boasting regional firsts, available at <http://www.tum-create.edu.sg/press/news-detail/tum-create-opens-new-battery-lab-boasting-regional-firsts>, accessed 22 May 2013.
- Yoffie, D. B. (1997): CHES and competing in the age of digital convergence, in: Yoffie, D. B. (ed.), *Competing in the age of digital convergence*, Boston (MA), Harvard Business School Press, 1–36.
- van Bree, B., Verbong, G. P. J., Kramer, G. J. (2010): A multi-level perspective on the introduction of hydrogen and battery-electric vehicles, *Technological Forecasting and Social Change*, **77** (4), p. 529–540.
- von Delft, S., Kortmann, S. (2013): Neue Geschäftsmodelle – Neue Möglichkeiten, *Nachrichten aus der Chemie*, **61** (5), 545–547.
- Weaver, B. (2007): Industry convergence: Driving forces, factors and consequences, 19<sup>th</sup> NFF (Nordic Academy of Management) Conference, Bergen, Norway, 09.-11.08.2007.
- Weinert, J., Ogden, J., Sperling, D., Burke, A. (2008): The future of electric two-wheelers and electric vehicles in China, *Energy Policy*, **36**, 2544–2555.
- Werber, M., Fischer, M., Schwartz, P.V. (2009): Batteries: Lower cost than gasoline?, *Energy Policy*, **37**, 2465–2468.
- Winter, M., Besenhard, O. (1999): Wiederaufladbare Batterien – Teil II: Akkumulatoren mit nicht-wässriger Elektrolytlösung, *Chemie in unserer Zeit*, **33** (6), p. 320–332.
- Zhang, T., Gensler, S., Garcia, R. (2011): A study of the diffusion of alternative fuel vehicles: An agent-based modeling approach, *Journal of Product Innovation Management*, **28** (2), p. 152–168.
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## Appendix

Appendix 1 Industry sample (BE=Belgium, CI=Chile, DE=Germany, FR=France, IN=India, IT=Italy, JP=Japan, KS=South Korea, RU=Russia, US=USA).

Automotive manufacturers		Automotive suppliers	
Company name	Country	Company name	Country
Avtovaz	RU	Aisin Seiki	JP
Beijing Automotive	CN	Bosch	DE
BMW	DE	Bridgestone	JP
Chana Automobile	CN	Calsonic Kansei	JP
Chrysler	US	Continental	DE
Daimler	DE	Dana	US
Dongfeng	CN	Delphi	US
FAW	CN	Denso	JP
Fiat	IT	Faurecia	FR
Ford	US	Federal-Mogul	US
Fuji (Subaru)	JP	Goodyear	US
General Motors	US	Hitachi	JP
Honda	JP	Johnson Controls	US
Hyundai	KS	Lear	US
Isuzu	JP	Magna	CA
KIA Motors	KS	Magneti Marelli	IT
Mazda	JP	Mahle	DE
Mitsubishi	JP	Michelin	FR
Nissan	JP	Schaeffler	DE
PSA Peugeot Citroën	FR	Sumitomo	JP
Renault	FR	Toyota Boshoku	JP
Suzuki	JP	TRW Automotive	US
Tata Motors	IN	Valeo	FR
Toyota	JP	Yazaki	JP
Volkswagen	DE	ZF Group	DE



Chemical industry (including battery producers)			
Company name	Country	Company name	Country
3M	US	Nichia Corporation	JP
A123	US	Nihon Chemical	JP
AC Propulsion	US	Nippon Chemical	JP
All Cell Technologies	US	Novolyte Technologies	US
Altair Nanotechnologies	US	Osaka Gas Chemical	JP
Applied Materials	US	Panasonic	JP
Arkema	FR	Panex	KS
Asahi Kasei	JP	Polypore Industries (Celgard)	US
BASF	DE	Pyrotek	US
Boston Power	US	Quantum Technologies	US
BYD - Build Your Dream	CN	Saft	FR
Chemetall	DE	Samsung (Cheil Industries)	KS
Coda Automotive	US	Sanyo Electric	JP
ConocoPhillips	US	SBS - Storage Battery Systems	US
Dow Kokam	US	Seimi Chemical	JP
DuPont	US	Shan Shan	CN
Ener1 (EnerDel)	US	Shinestar	CN
Entek Membranes	US	SK Group	KS
Evonik Industries	DE	Stella	JP
FMC Lithium	US	SQM	CI
Furukawa Electric	JP	Süd-Chemie (Phostech)	DE
Future Fuel Corporation	US	Superior Graphite	US
Gelon	CN	Tanaka Chemical	JP
Honeywell	US	Tesla Motors	US
Kansai Catalyst	JP	Toda Kogyo	JP
Kansai Gas Kagaku	JP	Tomiyama Yakuhin	JP
Kanto Denka	JP	Toray Industries	JP
Kureha	JP	Toshiba	JP
L&F	KS	Tronox	US
LG Chem	KS	TSC Michigan	US
Lishen	CN	Ube Industries	JP
LitChem	US	Umicore	BE
LTC	US	Valence Technology	US
Maxpower	US	Yardney	US
Mitsui Group	JP	Zeon	JP

Appendix 2 Scientific journals with the highest number of articles in the period from 1990 to 2009 (results of the analysis in SciFinder).

Journal	Number of articles
Journal of Power Sources	1,171
Journal of the Electrochemical Society	461
Electrochimica Acta	444
Dianyuan Jishu	273
Electrochemistry Communications	243
Solid State Ionics	204
ECS Transactions	192
Electrochemical and Solid State Letters	192
Dianchi	180
Proceedings of the Power Sources Conference	171
Chemistry of Materials	153
Dianchi Gongye	146
Journal of Alloys and Compounds	140
Journal of Physical Chemistry C	104
Journal of Solid State Electrochemistry	88
Ionics	83
Wuji Huaxue Xuebao	77
Journal of Materials Chemistry	71
Gongneng Cailiao	64
Materials Chemistry and Physics	60
...	...
Others	3,621
<b>Total</b>	<b>8,138</b>



# Practitioner's Section

## Are you still comparing or already learning? Experience report of a Facility Management benchmarking for laboratory buildings

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The founding of the "IFMA Benchmarking® Research Group Chemistry, Pharma and Life Science" actually has its roots in the former professional association IFMA Deutschland e.V., which preceded the organization RealFM e.V.. The acronym was redesignated as „Industrial Facility Management Benchmarking“ and the right to this name was secured. With the founding of the research group in 2004, the goal was set to identify the most efficient concepts related to the special requirements of constructing and operating laboratory and office buildings in the chemical and pharmaceutical industry through benchmarking. The research group has grown to include 15 participating companies. The results of this long-standing and successful cooperation are being increasingly acknowledged outside of the research group and more and more inquiries from third party companies are being made. The present article entails key findings of our conducted benchmarking study.

### 1 The Concept

Upon beginning the work of the benchmarking research group all participants agreed that a thorough methodic preparation is the decisive factor for success. A particularly important part of this is the decision not to use benchmarking as a pure process of comparing figures, a practice which is unfortunately applied too often. The actual benchmarking, the analysis of the causes and the conditions for the expected deviations between the specific variables for each building should be in the focus point.

To reach these goals, a method developed by the „Bauakademie Gesellschaft für Forschung, Entwicklung und Bildung mbH“ for working in closed benchmarking pools (agito®-Method) was employed. The core of this method is a rare organization form of benchmarking in the industry by today's standards: The so-called benchmarking wheel: all participants in the benchmarking are familiar with each other and have set the goals and frame conditions of the benchmarking cooperatively. As opposed to the organization form of the benchmarking star, where the benchmark coordinator sets the

goals of the benchmarking and all participants are exclusively in contact with this coordinator, the participants of the benchmarking wheel have the opportunity to exchange information with each other. Only in this manner is the actual sense of the benchmarking evident: learning.

The benchmarking itself, which is continuously carried out in an anonymous manner in accordance with the competition law, is used by the participants to determine their own standing in a group of comparable companies. The main focus point of the work consists of Best Practice Workshops, where the participants discuss experiences and concepts in a structured environment. This moderated experience exchange continuously provides all participants with inspiration and potential for improvement. Solution methods that are widely accepted, the so called Good Operating Practices, are universally revised and are used by the participants as a guideline for developing company specific solutions

By starting from the basic situation of the participants before benchmarking, figure 1 illustrates the gaining of knowledge obtained during the benchmark process. Each participating company

Figure 1 Gaining of knowledge during the benchmarking process.

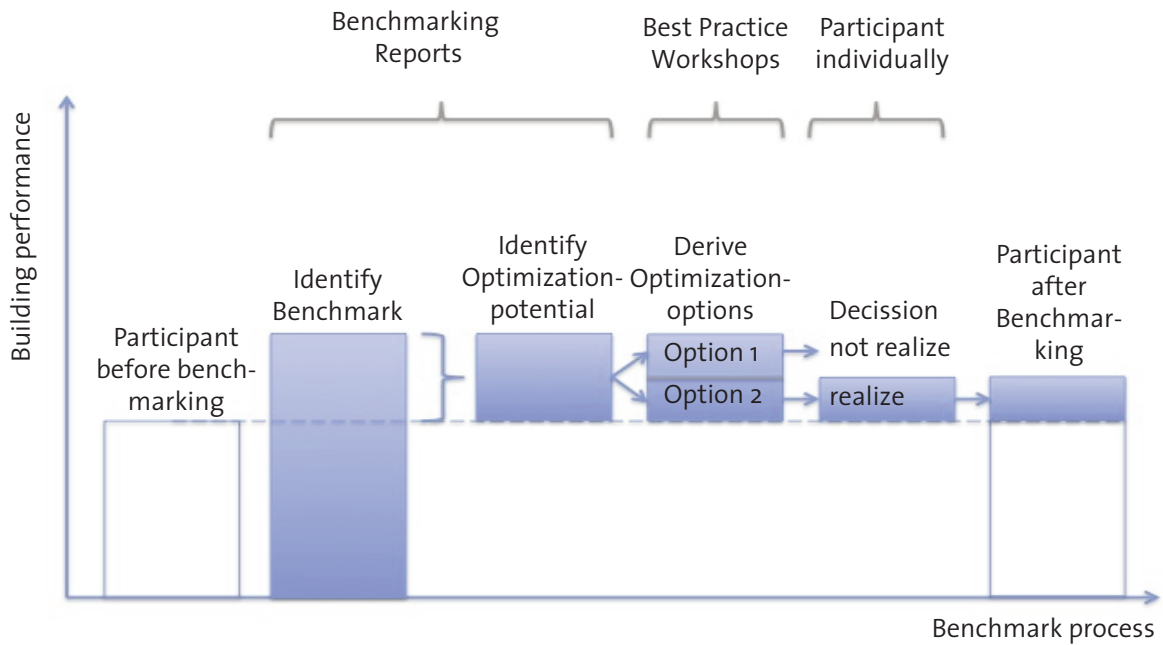
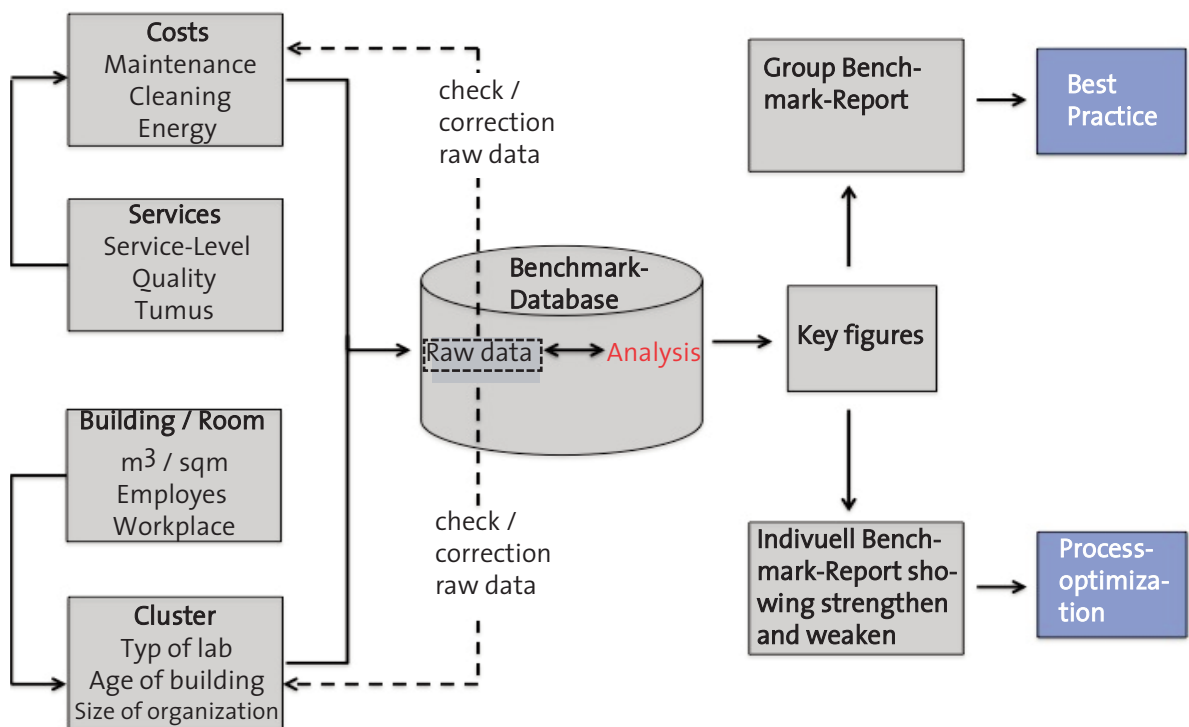


