RFID chips: enabling the efficient exchange of information

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Enabling the efficient exchange of information

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The RFID market is set for further robust growth despite many a challenge. While turnover is likely to increase by an average of 19% p.a. in Germany between 2006 and 2016, the pace may reach as high as 25% p.a. worldwide. With the shift in the market shares of individual RFID components and the exodus of production of less sophisticated products from the high-wage countries, Asia is likely to contribute an ever increasing share and become the continent with the strongest turnover by 2016.

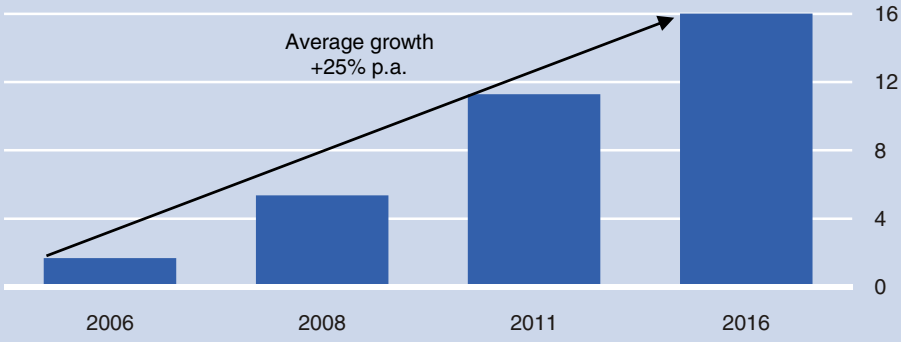
RFID links the physical good with the corresponding information. In fact, the RFID principle has been used in a broad spectrum of military and civilian applications for decades. However, it was not until the introduction of the electronic passport and the use of RFID tags on some consumer goods in the retail sector that public interest in the technology surged.

Political and technological challenges will shape RFID's commercial outlook. In the technology area, the issues seem to focus primarily on energy consumption, production costs, manufacturing speed and reading errors, while politically the focus will be on frequency harmonisation, standardisation, and environmental and data protection.

Not every RFID project driven by a technological vision will necessarily become a commercial success. Before they start using RFID, companies must take a critical look at the cost and income aspects.

RFID promotes innovativeness in the economy as a whole. RFID-based process automation not only boosts the efficiency of innovative companies, it is also instrumental in expanding the overall supply of goods and services.

Huge potential unfolding
RFID revenues, worldwide, EUR bn



Source: DB Research, 2009

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Technology linked with paradigm shift

Information and communication technologies are playing an increasingly important role in the implementation of value-added processes that overarch several steps. Specialists in corporate foresight say that Radio Frequency Identification (RFID) technology in particular is a very symbol of the paradigm shift. In the new paradigm the separation between the physical good and the information corresponding to it is eliminated.

As the technology becomes more widespread, interest also grows

RFID is not a brand new technology, however. Back in the Second World War the Allies used the same principle to distinguish between friend and foe. In the 1970s RFID came to be used more and more often in civilian applications as advances were made in micro-electronics. The broad spectrum of applications ranges from logistics and trade, industry and agriculture right through to health care and leisure events. However, it was not until RFID became more relevant in everyday life – e.g. with the electronic passport, labels on certain retail goods and access cards in the workplace – that the public started to take substantially greater notice of the technology.

Systems have three technical components

EPC: Number for every physical good

The electronic product code (EPC) assigns physical products an individual number. To do so, the EPC combines the scheme of the conventional bar code with an additional combination of digits.

Every RFID system consists of an *RFID tag* (also: transponder, a small chip encoded with a product number and containing a radio antenna, see box), a *reader* and *data-processing software*.

RFID systems work on the principle that the individual components can communicate with one another via electromagnetic fields without physical or visual contact. This form of information exchange differentiates RFID from other information systems that use a bar code or contact chip card, for instance, as well as from radio-based systems such as Bluetooth.

Broad variety of RFID systems on the market

Differences in physical form, energy supply, sensors

RFID systems differ very significantly from one another in their features (see Figure 1 and box on p. 3).