Figure 2 Data workflow during the benchmarking process.



receives its individual results and can deduce the theoretical optimization potential from the benchmarking report. Practical approaches as well as experiences concerning the optimization potential are exchanged as part of the best practice workshops. The participants take this basis to evaluate the options and decide which actions will be the most suitable ones for their firm. If the chosen measures are successfully implemented, an increase in quality and cost savings will derive for the participants at the end of the benchmark process.

All companies participating in the benchmarking have specific experiences which can be interesting and useful for other participants. Each participant regularly shares his own experiences with the group in Best Practice Workshops. There is no "Best Performer", who can no longer learn anything.

## 2 The Methodology

Important guidelines for carrying out the benchmarking were decided with the collectively refined methodic concept. Among these are:

- An efficient data entry using a special tool which eases the work of the employee responsible for the data acquisition. An entry tool which is intelligent, automatically indicates possible errors and gaps and enables a comparison with the data from the previous year.
- To ensure a high quality of data, all acquired primary data is subject not only to a plausibility check but also to additional special checks before being entered into the data pool.
- The Benchmark Coordinator provides each participant with the usual comparison overview and additionally an interactive evaluation tool with which the key data can be modeled and independent numerical and graphical evaluations can be carried out without compromising the anonymity of the data.

To meet these requirements and to comply with the competition law, the independent Benchmarking Coordinator, „Bauakademie Gesellschaft für Forschung, Entwicklung und Bildung mbH“, took over the tool development, the data management and the moderation of the Best Practice Workshops. The development of the tool includes the IT-technical creation and adjustments of the excel-based data collection and outcome reports according to the requirements, as well as the programming and maintenance of the benchmarking database.

Figure 2 entails the flow of information during the benchmarking process. The affected buildings and the associated performances of the respective facility management as well as the subsequently arising costs can be identified with the help of the data management tools. The relevant informa-

tion on the buildings are static data, which represent important reference values for establishing key indicators as well as for clustering the buildings.

## 3 The Data

There are 284 laboratory and office buildings with a total of approximately 2.604 Mio. m<sup>2</sup> of gross floor space in the data pool of the IFMA Benchmarking Research Group Chemistry, Pharma and Life Science. The buildings have a structural value of 5.372 bn EUR and provide a working place for 50,837 employees. This forms a solid basis for informative benchmarks. Even more important than the scope of the data pool in a benchmarking is the quality of the data contained in it. The comparability of the results requires a high level of homogeneity in the primary data. This is particularly relevant for the services related to the cost and consumption figures. As expected, satisfactory data homogeneity could only be achieved in the course of time in spite of comprehensive coordination and supporting measures. This can be recognized in the range between the minimum and maximum values of the acquired key data. The size of this difference can be used as an indicator for the quality of the data acquisition and of the total benchmarking.

Since the different types of laboratories differ greatly in their technical equipment and the intensity of use, a total of nine different laboratory types are considered. The largest portion with approximately two thirds of the laboratory space is occupied by chemical, application engineering and analytical laboratories. The data, however, also showed tendencies that are independent of the type of use. These tendencies include for example connections between the technical costs, the age of the building and the cycle of complex maintenance. The results confirm in an impressive way the meaning of life cycle considerations in Facility Management.

## 4 Selection of key figures

In the following, the key figures of the last benchmarking in 2012 are compared to the mean values of the last three and five years (figure 3, 5, 7 and 9). Next to the comparison over several years, a detailed illustration of the respective key figures (figure 4, 6, 8 and 10), which differentiates the current value of 2012 according to the share of the laboratory area, is shown in the diagram below. Furthermore, the average variation to each mean of a laboratory part is illustrated (area between the 0.25- and 0.75-quantile). Unless otherwise stated, the net floor area (NFA) represents the reference value

for all area-specific key figures.

#### 4.1 Productivity per area unit

In accordance with the German standard DIN 277, the average floor space (FS) ("Nutzfläche") required for each workstation (WS) accounts for about 23 sqm in office buildings and for about 41 sqm floor space in laboratories (see figure 3 and 4). Besides the office or the laboratory floor area, the useful area additionally includes sanitary spaces, meeting and recreation rooms.

#### 4.2 Infrastructural facility management

The costs of the infrastructural facility management comprise of the costs for services like gardening, housekeeping, facility cleaning and winter services. These costs have to lowest portion of the overall operating expenses. In the case of cleaning laboratory buildings, the significant share of the costs that is borne by the labor user has to be considered, as it is generally not recorded and thus not included in the key figure.

Figure 3 Floor area productivity in year comparison.

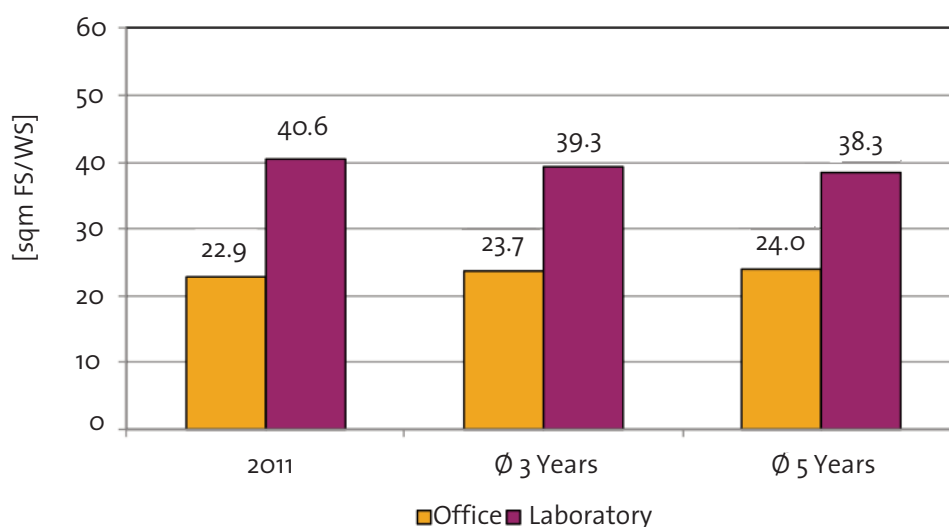
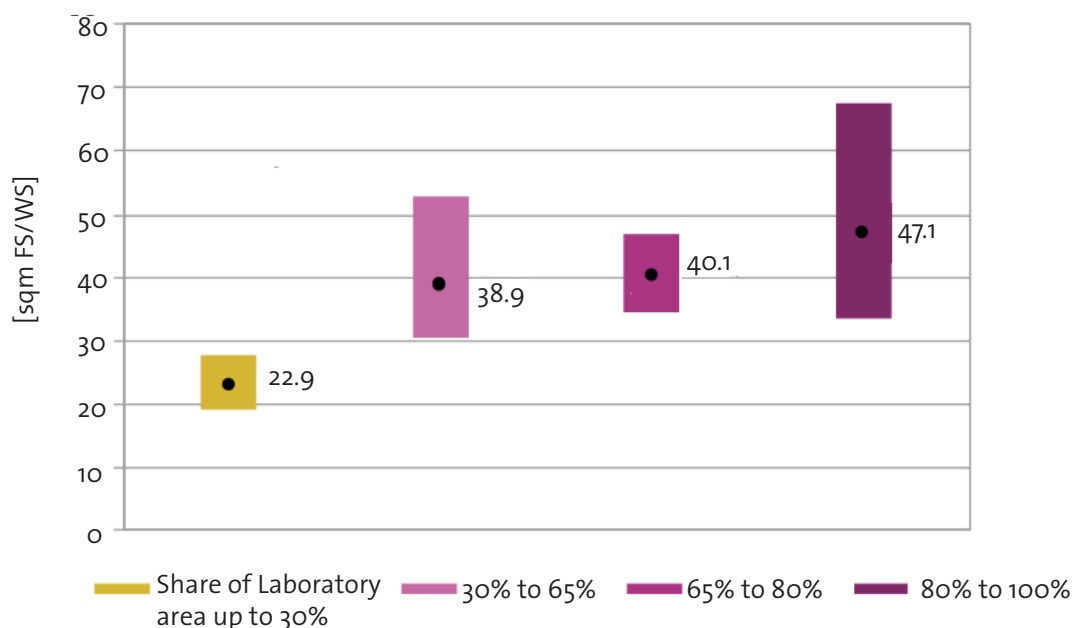


Figure 4 Floor area productivity in laboratory comparison.



### 4.3 Life cycle-oriented maintenance

The costs of the maintenance account for the second highest share of the overall expenditures and cover planned and corrective maintenance, only the expenses for user-specific laboratory equipment are excluded (see figure 7 and 8). The life cycle-oriented maintenance is a regularly topic in Best Practice Workshops whereby the search is focused on the "optimal" maintenance strategy. The group is currently working on a study including empirical values for maintenance and inspection inter-

vals of ventilation systems in laboratory buildings.

### 4.4 Energy supply and waste disposal

The costs of supply and disposal, depicted in figure 9 and 10, represent the largest share of the operating expenses. They include the costs of supply for power, heat, cooling, drinking water, desalinated water, process water, nitrogen and compressed air as well as municipal waste and waste water management.

The energy costs which are caused by the ener-

Figure 5 Facility Management softservices in year comparison.