These differences pertain to:

— *Degree of freedom* (open vs. closed),

— *Data storage* (centralised vs. decentralised),

— *Data processing* (real-time vs. batch-processing),

— *Physical form* (e.g. earmark, ceramic bolus, glass encapsulation for implantation, nail, smart label),

— *Storage capacity,*

— *Energy supply* (with/without battery),

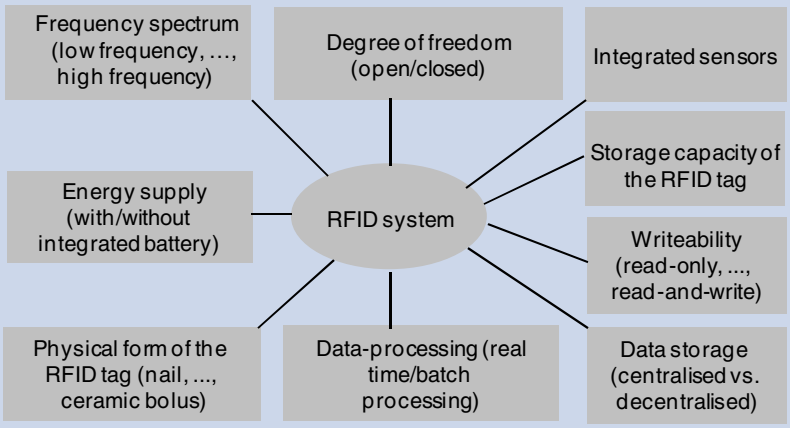
— *Writeability* of the RFID tag (e.g. read-only; write-once-read-multiple; read-and-write),

— *Radio frequency* (from low frequency [LF] to ultrahigh frequency [UHF]),

— *Integrated sensor technology* (e.g. temperature sensors).

Project demands and work environment explain broad variation

Wide variety of shapes and sizes
Technological dimensions of RFID systems



Source: DB Research, 2009 1

This broad variation is due to the various project requirements (e.g. in respect of the tolerable error rate in reading performance) and the diversity of work environments (e.g. as regards the environment of the material and/or ambient temperature) in which the RFID systems are deployed.

Degree of freedom, data storage, energy supply and radio frequency: Dimensions of the technological diversity

By and large, open systems are more complex

RFID systems can be *open or closed*. Closed systems are used in a closed process. This closed process is characterised by the fact that RFID tags are neither added nor removed in uncontrolled fashion. Since the process is closed the user can freely select the parameters of the individual components (such as software, frequency range, physical form of the RFID tag) without coordinating them with another company and can thus adjust them optimally to the requirements of his own internal business operations. By contrast, open systems always have interfaces to other companies within the value-added chain. Without a generally acknowledged technological standard the degree of complexity in open systems rises rapidly with the number of partners to be integrated. There needs to be smooth-running interoperability between the existing processes, particularly in the areas of enterprise resource planning (ERP) and warehouse management systems (WMS), along the entire value chain. The numerous initiatives (e.g. the technological solution UHF Gen2) divised by the not-for-profit organisations EPCglobal and GS1 in Europe are boosting the pervasion of RFID.

Easy availability of information cuts both ways

RFID systems can store data on a *centralised or decentralised basis*. With the currently very widespread form of centralised data storage the RFID tag merely stores a number code, but not the object-related information itself. The object-related information is unambiguously assigned to this number code and is stored by the central database. By contrast, in decentralised data storage, the RFID tag stores not only a number code but also object-related information (data on tag). The advantage of decentralised data storage is that the companies along the value chain can obtain the relevant information directly from the RFID tag. This advantage is particularly important in the case of time-sensitive processes as found, for example, on the production floor. But this simple availability of object-related information also brings with it two major disadvantages. Firstly, the decentralised systems have to be protected from unauthorised access by third parties. Secondly, they tend to be more prone to malfunction, since a greater volume of data must be read per unit of time.

Costs, operating life and range hinge on energy supply

The criterion of *energy supply* is what distinguishes active from passive RFID tags. While active RFID tags can draw on their own energy supply, passive RFID tags have to draw their energy from the difference in voltage in an electromagnetic field. The energy supply has a substantial influence on the application area, costs, operating life and frequency range of the RFID tag.

Radio frequency influences vulnerability to distortions

Even though many RFID tags work in the high-frequency (HF) or ultrahigh-frequency (UHF) range, there is ultimately no optimum *frequency spectrum* for all the applications desired. The best frequency band at any given time depends directly on the respective requirements and the environmental conditions. Applications that work in the high frequency range are suitable particularly for parallel bulk reading, since they achieve higher data rates, shorter reading times and greater transmission ranges. However, this advantage with the frequencies comes at the price of greater liability to malfunction when transmitting data in the vicinity of liquids or metal.

RFID paves way to a host of innovations

Concept acts along the entire value-added chain

Given this large variety of systems the essence of RFID technology can only be understood in a larger context than as a potential competitor to the bar code. The aim of the RFID basis technology is not simply to crowd out the bar code. Instead, RFID represents a comprehensive concept that is changing the business world through various innovations.

Automation and transformation lie ahead

One example is that RFID opens new ways to automate value-adding processes. The flows of goods along the global value chain are managed and documented with the help of RFID. This "automation effect", or "effect of the first order", boosts the efficiency of innovative businesses and thus improves their competitive standing. In the medium term, RFID will be instrumental in expanding the overall supply of goods and services. This "transformation effect", or "effect of the second order", will drive the innovativeness of the economy as a whole.

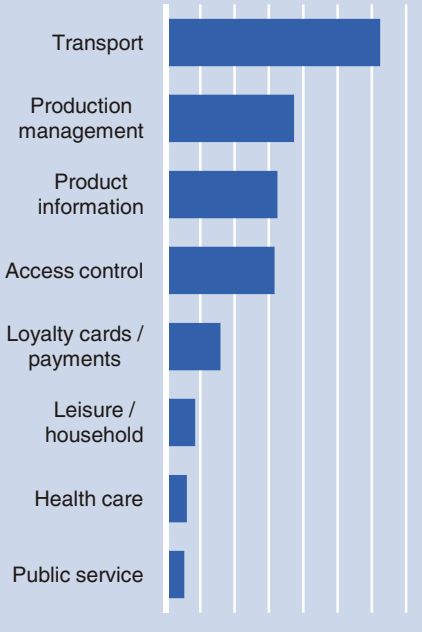
Technology influences many areas in everyday life

RFID is found in many areas of our everyday lives – from business (especially production, trade, transport) and sovereign duties (especially defence, border policing, internal security), right up to access controls and leisure pursuits (see Figure 2). For example, RFID projects in the distributive trade aim to capture the location of goods and transport containers (e.g. roll cages, containers) in real time. In this way, capital employed can be reduced and planning errors that compound themselves can be avoided. The aim of reducing capital employed is to be achieved partly by lowering the volume of inventories while maintaining the same degree of availability and partly by raising the capacity utilisation of the transport containers.

The objective of avoiding planning errors that compound themselves is to be achieved by ruling out erroneous out-of-stock messages. If an inventory management system determines that goods are out of stock even if they are actually still in stock, this erroneous message ultimately leads to high costs not only for traders but also producers in second and third-round effects. If it were possible to prevent these false missing inventory messages, traders and producers would both benefit.

In the worldwide value chain there is demand for cheap handling of the increasing volume of goods being delivered at frequent intervals. In particular, it is necessary to link the flow of materials more closely with the corresponding flow of information and coordinate the processes on the individual steps of value creation with one another. RFID has made a name for itself accordingly in the transport industry, particularly in the following four fields:

Transport is the biggest application area
RFID by field of application; % of projects covered by the survey



n=493 companies in Germany

Source: IIG Freiburg, 2008 2

— *Visualisation of physical goods flows* (also: tracking and tracing),

— *Automation of status information* on the condition of goods (also: condition monitoring),

— *Support for transport security* (e.g. warning emergency services in cases of accidents with hazardous goods),

— *Documentation for liability issues* (e.g. record of irregularities during transport).

These four fields are key factors for the transport industry in boosting the efficiency of its own processes.

Fascination of realised projects

Cost-income ratio limits use of RFID

German logistics provider DHL estimates that today there are over 1.3 million pallets worldwide marked with an RFID tag. However, cost-income ratios at present limit the use of RFID to larger transport units and high-value products.[1] This means that McKinsey consultants are very optimistic in forecasting that in 2010 RFID tags will be attached to 1 in 3 packages and no less than 50% of all pallets, but to just one single article in 20.