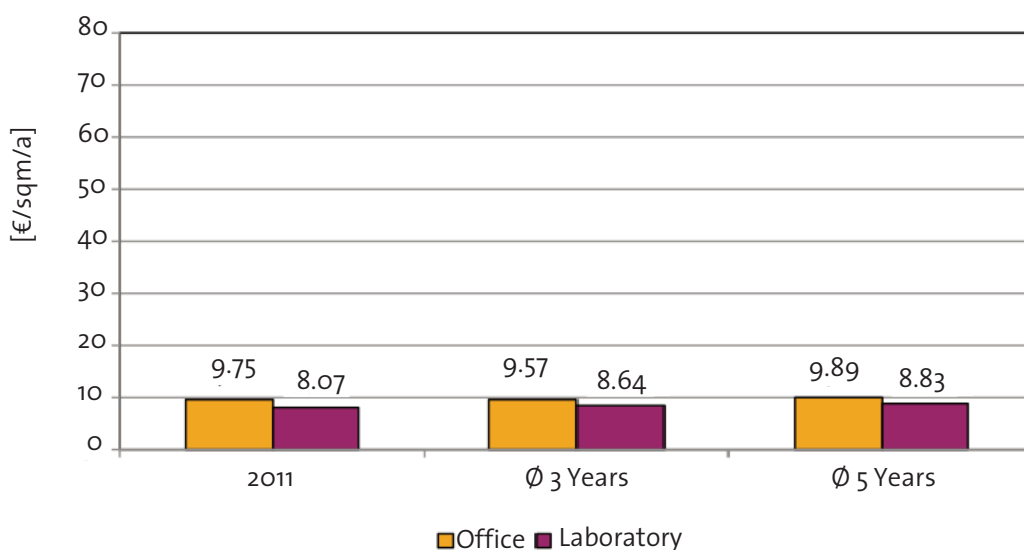
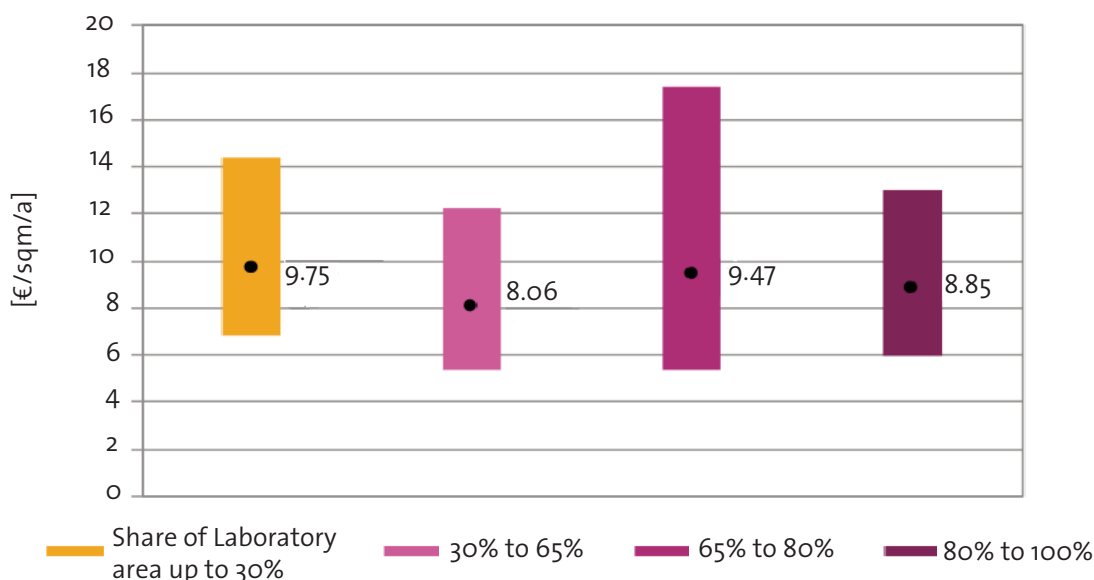


Figure 6 Facility Management softservices in laboratory comparison.





gy consumption for electricity, heat and cooling are illustrated in the figure 11 and 12.

### 5 The Good Operating Practices (GoP)

The emphasis within IFMA Benchmarking refers to Best Practice Workshops. These are designed to enable the discussion between the participants on experiences and optimization concepts for facility management. The structured exchange of knowledge leads to continuous inspiration for potential improvements. The approaches enjoying a broad

consensus, the so-called Good operating Practices (GOPs), are adapted to be universally applicable. These templates serve as guidelines for the development of company-specific solutions for the participants. A selection of GOPs is published.

#### 5.1 GoP "Energy efficiency"

A special interest for the representatives of the participating companies is the monitoring and improvement of the energy efficiency of laboratory buildings. The group has been involved with the

Figure 7 Maintenance costs in year comparison.

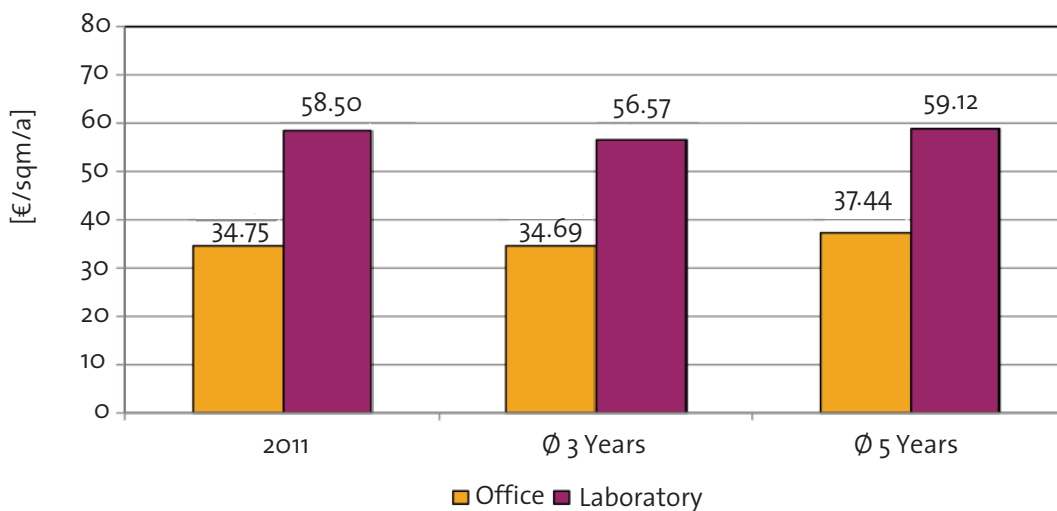
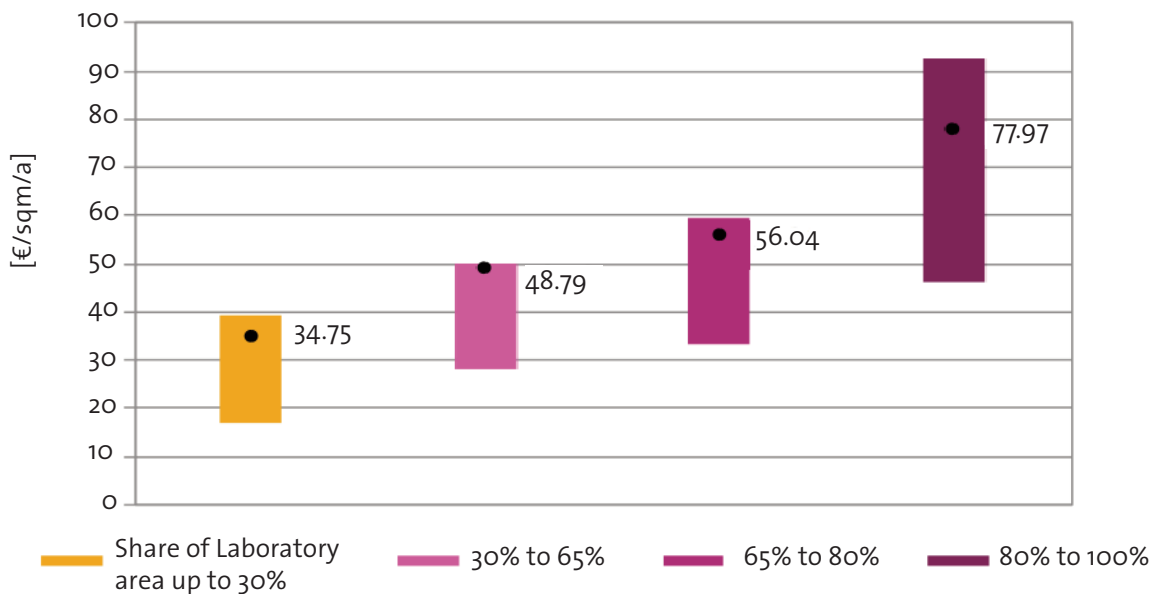


Figure 8 Maintenance costs in laboratory comparison.



acquisition of reference key figures for the energy consumption in laboratory buildings since 2007. This work can be traced back to an enquiry of the German Federal Office for Building and Construction ("Bundesamt für Bauwesen und Raumordnung") to collect data about energy consumption for the purpose of updating a German law to reduce the energy consumption of buildings in Germany ("Energieeinsparverordnung / EnEV").

Since it is well known that laboratory buildings have a high energy consumption based on their usage, the creating of specific energy benchmarks

is of great interest to the operators of these buildings. For this reason the research group investigated the factors which influence the energy consumption of laboratory buildings in a comprehensive empirical study.

A significant result of the study is that the energetic consumption of the laboratory buildings does not depend on the categorizing into various laboratory types (chemical, microbiological, analytic, etc.). It could be empirically proven that the median air exchange rate (AER) (distributed over the entire building) is the most influential factor rela-

Figure 9 Costs of energy supply and waste disposal in year comparison.

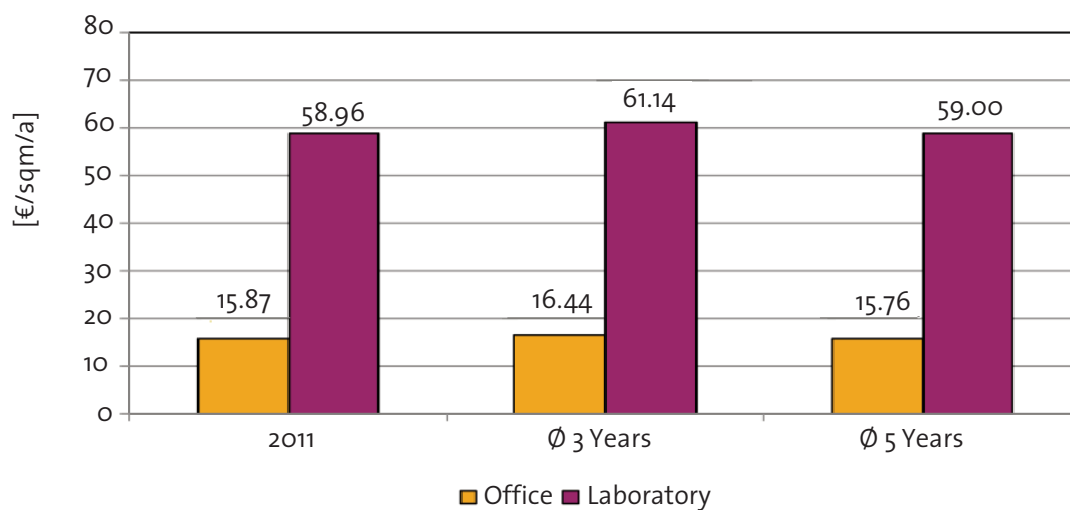
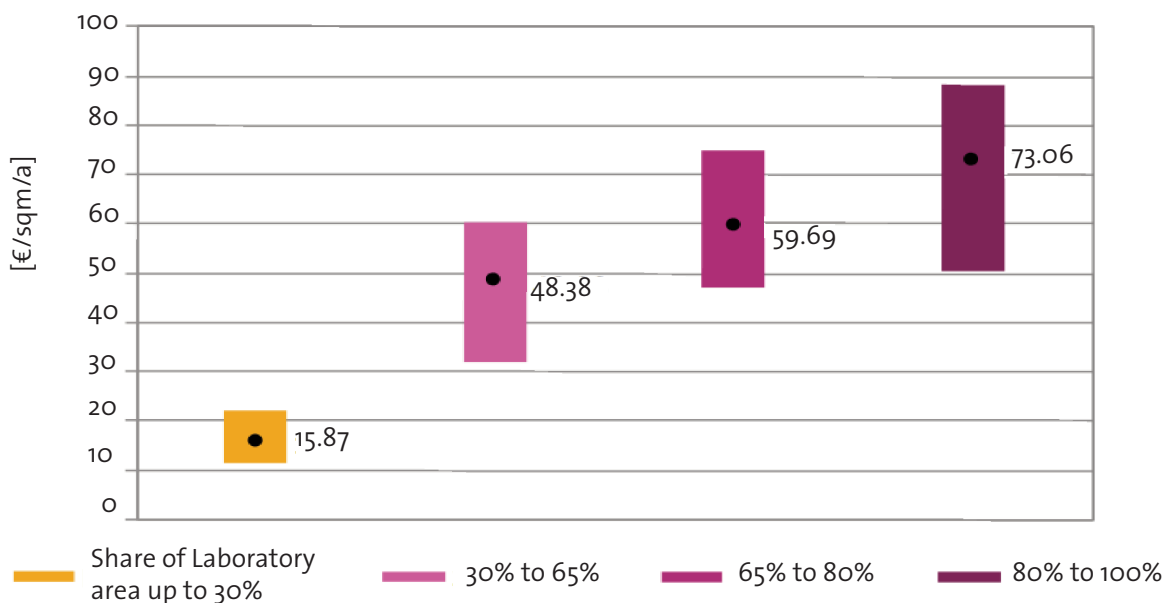


Figure 10 Costs of energy supply and waste disposal in laboratory comparison.



ted to energy consumption. Figure 13 entails the ascertained connection between the air renewal rate and the energy consumption.