From fish and staff cafeterias right up to home helpers for the physically challenged

The following small selection from a massive spectrum of realised projects points out the innovative potential of RFID.[2]

— With 200,000 marked transport crates, Danish fishermen document date of catch, type of fish and fishing method. The fish traders feed this information directly into their own systems. Thanks to this fast way of processing they can offer a freshly caught and hence higher-quality product.

— A pharmaceuticals manufacturer is intent on preventing counterfeiting of high-value lifestyle drugs. The bulk packages of the products are fitted with an RFID tag with an electronic certificate of authenticity (e-pedigree). Using a reader, pharmacists can quickly check the authenticity of the drug.

— In the jewellery trade, RFID helps in inventory-taking and preventing theft. A trader marks his jewellery pieces with a miniature RFID tag. This tag links the physical good with information in the trader's database. In this way, the trader can quickly check his inventory every evening for completeness and, if anything is missing, use the product description in his search.

— An operator of staff cafeterias stores information on the meals issued on an RFID tag in the plates. This information is then read at the checkout, enabling the avoidance of waiting times and manual errors by the cashier.

— Passengers of one of Germany's local transit associations can pay for tickets by near-field communication via an RFID tag integrated into their mobile phone. When entering and leaving a vehicle passengers hold their mobile in front of the reader. A central system collects this information and prepares the monthly invoice with the cheapest applicable fee.

— The EU wants to prevent pets from spreading diseases across national borders. Therefore, the EU requires that vaccinations be documented in the pet's ID document. To be able to allocate the

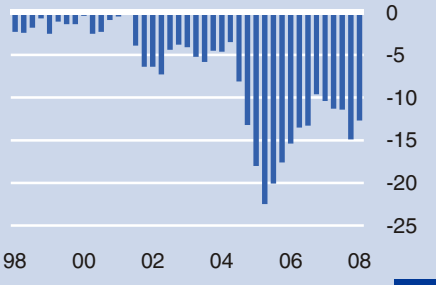
[1] See Ehmer, Philipp, Stefan Heng and Eric Heymann (2008). Logistics in Germany: A growth sector facing turbulent times. Deutsche Bank Research. Current Issues. Frankfurt am Main.

[2] See Heng, Stefan (2006). RFID chips: Future technology on everyone's lips. Deutsche Bank Research. E-conomics 55. Frankfurt am Main.

Not all sweetness and light
RFID project targets that were actually achieved; % of companies surveyed

Source: IIG Freiburg, 2008 **3**

Semiconductor prices continuing to tumble
Electronic components, Germany, producer prices, % yoy



Source: Federal Statistical Office, 2008 **4**

ID unambiguously, the animals are marked with an RFID tag under their skin.

— Blind people have an easier time of finding everyday objects (e.g. drugs, keys) in their homes if these objects are marked with an RFID tag. In this way, RFID enables a blind person to enjoy a more independent lifestyle.

Not all expectations were fulfilled

Besides all the positive experiences, though, practice shows that the use of RFID does not necessarily boost efficiency. The decision-makers in a company should therefore familiarise themselves in advance with the expected costs and income associated with an RFID project and perform a feasibility study. Furthermore, the targets should be reviewed critically at regular intervals. To give an example, RFID has in practice largely fulfilled expectations as to reducing production downtimes and improving quality control. By contrast, though, the expectations as to the reduction of the need for adjustments after deliveries and a decrease in material waste have often been disappointed (see Figure 3).

RFID carries no unconditional guarantee of success

Public debate places particularly heavy emphasis on the significance of falling chip prices for the spread of RFID systems (see Figure 4). This argumentation is easy to follow, but it does not entirely do justice to the complexity of the RFID issue. For besides the price of RFID tags there are numerous no less important factors from the three areas entrepreneurial environment, technology and politics shaping the cost-income ratio of an RFID system.

Experience shows that there are three preconditions from the entrepreneurial environment that are crucial for project success:

— *Degree of RFID use along the value chain*: The more the technology is integrated into the value chain, the higher the returns that can be generated on investment projects.

— *Fit of the software*: There is no cheap standard solution that fits all RFID projects. Producers, traders and transport service providers have to coordinate their infrastructure with one another. The important thing is that the new technology is efficiently integrated into existing processes and the existing IT infrastructure.

— *Allocation of costs*: Costs/income linked with RFID deployment are usually incurred/generated by different participants along the value chain. To allow investment in the first place there has to be an extensive cost-benefit analysis. This calculation should help ensure that producers, traders and transport service providers appropriately distribute the costs incurred.

While in the entrepreneurial environment the aspect of cost allocation is a general precondition for investment, the two aspects of fit of the software and RFID diffusion along the value chain have a particular bearing on the feasibility of the RFID project.

Tough nuts to be cracked in technology and politics

Besides the challenges from the entrepreneurial environment there are also still unmet challenges from the areas of technology and politics which directly impact the market success of RFID.

RFID not always the best solution

Advantage of RFID over bar code	Advantage of bar code over RFID
• Data captured without physical or visual contact in real time • Bulk reading range possible • Long reading range possible • High storage capacity possible • Less sensitive to dirt or pollution • Possibility of extensions: – Storing and updating data – Combination with protection mechanisms against unauthorised reading – Combination with sensor technology	• Considerable market experience • Lower project costs: – Simple printing solutions are possible – Out-of-the box standard solutions available • Not affected by major fluctuations in temperature

Sources: Informationsforum RFID e.V. Berlin, DB Research, 2009

5

The four technology issues are as follows:

— *Energy consumption* (the focus here is on conserving energy, so-called power management) and obtaining operating energy from the system environment (so-called energy harvesting),

— *Cheap production* (with the emphasis on printed antennas and conducting polymers),

— *Speed of data processing* (software should process the large volume of data collected in real time if at all possible instead of only in batch processing with a time lag and thus produce decision-relevant information as quickly as possible),

— *Reading errors* (in particular, it is important to undercut the tolerable error rate for the process during bulk reading).

In addition, there are four points on the politics side:

— *Frequency harmonisation* (on the use of important frequency bands in particular regions),

— *Standardisation* (this is about data formats, air interfaces, communication protocols),

— *Health protection and environmental protection* (concentrates on harmful materials in the RFID tags),

— *Data protection and data security* (in particular, focus is on the right of the consumer to decide on information related to his or her person).

The significance of the political aspects has an unequal weighting in the different application areas of RFID. For instance, the two aspects of data protection and data security as well as health protection and environmental protection are particularly important when the consumer comes into direct contact with the technology. By contrast, the two aspects of frequency harmonisation and standardisation play a particular role in international goods trade.

Difficulty of agreement in complex web of interests

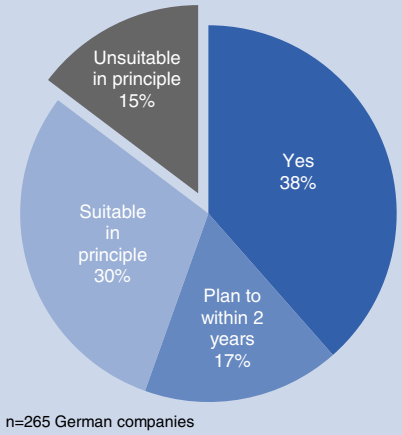
Apart from these differences in weighting, all these areas of activity have in common that numerous interests in business, technology and society – in some cases even opposing ones – clash at the national and international levels. This complex mix of interests means that only slow progress is being made in the agreement process – in spite of numerous efforts by various political institutions.[3] This is holding back the development of the RFID market, which by nature is highly dynamic.

The difficulty of attaining a manageable political settlement between entirely warranted but opposing interests can be seen for instance in the dispute over the opt-out and opt-in-options in the retail trade. Opt-out means that the RFID tag on an article is only deactivated when a customer leaves a store if the customer expressly asks for this to be done. By contrast, opt-in means that the RFID tag on an article is only left activated when a customer leaves a store if the customer expressly makes this request.

This dispute between opting-out and opting-in puts policymakers in the line of fire between the demands of companies and those of consumer advocates. In this debate, the companies make a case for the opt-out by emphasising that the full efficiency potentials can only be tapped in a comprehensive and distortion-free concept all along

[3] Examples of the many diverse efforts are the expert conference “RFID: Towards the Internet of Things” or the “Autonomik” initiative of the German government.