This finding was then implemented in the german law to reduce the energy consumption of buildings in Germany ("Energieeinsparverordnung / EnEV") It is notable that the reference key figures of the energy consumption in the EnEV are indicated in the EnEV only as concrete numerical numbers in kWh/sqm. If, however, the air exchange rate of a laboratory building as a building specific parameter should be used in the determining of a reference key figure, then it must be separately calcu-

lated for each building. To make this possible, the study results were summarized in terms which allow the user to calculate the building specific reference key figure for heating and electricity under consideration of the building specific air exchange rate. These terms are a result of the empirical study of the IFMA Benchmarking Research Group and were taken over as reference key figures into a special category for laboratory buildings („Labore privater Einrichtungen“) in the german law to reduce the energy consumption of buildings in Germany ("Energieeinsparverordnung / EnEV") from 30.07.2009. With this, a change of philosophy in

Figure 11 Energy consumption in year comparison.

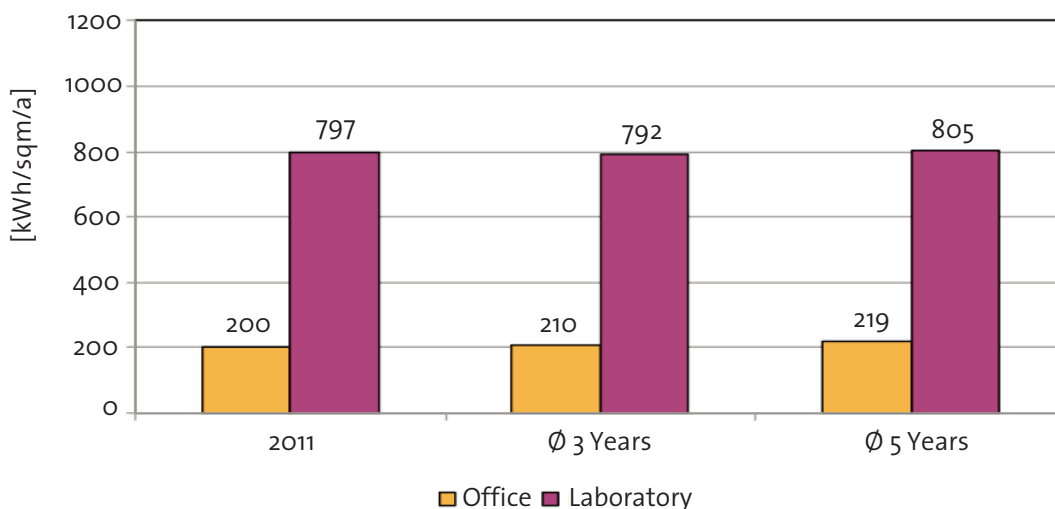
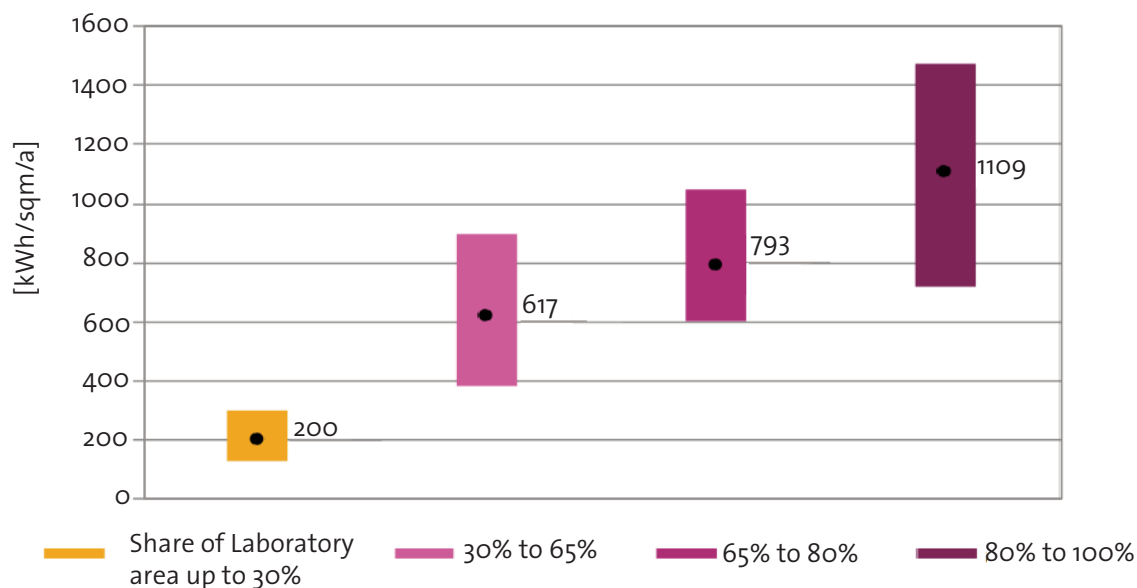


Figure 12 Energy consumption in laboratory comparison.



the EnEV was executed, since for the first time no concrete numerical number is given as a reference value, but a term which provides a result based on the specific circumstances of the energy consumption of a building.

### 5.2 “Legal Responsibility for Operators”

A further theme of great interest for the participants in the benchmarking is the management of legal obligations and duties. Legal Responsibility for Operators means the fulfilling of legally required protective measures, in particular those which are related to the safety of persons, the protection of third party rights and the protection of the environment. The operation of laboratory buildings involves special requirements related to laboratory safety due to the high danger potential (illustrated in figure 14).

Each company which participates in the benchmarking has special experience and solution approaches for individual obligations. In the Best Practice Workshops, these solution approaches were put together like a puzzle and optimized into a comprehensive concept developed by the Bauakademie. The results of this process worthy of generalizing were documented in the form of principles for the administering of operator responsibility. Hence the operating company is basically responsible for the operation of laboratory buildings. The area building operation usually encompasses the responsibility for the provision of a safe and danger free basic building structure including the general technical equipment of the building. Those in charge of the operation of the laboratory, on behalf of the laboratory manager, are responsible for the safety in their lab. The developed principles provide behavior guidelines and checklists

Figure 13 Energy consumption of laboratories in dependence of the air exchange rate

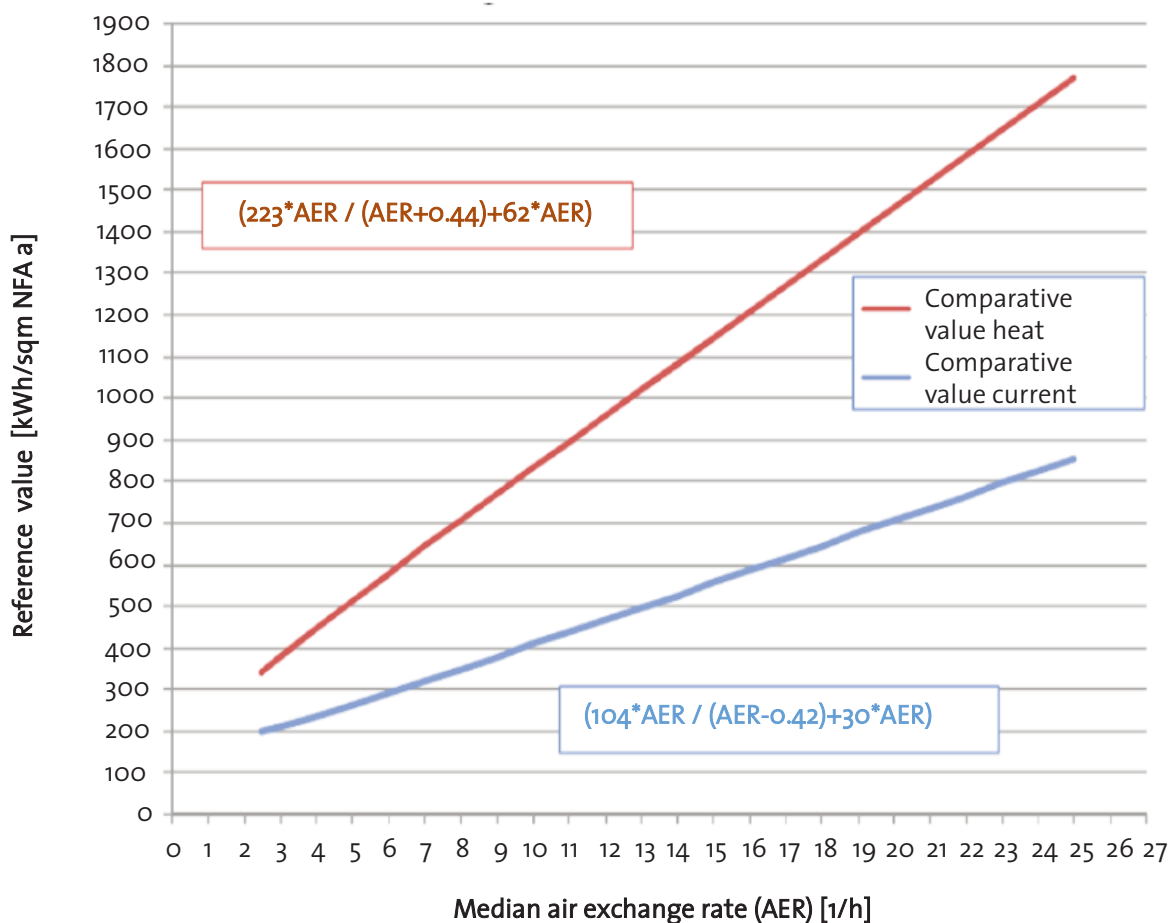
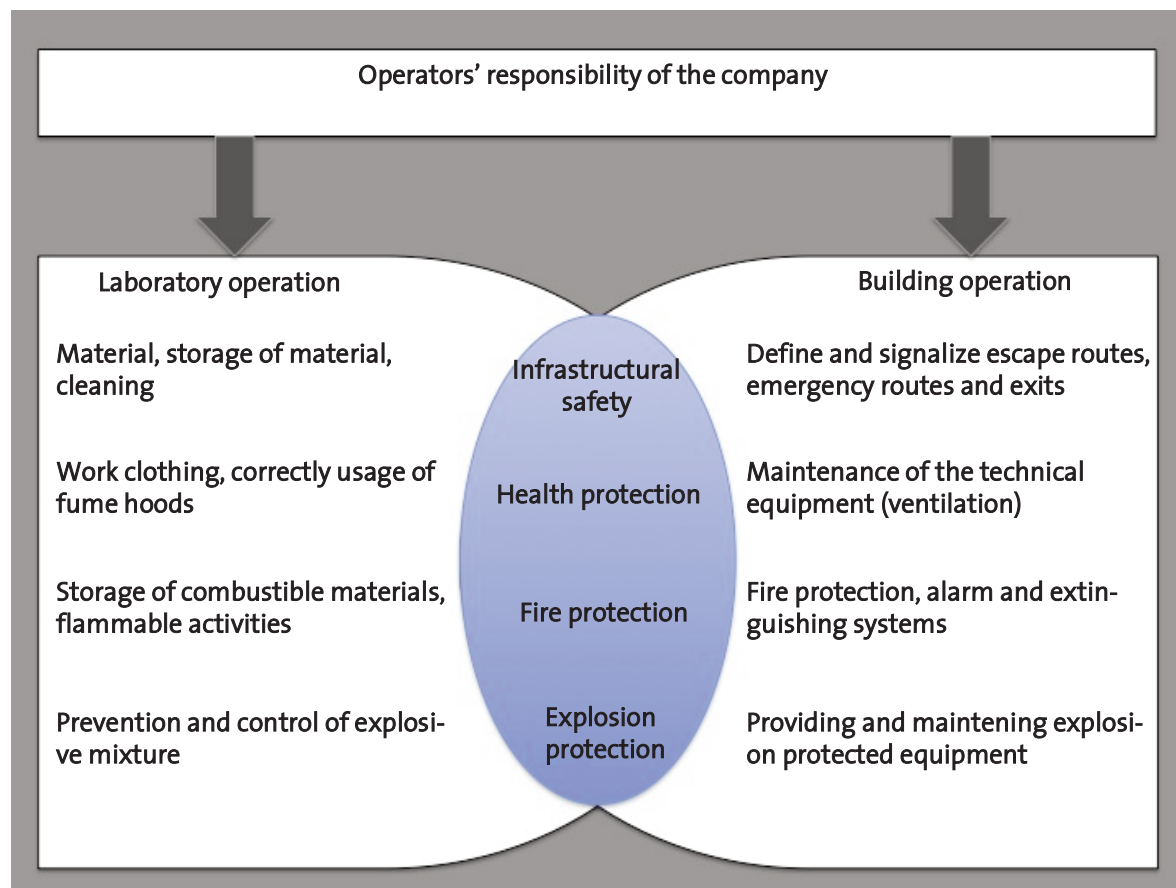