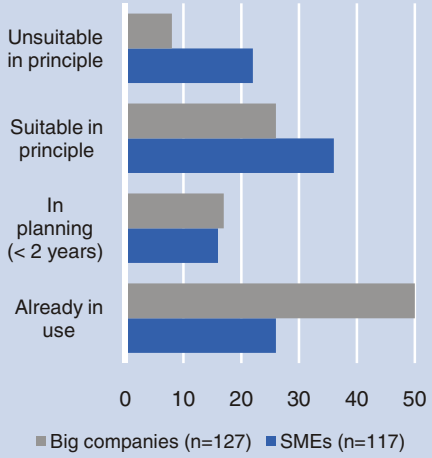
Only one company in seven says "no"
"Will you use RFID in your company?"; % of those surveyed



n=265 German companies

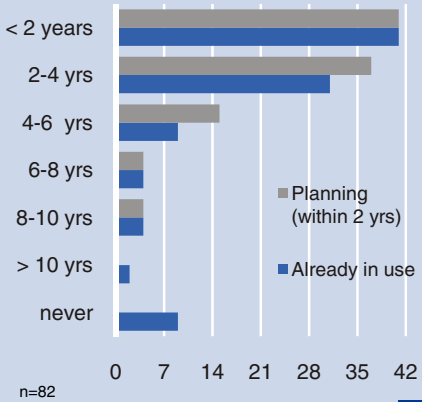
Source: IIG Freiburg, 2008 6

Small companies less bullish
RFID in German companies; % of those surveyed



Source: IIG Freiburg, 2008 7

Great hopes for the near term
Time expected for amortisation of RFID investments; % of those surveyed



n=82

Source: IIG Freiburg, 2008 8

the value chain. By contrast, consumer advocates support the opt-in system by emphasising the dangers for data protection. In the wake of the public consultation procedure, the EU now argues for the opt-in method in the retail trade with a further critical debate on this topic in 2011. Even though this recommendation from back in March 2008 is not legally binding on the EU member states, it nonetheless appears to constitute a preliminary decision in favour of opt-in in the retail trade.

The details show that the commercial success of RFID is influenced by many preconditions from the three areas of entrepreneurial environment, technology and politics. With these preconditions it becomes apparent that RFID is not a panacea for all business challenges. Contrary to some representations in the public debate there will continue to be a large number of application fields in which the RFID-based solution is not as good from a business standpoint as alternative solutions (especially ones based on the bar code or data matrix codes[4], see Table 5).

Companies pinning big hopes on RFID

Given the prominent examples of successfully implemented RFID projects and the broad public interest in RFID only two German businesses in five believe that RFID is generally unsuitable for their own field of business (see Figure 6). However, these assessments – which were captured in a survey conducted by the Wissenschaftliches Institut für Informatik und Gesellschaft (IIG, a research institute focussing on information technology and society) of the University of Freiburg – strongly depend on the size of the company surveyed. For while only about one big company in twelve says that RFID is unsuitable, the ratio among the small-to-medium-sized companies is nearly one in four – even though no RFID application is technically unsuitable *a priori* for small or medium structures (see Figure 7).

The companies that opt to use RFID pin big hopes on these projects. More than 70% of the companies surveyed hope that their investments will amortise themselves within 4 years (see Figure 8).

The efficiency gains achieved in most of the realised RFID projects hold considerable attraction for potential RFID users. The companies hope that the potential efficiency gains of the technology may also be realised in their own business environment.

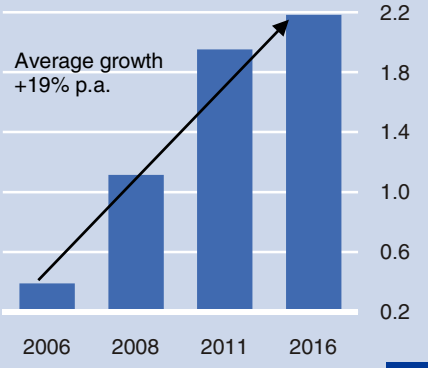
RFID is a dynamic market

As with many other technological innovations, more time will be needed to address the challenges of RFID than originally anticipated. There has been only limited progress on numerous issues over the past few years. Owing to the still unresolved challenges in the three areas of entrepreneurial environment, technology and politics, the market was unable to expand at the breakneck pace predicted by some research institutes only a few short years ago.