Figure 14 Interface between lab users and building operators (FM) in laboratory safety.



for the management of the interfaces between the concerned company departments.

Figure 14 illustrates the interface between the laboratory attendants/user and the facility management department (FM) regarding infrastructural safety, health protection, fire protection and explosion protection.

The German versions of both GoP's are available on request (mail to [ifmabenchmarking@bauakademie.de](mailto:ifmabenchmarking@bauakademie.de)). To gain further validation of the suggested concept, more studies are required. By acquiring additional participants from the chemical, pharmaceutical and life science industry, new insights and recommendations for facility management can be deduced.

## Practitioner's Section

# How to secure sustainable competitiveness of Chemical Industry Parks: Global competitive challenges and a systematic, customer-centric response

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The central question of the following paper is how Chemical Industry Park operators could systematically integrate the external investors' perspective into their decisions about the park's future competitive positioning and continuous improvement of operational excellence. In today's chemical industry landscape, Chemical Industry Parks and their operators face great challenges. On the one hand, they have to meet increased and more complex demands of globally-active chemical companies. On the other hand, ongoing globalization leads to an intensified competition amongst Chemical Industry Parks that try to be successful in attracting investors on an international level. The presented methodology and some insights from an international competitiveness study of leading Chemical Industry Parks shall serve as a guideline as to how operators of Chemical Industry Parks could introduce customer centricity in their business model and how they could effectively compete on a global scale.

### 1 Introduction

Strategic positioning based on investors' key investment criteria combined with operational excellence in site operations is decisive. Chemical park operators have to contribute added value to the competitiveness of the chemical companies at the chemical park and, at the same time, have to organize their site operations in a customer-oriented, flexible and cost effective manner, defining their core competencies while outsourcing non-core services to external companies. In order to understand and best meet the requirements of investors, site operators have to put themselves in the perspective of the investing chemical production company as the "customer". This is valid for both the European Chemical Industry Parks with a high degree of integration and long production history as well as for the developing chemical production clusters in South-East-Asia, China and the Middle East that were designed on the drawing board following decade oriented master plans. Role models like

Jurong Island in Singapore together with the Singapore Economic Development Board (EDB) have a very proactive chemical investor acquisition strategy. Before even speaking to potential investors, they have already done thorough business and technology analyses. From the beginning, they are able to discuss with the potential investor about best value chain fit and future requirements of infrastructure and service integration.

In general, the definition of 'customer' does not only include potential investors, but also already existing production companies on site. The terms chemical site operator and chemical park management are used analogous and describe the management unit of a Chemical Industry Park.

The following Site Benchmarking Framework focuses on different options to improve competitiveness and increase attractiveness of Chemical Industry Parks and related site services from an investor's perspective. It shows how this could be achieved in as a systematic, ongoing and customer-centric approach.

The following key questions define the initial situation of the Chemical Industry Parks and their challenges:

- How can Chemical Industry Parks successfully position themselves in global competition for future investors?
- How can Chemical Industry Park operators systematically integrate the customer perspective into their strategic and operational decisions to increase the sites' competitiveness?
- How could Chemical Industry Parks systematically identify, develop and promote their key competitive advantages compared to the global peer group?
- How could Chemical Industry Park operators define areas for improvement in the park's strategy and operations with the highest leverage to increase the competitiveness and attractiveness?
- How could Chemical Industry Park operators continuously measure the investors' confidence and satisfaction for an ongoing site development?

The following sections of the paper first describe the basic methodology and the approach that has been developed as a result of continuing business and technology consulting work in the chemical industry with special focus on Chemical Industry Parks. Secondly, the added value of the Site Benchmarking Framework as a management tool is defined by presenting different result formats of benchmarking exercises. Following this section, results from an international study of Chemical Industry Park's competitiveness using the herein presented Site Benchmarking Framework are presented. Finally, an outlook and short summary of key aspects should initiate both continuous practical and theoretical discussions on the topic as to how to secure sustainable competitiveness of Chemical Industry Parks in the future.

## 2 Basic methodology and approach: Site Benchmarking Framework

The presented integrated approach is based on the principles of benchmarking as a management tool (Mertins and Kohl, 2009). The basic objective of systematically comparing one Chemical Industry Park with its peer group aims at identifying different options to improve competitiveness of individual Chemical Industry Parks.

Two central arguments have been followed by developing the framework:

1. Chemical Industry Parks gain competitive advantages by continuously orienting themselves towards key investment criteria of global

chemical producers.

2. Chemical Industry Parks compete on an international level for potential investors and have to position themselves towards their global peers based on clearly defined site-success-factors derived from the key investment criteria

In the following, the elaboration on the Site Benchmarking Framework will concentrate on Chemical Industry Parks as benchmarking object. Basically, the used term Chemical Industry Park defines a settlement of several chemical production companies or production units, i.e. chemical plants within the so-called battery limits of a defined production area. Entrance to the park is constantly controlled and only possible through secured access gates. The single production units in a Chemical Industry Park tend to show a high degree of mass flow and infrastructure integration. In most cases the central provision and management of infrastructure and services is done by a so-called site operator. Availability and efficiency of site services and infrastructure are decisive for the site's attractiveness because Chemical Industry Park investors can focus on their core business and competences. Major objective of the production companies is to gain a competitive advantage from synergies and scale effects while sharing capital intensive site infrastructure and cost intensive site service provision.

In comparison, the term chemical site refers more to the single plant and the location of a specific production unit within a Chemical Industry Park or as a stand-alone production site. Chemical clusters, e.g. Antwerp Chemical Cluster, are a mixture of Chemical Industry Parks and single production sites of one major user company. Here, the whole area of the cluster has no security access gates or fenced battery limits as in the case of an access restricted park or single chemical production site with established security controls. Furthermore, the degree of infrastructure and mass flow integration tends to be lower in the cluster format than in an established Chemical Industry Park (Bergmann, Bode, Festel and Hauthal, 2004).

### 2.1 Site-success-factors for Chemical Industry Parks

Based on defined site-success-factors for high site competitiveness and attractiveness, Chemical Industry Parks could be objectively evaluated from an investor's or existing resident's perspective. This has to be done in a standardized way, both to generate comparable data over the years and to be able to compare the own Chemical Industry Park with its global peers applying the same set of evaluati-

on criteria and definitions. The site-success-factors and more than 80 underlying benchmarks are derived from companies' investment decision processes for new production sites and represent the first part of the Site Benchmarking Framework. The following presented factors are the result of a survey done with a selection of chemical producers in Germany. The objective was to identify the most important factors in new investment and site decisions. Interview partners have been the companies' investment project leaders, corporate development representatives, corporate finance representatives, plant managers and internal service providers.

The site-success-factors could be weighted according to the respective position of the investing company within the chemical value chain coming from petrochemicals, base chemicals towards polymers, specialty chemicals and down-stream areas of agrochemicals, pharmaceuticals and biotechnology.

Starting from a more general level, chemical park investors consider macroeconomic conditions, tax situation, financial investment incentives, regional laws and regulations in their investment and site decisions. They look at the geographical position of the site that best fits their individual business strategy. The perspectives of access to promising customer and cost-efficient sourcing markets are of highest relevance. The sourcing situation at the potential investment locations has not only a cost component. The availability of the required raw materials with the right specifications is decisive. Here, the already existing production network at the site could play an important role. Chemical companies could extensively benefit from production network effects with connected up- or downstream industries. Therefore, one major focus lies on the site's value chain coverage and range of companies already present on site. Site attractiveness is further increased by individual Investor Relations management and efficient administrative permission processes that enable "Plug & Play" plant investments with established up-to-date infrastructure and service provision, i.e. competitive lead times between investment decision and production start.

Chemical Industry Park investors further evaluate site factor bundles according to their business model and its needs, e.g. available, highly-qualified local workforce as well as labor cost level, site infrastructure, R&D facilities and technology, logistical infrastructure and pipeline connectivity. Especially, the performance of site operators and availability of comprehensive site service portfolios are decisive for the site's attractiveness as Chemical Industry Park investors can focus on their core business and outsource support processes. Existing shared on-site infrastructure generates cost-reducing

synergies, enables economies of scale, increases flexibility, minimizes risks and optimizes business related investment activities (InfraServ Hoechst, 2009).

Following the investment rationale of chemical companies, these site-success-factors are the basis for the Site Benchmarking Framework. They are used to derive the required benchmarking criteria, both qualitative and quantitative in nature. The site-success-factors and benchmarking criteria could be arranged according to the following three clusters:

The first cluster deals with the "Geographic position" of the Chemical Industry Park, and covers, amongst others, the following qualitative and quantitative benchmarking criteria:

- **Economic and administrative environment:** Political stability, financial stability, BERI-Index, Legal Corruption Perception Index (CPI), Logistical Performance Index (LPI), approval procedures, taxes (corporate income tax, withholding tax, etc.), tax deduction possibilities, investment incentives, customs and tariffs, etc.
- **Customer market:** Regional gross domestic product, chemical market growth rates, market volumes and size, etc.
- **Sourcing market:** Raw materials availability, Raw materials cost level, Electrical energy cost level, Natural Gas cost level, etc.
- **Intellectual Property:** Legislation and execution, Intellectual Property (IP) protection, etc.
- **Environment, Safety and Health:** Environmental regulative conditions, Safety standards on site, ESH Management, etc.
- **Employees:** Availability of qualified personnel (operational personnel, supervisor, engineer), labor cost level, personnel turnover rate, labor laws, variety of unit operations, expertise on site/in region, labor productivity, etc.
- **Site reputation and social environment:** Reputation and acceptance of site within public, attractiveness for (international) employees, hardship index, etc.