Nonetheless, considering the marked interest from the demand side we expect RFID suppliers to enjoy a generally positive environment. In this environment, global turnover is likely to increase by an

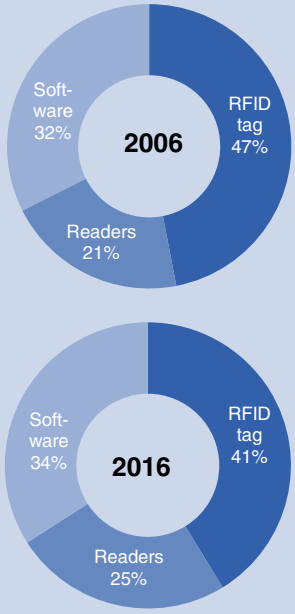
[4] The data matrix code was developed in the 1980s. It is the best-known two-dimensional code. Compared with the one-dimensional bar code, the density of information per area is much higher for the data matrix code. Today, the data matrix code is used *inter alia* in car production in the form of a needle stamp or in document handling as a printed picture (e.g. train tickets, postage stamps).

Still remarkable growth
RFID revenues, Germany, EUR bn



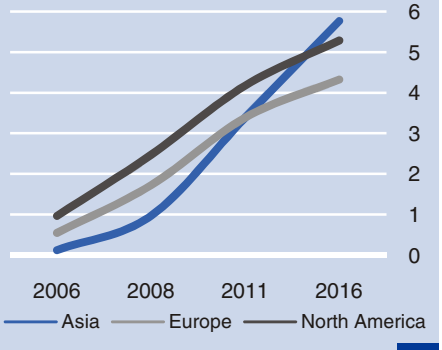
Source: DB Research, 2009 **9**

Tags losing ground but still on top
Global RFID market, %



Source: DB Research, 2009 **10**

Asia aiming for market leadership
RFID revenues, EUR bn



Source: DB Research, 2009 **11**

average of 25% p.a. to a total of around EUR 16 bn between 2006 and 2016.[5] In Germany alone, turnover is set to grow by 19% p.a. on average during this period, to EUR 2.2 bn (see Figure 9). Considering the burgeoning growth of the market the share of revenues claimed by RFID tags is set to decline vis-à-vis the shares of readers and software, from nearly 50% of total revenues to just over 40% between 2006 and 2016 (see Figure 10).

In regional terms, North America still contributes a considerably larger share of revenues than Europe, and far more than Asia. However, with the shift in market shares of individual RFID components and the exodus of production of less sophisticated products from the high-wage countries, Asia may be able to surpass not only Europe in terms of RFID turnover by 2016, but also the US (see Figure 11).

Summary: All things are in flux – RFID heading for new shores

To be able to hold their own in international competition, producers, transport service providers and traders have to keep close contact and exchange relevant information along the worldwide value chain. RFID radio chip technology will play a key role in the job of securing their competitiveness.

Accordingly, more and more companies are considering their options for using RFID in their line of business. The projects implemented in production, trade and the transport industry highlight the potential that can be realised with RFID in the private sector – initially for the company applying it itself, but subsequently also for the economy as a whole.

RFID is leading to the development of a multitude of innovations in the economy – process innovations in particular. But by no means every RFID project driven by a technological vision will necessarily become a commercial success for the user. Besides the much-discussed significance of falling chip prices a raft of other factors will be instrumental long term in shaping the commercial success of RFID.

These challenges will not be mastered as quickly as originally anticipated. The progress achieved over the past few years is still pretty minor in respect of many different issues. This suggests that the market was unable to achieve the astounding growth rates forecast by some research institutes only a few short years ago. Nevertheless, because of the enormous interest on the demand side we expect RFID suppliers to flourish. In this favourable environment RFID turnover is set to grow by 19% p.a. on average in Germany between 2006 and 2016, and in fact by 25% p.a. worldwide. With the shift in market shares for individual RFID components and the exodus of production of less sophisticated products from the high-wage countries, Asia is likely to contribute an ever increasing share and become the continent with the highest turnover by 2016.

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[5] In this analysis it has to be borne in mind that there is no clearly definable “RFID sector”. Instead, in the official statistics the companies dealing with RFID are classified in the electrical engineering, software or mechanical engineering industries.

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