The second cluster covers all aspects related to the "Production network" including the process of investment within the battery limits, amongst others the following qualitative and quantitative benchmarking criteria:

- **Site strategy and positioning:** Production network development, site services strategy, Investor Relations (IR) management, education and research facilities, existence of R&D facilities, investment volume for projects, PR/communication and lobbying, etc.
- **Production network:** Mass flow and infrastructure integration, value chain coverage, raw mate-



rial availability through network options, pipeline network and connections, etc.

- **Investment cost level:** Materials cost level, engineering cost level, construction cost level, administrative cost level, permitting cost level, etc.
- **Project handling:** Project handling time, project handling cost, project management support of site operator, authority management of site operator, etc.

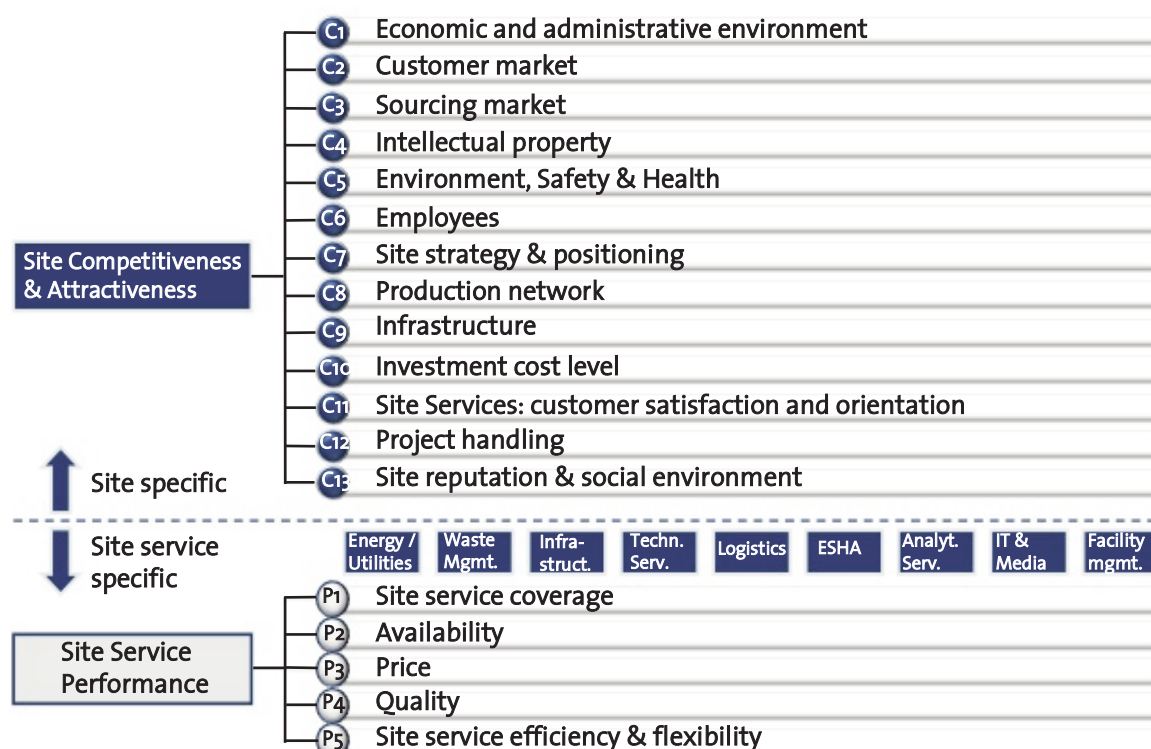
The third cluster “**Infrastructure**” looks at the installed infrastructure and site services provision on and next to the chemical sites, the following qualitative and quantitative benchmarking criteria:

- **Infrastructure:** Availability and condition of site infrastructure, “Plug & Play” readiness, access and support for special equipment, logistical infrastructure and connectivity, availability of vacant and developed site area, etc.
- **Site services – Customer satisfaction and orientation:** Customer orientation of service and pro-

duct portfolio, site service quality, monopolistic vs. competing site services, site service coordination (key account management), qualification level of site operators’ employees, etc.

These in total thirteen site-success-factors refer to the first part of the Site Benchmarking Framework, the “Site’s Competitiveness & Attractiveness” (see figure 1). The second part of the Site Benchmarking Framework consists of an assessment of the Site Service Performance. The Site Service Performance evaluation is based on a holistic function model for Chemical Industry Parks. All required site services and energies by the producing chemical companies are evaluated and analyzed applying criteria such as site service coverage, availability, price and cost level, quality as well as site service efficiency and flexibility (see figure 2).

Figure 1 Site Benchmarking Framework.



### 2.3 Practical implementation of Site Benchmarking Framework

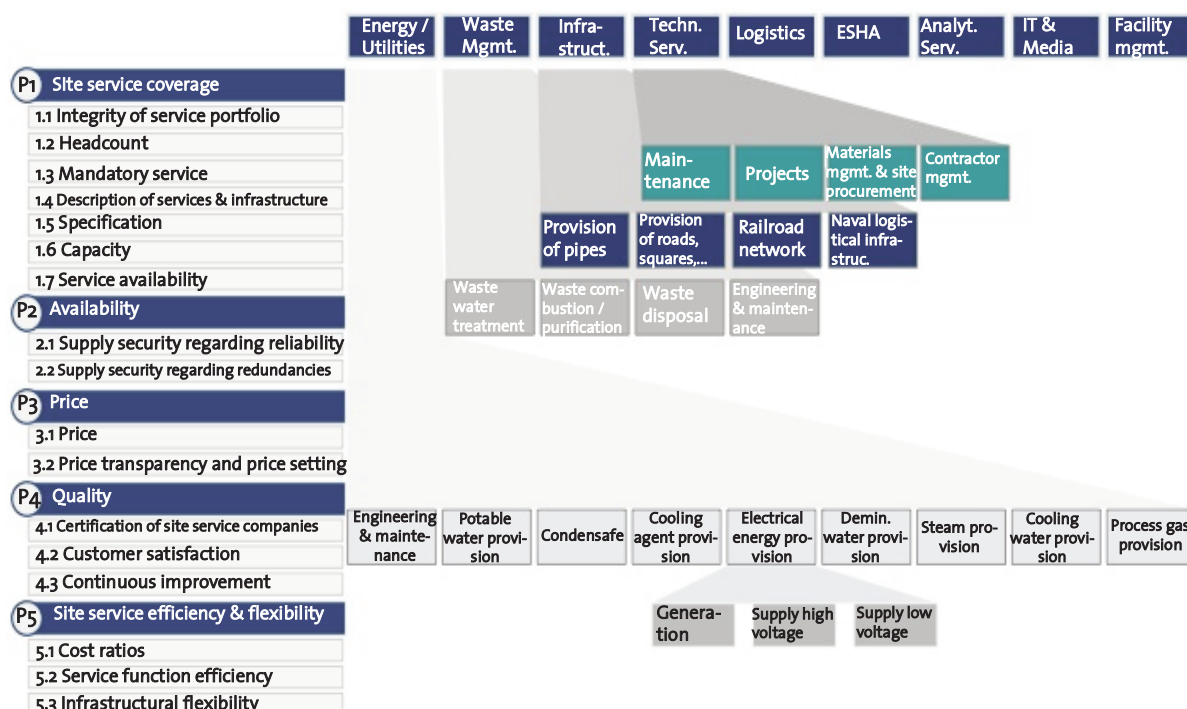
Besides secondary source research activities, structured on-site interviews with potential investors, the chemical park operator and owner, major chemical production companies and existing site service providers are particularly important for the gathering of all relevant site specific information. These interviews are mostly performed by an external service provider, but could be done as well in-house. Standardized questionnaires are used that can be automatically evaluated by a specific software that has been developed for these kinds of site assessments. Handed over to the site operator, this software is a useful tool to perform regular site benchmarking of the own Chemical Industry Park and develop internal benchmarks over the course of time. Obviously, external benchmarks of global Chemical Industry Parks have to be inserted into the analysis to leverage the own benchmarking

database. A kind of market intelligence function normally pursues these activities. External benchmarks can be either generated by own field research, by analyzing secondary data or by acquiring the data from specialized technological and management consulting companies. The software is easy to use and could be adapted to the site operators' needs.

### 2.4 Site Benchmarking instruments and result formats

In particular for Chemical Industry Park operators, access to detailed up-to-date knowledge of the relevant site-success-factors and best practices is crucial for long-term success in the market. Not all site-success-factors and benchmarking criteria could be directly influenced by the site operator. Nevertheless, a sound information basis of these factors can be crucial in investor negotiations when production companies evaluate poten-

Figure 2 Chemical Industry Park's function model.



tial production locations on a global scale, i.e. in Europe, Middle East, USA South-East-Asia or China. The structured collection, objective evaluation and targeted provision of information per site-success-factor and site service in a comparison with selected benchmarks and best practices of international Chemical Industry Parks represents an integral part of a thorough competitive analysis.

The global peer group comparison enables to assess the considered park's relative competitive position. The site benchmarking results helps site operators to make the most effective and efficient future investment decisions in order to further develop their competitive advantages and to close identified gaps. The benchmarking approach functions as facilitator to optimally apply instruments like best-in-class analysis per site-success-factor, strengths and weaknesses profiles, Site Service Performance evaluations, structured collection of investors' feedback as in Investor Confidence Surveys or more quantified cost structure analyses related to Costs of Goods Sold (COGS) or industry cost curves for specific production set-ups. Eight different instruments and corresponding result formats are exemplarily described to show the diversity of potential usage options. Each provides a value added to a best possible set-up and development of the Chemical Industry Park:

#### *2.4.1 Site Competitiveness & Attractiveness assessment*

The Competitiveness & Attractiveness assessment uses spider diagrams to evaluate the predefined site-success-factors and more than 70 qualitative and quantitative benchmarking criteria in comparison to global peers. Site operators that systematically use the benchmarking approach within regular periods are able to develop internal benchmarks and analyze the Chemical Industry Park development in the course of time. The transparency of development potentials could be used to define specific measures to close gaps or to further leverage competitive advantages of the site. When comparing with other peers, know-how transfer and learnings effects could be generated.

#### *2.4.2 Site Service Performance evaluation*

The Site Service Performance evaluation of available infrastructure and site service portfolio gives a comprehensive overview on the offered electrical energy, utilities and site services regarding their availability, quality and price/cost levels as well as the quality of the infrastructural development of the Chemical Park.

#### *2.4.3 "Best in Class"-Analysis*

Comparison with the world's leading Chemical Industry Parks shows the own competitive situation. An extensive site benchmarking database of world's leading Chemical Industry Parks provides best practices, site benchmarks and role models, among others from analyzed chemical sites in Europe, USA, China and Southeast Asia. A strategic positioning towards competing Chemical Industry Parks worldwide, especially in growth regions, can and should be elaborated.

#### *2.4.4 Cost Structure Analysis*

Cost structure analyses for investments and operations of chemical production plants could be elaborated using the information of the Site Benchmarking Framework. Comparison of cost structures of the Chemical Industry Parks could include industry cost curves, Cost of Goods Sold (COGS) analyses for specified products, etc.

#### *2.4.5 Site marketing and commercialization*

Benchmarking results such as site assessments and site profiles can be perfectly used for future site marketing and commercialization activities to attract new investments, i.e. communication campaigns, "Best-in-Class comparison", proactive communication and targeted approaching of potential investors. Clear understanding about own competitive advantages and strengths in relation to the peer group enables more effective discussions with potential investors. In addition, knowledge about continuously evolving requirements of chemical companies is essential to develop a customer-oriented service culture.

#### *2.4.6 Investor Confidence Study*

Analysis of investor needs and rate of satisfaction with investment and production conditions at the Chemical Industry Park enable more targeted site investment programs securing mid-to-long-term competitiveness. Furthermore, a communication channel for continuous information exchange between Chemical Industry Park management and investors will be established. Changing customer requirements will be identified more quickly and could be addressed in a more effective manner.

#### *2.4.7 Site development concept and international cooperation*

Continuous improvement of sites' competitiveness and attractiveness enable Chemical Indus-

try Parks to be best prepared for increased competition for potential investors. Targeted development of the Chemical Industry Park leads to a sustainable ensurance of site competitiveness beyond existing battery limits. Especially, the benefits from regional and international cooperations have to be taken into account to achieve further synergies and positive impulses for increased site attractiveness. Defined recommendations and measures as a result of the site benchmarking approach constitute the future action plan.

#### 2.4.8 Site profiles

Site profiles for each Chemical Park provide all relevant data compiled in one information brochure. It could be used as a fact book for potential investors and contains all relevant data that that investors need to make a first judgment on the site's compatibility with its requirements.

### 2.5 Selected real business applications of the methodology

#### 2.5.1 Practice example: Investment planning support

The following example describes how the Site Benchmarking Framework offers a valuable instrument in the site selection process for chemical plant investments. In the reference project, the site benchmarking exercise was applied to support the site selection process at a chemical production company. Furthermore, the methodology was finally handed over to the responsible organizational unit to support investment project leaders in different stages of the site selection process providing continuously ready-to-use site information. It enables a proactive investment planning support through neutral, project-independent and standardized competitiveness evaluations, site service performance assessments and basic site profiles visualized in standardized and comparable result formats.

Starting with the investment decision, the site benchmarking tool and database provides top criteria of global chemical parks supporting the generation of a long-list of potentially interesting sites identifying deal breakers at the beginning of the whole process while identifying the best fit investment locations at the same time. Next, the short-list of sites for further analysis could be derived by either using the existing database or pursuing new site benchmarking exercises that further complete the database. This includes the evaluation of the site's competitiveness and attractiveness based on the qualitative and quantitative benchmarking criteria as well as the analysis of site service perfor-

mance of all relevant site services at the selected Chemical Industry Park. Here, weighting factors for the different benchmarking criteria are used to account for the specifics of each plant investment project. Finally, the project specific site decision could be taken with a clear argumentation basis of why this site has been chosen. Furthermore, already detailed information about the target site could be used for both effective negotiations with the local Chemical Industry Park management and for the starting plant engineering activities.

The major advantages for the chemical production company of applying the Site Benchmarking Framework in a systematic manner have been the following. First, the whole site selection process has been significantly accelerated with instant information available. Second, the quality of the final decision and the whole selection process has been more resilient due to objective and detailed information about the leading global sites. Third, the selection process becomes more transparent and comprehensible to top management and site decisions could be more effectively challenged to identify the optimum for the company. Finally, it enables the company to effectively develop and steer its whole production network by establishing key strategic productions sites preventing a fragmented production set-up.

#### 2.5.2 Practice example: Future Chemical Industry Park development

The following example describes the application of the Site Benchmarking Framework for a worldwide leading Chemical Industry Park. The objective was to elaborate strategic optimization levers with regard to site attractiveness and competitiveness in comparison to its global peers based on standardized performance indicators and existing benchmarks. The underlying rationale of the project was that continuous site development and objective assessments are necessary to get an up-to-date competitive picture of the site and to identify areas for improvement. Using the Site Benchmarking Framework and the underlying benchmarking criteria, improvement hypotheses and recommendations have been defined on various dimensions, where gaps to leading international best practices or requirements from potential investors were not met.

The project started with an extensive interview series and data collection to gather the required information for benchmarking exercise. Interview partners have been the official authorities, the site operator itself, existing production companies, potential investors and the various site service providers within and outside the battery limits of the

Chemical Industry Park, e.g. energy providers, logistics service providers, waste management service providers, technical service providers. Afterwards, interviews results were consolidated in the benchmarking database to identify the most promising improvement hypotheses. Furthermore, a detailed Strengths and Weaknesses profile of the respective park in comparison to other chemical parks have been compiled.

Finally, recommendations have been elaborated with detailed action plans, business cases and responsibilities to prepare the implementation of the whole recommendation catalogue handed over to the Chemical Industry Park operator.

Examples for improvement hypotheses and related recommendations could cover various dimensions, for example Chemical Industry Park strategy and commercialization as well as the site service concept. Here, exemplary recommendations ranged from a more proactive analysis of potential investors and their requirements as well as fit into existing and targeted value chain on site or the establishment of a central coordination function supporting authority management (key account management enabling "One-stop-shopping"). Regarding the site service concept, the introduction of market oriented pricing for provided site services in the chemical park due to in a global comparison partly higher service costs should have been addressed by breaking up the monopolistic supply situation for specific site services.

### 3 Insights from a Global Site Benchmarking study

#### 3.1 Region-based assessment of international Chemical Industry Parks

The most important and still valid conclusion drawn from benchmarking the worlds' leading chemical industry parks is that the "ideal chemical site for all kinds of investments with best-in-class chemical production conditions" does not exist. Instead, each site offers a portfolio of favorable and less favorable factors to be evaluated according to the projects' specific requirements. The challenge for globally operating chemical companies is to find the best-fit investment location facing the heterogeneity of chemical production locations. At the same time it is an opportunity for Chemical Industry Parks and their operators to present themselves at their best. The global site benchmarking is key to both, identifying optimization levers for increased competitiveness for the own site and having a detailed and structured set of information regarding strengths and weaknesses of other

worldwide leading Chemical Industry Parks.

As already stated, not all site relevant factors could be influenced by the chemical park management. Various factors are controlled by other institutions, e.g. the local government, or are pre-determined by geographic and natural conditions. Despite the partially limited or restricted influence on some factors like taxes, deep sea port access or customer market, chemical site operators are empowered in the negotiations with potential investors to best promote their site. Furthermore, they are enabled to better lead discussions with regional institutions to best develop not only the site within the battery limits, but to influence the general investment conditions in the region to their interest.

Figure 3 shows the results of a global competitiveness assessment of Chemical Industry Parks, summarized for the different regions Europe, Middle East, USA, South-East-Asia and China. The characteristics of the 13 analyzed site-success-factors are based on the 70 underlying qualitative and quantitative benchmarking criteria.

#### 3.2 Competitiveness insights per site-success-factor

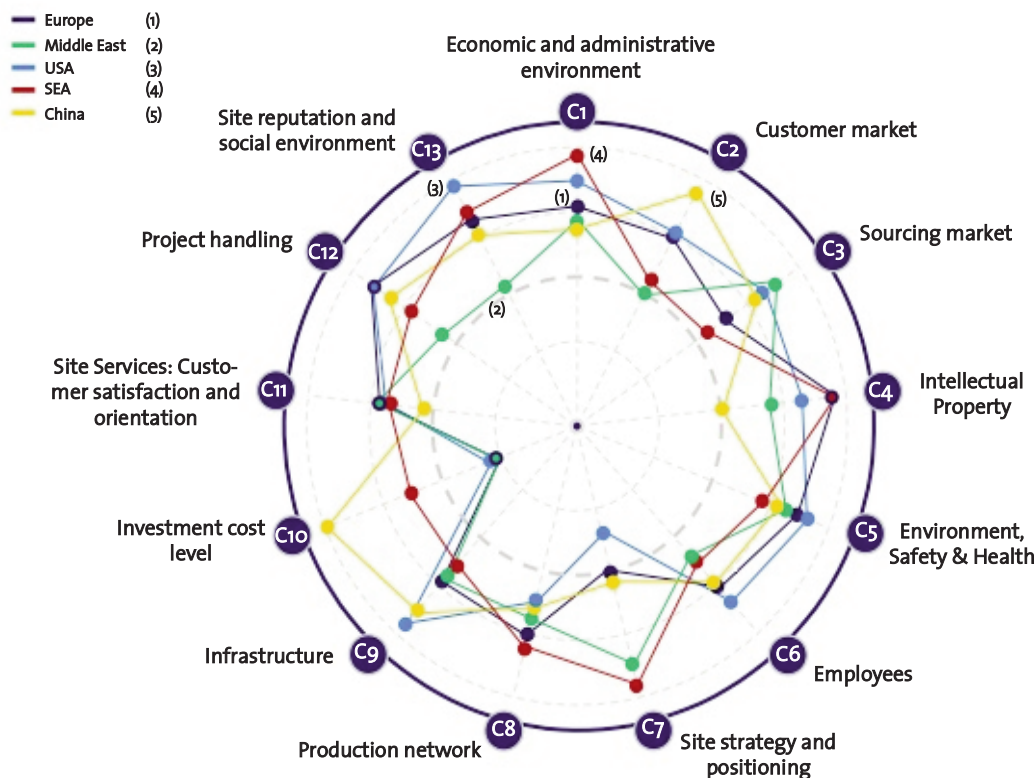
In the following, assessment results are described per site-success-factor with corresponding regional specifics and characteristics. The results are shown as an extract of the whole Site benchmarking Framework in figure 4.

##### 3.2.1 C.1 Economical and administrative environment

Basically, all regions show positive characteristics as far as criteria like political, legal and financial stability and management complexity of approval procedures are concerned. Legal prerequisites for equity participation schemes in joint venture structure with local partners in the Middle East and China could lead to deterring effects. In Qatar, foreign companies need a local sponsor to establish joint ventures that are characterized by a statutorily fixed share distribution among the partners.

In particular, taxation and investment incentives largely differ between the analyzed chemical sites in the different regions. Favorable conditions can be identified at Chemical Industry Parks in the Middle East and South-East-Asia. For example, investments in Jurong Island, Singapore, benefit from a world-class administrative environment that offers very favorable tax incentives and shows a very effective site commercialization. Tax holidays up to 12 years and a reduced corporate income

Figure 3 Competitiveness assessment of worlds' leading Chemical Industry Parks.



me tax of 17% could be highlighted. In comparison, investments at German sites have to show positive return with a nearly double as high tax burden and without further tax related investment incentives. In the USA, a rather high income tax up to 39.5%, due to high federal tax, has to be considered. The attractiveness of European and in particular German sites is very depending on the introduction of targeted investment incentives as the basis of a long-term oriented industrial politics.

### 3.2.2 C.2 Customer market

Without referring to the individual chemical product, high attractiveness for the accessibility of a large chemical market has been stated for the European, American and Chinese Chemical Industry Parks. In comparison, the expected growth potential of the markets has been evaluated differently. Here, the dynamic Chinese chemical market is expected to show high growth rates.

### 3.2.3 C.3 Sourcing market

Cheap feedstock access to the world's largest crude oil and Natural Gas reserves, good raw materials' availability and cost levels as well as very favorable electrical energy prices compared to all other global sites are key investment advantages for the Middle East region. At the Chemical Park Al Jubail, Saudi-Arabia, Natural Gas costs amount up to US\$ 0.75 to US\$ 1.00 per mmBtu. These conditions belong to the most competitive in the whole world. In comparison, European and South-East-Asian chemical sites face energy cost disadvantages because of price surcharges for electrical energy up to 150% to 400%. Missing concepts of secured energy availability and expected negative impacts of new federal legislations to support renewable energy sources put pressure on the local companies at the Chemical Industry Parks in Germany. Site-crossing energy concepts to increase the energy efficiency could be one solution to restore and maintain competi-

Figure 4 Site-success-factors in an international comparison.

Criteria (extract)		Regions	EU	USA	SEA	ME	China
C1	Political, legal and financial stability		●	●	◐ - ●	◐	◐
	Approval procedures		◐	◐	◐ - ●	◐	◐
	Taxes		◐	◐	◐ - ●	◐ - ●	◐
	Investment incentives		○ - ◐	◐	●	◐	◐
C2	Regional market size and growth level		◐	◐	◐	◐	●
C3	Raw materials availability		◐	◐	◐	◐	◐ - ◐
	Raw materials cost level		◐	◐	◐	●	◐ - ◐
	Electrical energy cost level		◐ - ◐	●	◐ - ◐	●	◐ - ◐
	Natural Gas cost level		◐ - ◐	●	◐ - ◐	●	◐ - ◐
C4	IP Protection		●	●	◐ - ◐	◐	◐
C5	ESH regulations		◐	◐	◐	◐	◐
C6	Availability of qualified personnel		●	●	◐	○	○ - ◐
	Labor cost level		◐	◐	◐	◐	●
C7	Site strategy, position and IR management		◐ - ◐	◐	◐ - ●	◐	◐ - ◐
C8	Mass flow and infrastructure integration		●	◐	◐ - ◐	○ - ◐	◐
	Value chain coverage		◐ - ●	◐ - ●	◐ - ◐	○ - ◐	◐
C9	Site infrastructure		●	◐	◐ - ●	◐	◐ - ◐
	Logistical connectivity		◐ - ●	●	◐ - ●	◐ - ●	◐ - ◐
C10	Investment cost level		◐	◐	◐ - ◐	○	●
C11	Site service provision		●	●	◐ - ◐	◐	◐
C12	Project handling		●	●	◐ - ●	◐	◐ - ◐
C13	Reputation		◐	◐	◐ - ◐	●	◐
	Attractiveness for employee		●	●	◐ - ●	○ - ◐	◐ - ◐
Evaluation scale: ● very good (World-Class) ◐ good ◐ satisfactory ◐ sufficient ○ deficient							

tiveness of local production conditions.

Major disadvantages in Singapore are electrical energy prices that are as high as at several chemical sites in Europe, e.g. chemical cluster Antwerp, but double the price of other co-located South-East Asian chemical sites. At European sites, the long-term secured availability of cheap Natural Gas is a major concern, even though German sites are well connected to the far reaching West European pipeline network. The foundation of the „Allianz zur Rohstoffsicherung“ of the German industry is a first positive signal on a national level to address the concern of long-term, raw materials availability with dedicated raw material alliances between different companies depending on the same raw materials for their productions.

### 3.2.4 C.4 Intellectual Property

Intellectual Property (IP) protection remains an issue in China, although legislation has been adjusted to international standards in the meantime. Chinese approval procedures with substantial disclosure obligations for new plant constructions and import of technologies offer various risks for IP leakages and an uncontrollable outflow of confidential business and technological information.

In comparison, IP protection regulations and enforcement is seen to be very effective in the Middle East, Europe and USA. Most Arabic states are actively looking for foreign investment and technology partners following their economic development strategies, amongst others the settling of downstream chemistry. Therefore, all concerns of possible IP violations shall be avoided to attract international technology joint venture partners to the region by effective IP protection rules.

### 3.2.5 C.5 Environment, Safety & Health

Basically, Environment, Safety and Health (ESH) regulations at the examined Chemical Industry Parks follow international standards. In most cases, the global players among the chemical production companies have even installed stricter company internal ESH rules at their plants. In comparison to strongly integrated chemical sites in Europe, where the ESH management is strongly monitored and controlled by the chemical park operator, chemical production plants in South-East-Asia or China are somehow separated from the other plants in the chemical park. The production units have more of an “island” character with their own battery limits. Here, ESH management is much more driven by the chemical plant manager complementing the general ESH regulation of the whole local chemical cluster area.

### 3.2.6 C.6 Employees

Main advantage of European and American sites is the availability of well-qualified personnel on all levels, i.e. blue collar workers, supervisors and engineers. For plant investments and operations in regions such as South-East-Asia, Middle East and China, there is a strong need for internal company training on the job, because of the lack of an effective dual education system. The availability of skilled labor is partially very limited. The German education system still functions as a role model for several initiatives started in Asia and elsewhere. The network of universities, universities of applied sciences and research institutes combined with Germany's system of on-the-job-training represent a key competitive advantage. Nevertheless, the demographic development and partial shortages for skilled labor put this favorable condition under pressure.

Low labor costs put Chinese Chemical Industry Parks in a favorable position when compared to other considered chemical sites. Labor cost levels amount to less than 10-20% compared to European sites. Comparing South-East Asian sites with European Sites, this labor cost advantage still amounts up to 50%, excluding sites like Jurong Island in Singapore from this consideration. Besides pure cost considerations, in the USA, labor productivity is very high in comparison with the rest of the world.

### 3.2.7 C.7 Positioning and strategy

Clearly defined Chemical Industry Park strategies and value chain positioning could be identified for “Greenfield”- designed chemical parks in South-East-Asia, China and in the Middle East. Here, the settlement of defined industries and companies is outlined in extensive master plans. These plans include the whole site development from the scratch. Value chains are partially planned on single product and technology level with ranked potential investors. In comparison, chemical sites with a long production history like in Germany proactively have started to address the challenges of increased globalization and structural change and position themselves with their inherent advantages towards global investors.

### 3.2.8 C.8 Production network

It is one of the major competitive advantages of European and especially German Chemical Industry Parks, the so-called „Verbundproduktion“, a high degree of chemical production integration. This high degree of mass flow and infrastructure inte-



gration with all resulting synergies and the high coverage of complete chemical value chains at one site still function as role models for the planning and set-up of new integrated Chemical Industry Parks in the world. At Chinese Chemical Industry Parks, the low degree of production integration at the considered sites is currently not really addressed by a proactive intercompany production network planning and site commercialization by the Chinese site operators. Production could be characterized rather as “island” solutions than an integrated chemical park concept.

### 3.2.9 C.9 Infrastructure

Existing infrastructure in Chemical Industry Parks is of major investors' interest, amongst others availability of internal logistics, supply and disposal networks and communication infrastructure. Here again, German Chemical Industry Parks show favorable conditions because of the high degree of infrastructure integration, resulting in cost synergies and competitive advantages for local producers. Especially at some South-East-Asian and Chinese Chemical Industry Parks, security of supply and quality of provided infrastructure show substantial deficits. In the Middle East region as in the United Arab Emirates and Saudi-Arabia, the picture is different. Most Chemical Industry Parks in the Middle East region are centrally-managed and developed by governmental institutions or state companies that are specifically responsible for the construction and operation of basic infrastructure facilities (land provision). Large investment programs in world-class chemical site infrastructure, such as in Qatar, generate very favorable conditions for investments and operations.

The favorable logistical location in the Middle-East between Europe and Asia and the availability of deepwater port access at major chemical sites are prerequisites to optimally serve the export-oriented chemical production at place, especially because of a very small local customer market. Similar, Jurong Island in Singapore or the chemical cluster in Antwerp, Belgium, offer favorable logistical connectivity with the access to a deep sea water port to serve the global market. Chemical production at European or American sites, in case they have a more regional customer market focus, benefits from an excellent logistical infrastructure of railroads, motorways and water channels for the whole region.

### 3.2.10 C.10 Investment cost level

In general, investment cost levels in Europe and the USA are higher than at the Asian sites because

of higher material, engineering, construction and permission costs, but far lower than expected cost levels in the Middle East. Major challenges for investing companies in the Middle East are high investment cost induced by extreme climatic conditions. Special materials, technologies and maintenance services are required to achieve global utilization rates from the plants. Compared to the European sites, cost surcharges amount to a plus of 25-30% for plant investments. On the other side, production investment in China and some South-East-Asian sites can be calculated with investment cost levels that are as much as 25% lower than the European reference values.

### 3.2.11 C.11 Site services – Customer satisfaction and orientation

European chemical production sites provide very stable production conditions thanks to their long production history and highly professional site operators. Here, site service providers offer a very comprehensive site service portfolio and reliable infrastructure for chemical production companies according to the “Plug & Play” principle. This results in a high degree of customer satisfaction. Wide range of site services with high customer orientation, secured availability, quality and efficiency lead to a clear competitive advantage in the global comparison. In the USA, American Chemical Industry Parks also offer a very favorable environment for investments and operations of chemical plants. The cost situation regarding all major utilities such as electrical energy, steam and especially natural gas are at a world class level.

The provision of site services in China shows a more heterogeneous picture. In most cases, there are monopolistic structures of site services supply that could lead to substantial dependency on the often state-owned providers. However, in total they have no influence on currently very favorable production costs for electrical energy, waste water treatment or maintenance services.

### 3.2.12 C.12 Project handling

Reliable adherence to time schedule and investment budgets within the planning and execution of investment projects could be stated especially at European and American Chemical Industry Parks. Here, the support from official institutions and the chemical park management has been valued extremely effective and efficient. At Chinese chemical parks, investors face much more heterogeneous conditions. Especially, more rural Chemical Industry Parks in China show a high development backlog.

### 3.2.13 C.13 Reputation and social environment of the Chemical Park

Chemical parks in the USA and the Middle East benefit from a high reputation in the local population. A different picture exists when considering the attractiveness of some Chemical Industry Parks from a Western employee perspective. Life conditions in the Middle East and some South-East-Asian and Chinese sites could generate a severe problem for investing companies to convince required highly skilled employees to work there for several years, e.g. Al Jubail in Saudi-Arabia, Map Ta Phut in Thailand or Chongqing in China.

## 4 Summary

European Chemical Industry Parks claim their position in an increased international competition for investors. They enable chemical producers to benefit from largely integrated mass flows and infrastructure at the various sites. The success model "Chemical Industry Park" with its comprehensive provision of site services, energies and infrastructure for the production plants on site secures the competitiveness of whole chemical value chains. The targeted and sustainable development of Chemical Industry Parks in Europe represents the prerequisite for long-term economic success combined with social and environmental responsibility.

## 5 Outlook

In summary, a clear strategic positioning, a synergy-targeted infrastructure as well as a comprehensive and customer-oriented site services portfolio are basic requirements for future high competitiveness of existing Chemical Industry Parks. Site operators need to effectively integrate the customer perspective of potential and existing investors into their development efforts of the Chemical Industry Parks. Close alignment with continuously changing customer needs and full transparency of the parks' individual strengths and weaknesses portfolio allow a target improvement of the sites' competitiveness and service performance. The Site Benchmarking Framework and the diversity of result formats that can be generated by applying it should offer a systematic and coherent approach for targeted site development, communication and promotion.

Comparison of the world's leading Chemical Industry Parks shows the own competitive situation. This approach however creates a value-add beyond grasping the gap to best-in-class peers. It guides to new ways of goal-oriented and sustainable site development, based on best-practices, role models, site benchmarks and other valuable inside

views into the leading chemical sites in Europe, USA, China, South-East-Asia and the Middle East.

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## References

Bergmann, T., Bode, M., Festel, G. and Hauthal, H.G. (2004): *Industrieparks - Herausforderungen und Trends in der Chemie- und Pharmaindustrie*, Festel Capital, Hünenberg, Germany.

InfraServ Hoechst (2009): *Standortfitness*, CHEMAnager Special edition.

Mertins, K. and Kohl, H. (2009): *Benchmarking - Leitfaden für den Vergleich mit den Besten*, 2nd revised edition, Düsseldorf, Germany: Symposion Publishing GmbH.

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