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Federal Ministry of Economics and Technology:
Dr. Goerdeler, Andreas (leading subdivision)
Dr. Glasmacher, Klaus (leading subdivision)
Bleeck, Peter
Dr. Hochreiter, Rolf
Knebel, Thomas
Walter, Wilfried
Warmbold, Heike
Dr. Weissman, Bernd

Federal Ministry of Education and Research:
Dr. Diehl, Carsten

Federal Ministry of the Interior
Bröhl, Alexander

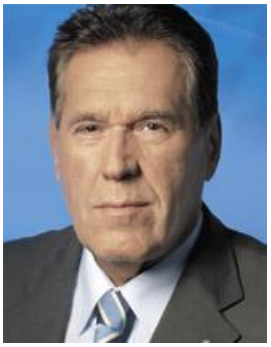
European Commission ï DG Information Society and Media:
Dr. Frederix, Florent
Dr. Friess, Peter
Santucci, Gérald

Authorities, institutes, organisations and associations:

Fabian, Benjamin	Humboldt-University Berlin
v. Braunmühl, Patrick	vzbv ï Federation of German Consumer Organisations
Prof. Günther, Oliver	Humboldt-University Berlin
Hansen, Wolf-Rüdiger	AIM-D ï Association for Automatic Identification and Mobility Germany
Prof. Hilty, Lorenz	EMPA ï Swiss Federal Laboratories for Materials and Research
Houben, Marc	VDEB ï Verband der EDV-Software- und Beratungsunternehmen
Dr. Huber, Andrea	Informationsforum RFID e. V.
Japs, Simon	Informationsforum RFID e. V.
Jimenez, Marisa	GS1/EPCglobal
Kelter, Harald	BSI ï Federal Office for Information Security
Dr. Kuhlmann, Kai	BITKOM ï German Association for Information Technology, Telecommunications and New Media e. V.
Kreuzer, Peter	VDA ï German Association of the Automotive Industry
Landvogt, Johannes	BfDi ï Federal Commissioner for Data Protection and Freedom of Information
Prof. Monse, Kurt	FTK Institute
Pique, Stephane	GS1/EPCglobal
Dr. Pötter, Harald	Fraunhofer Institute for Reliability and Microintegration
Sander, Ralf	AIM-D ï Association for Automatic Identification and Mobility Germany
Dr.-Ing. Schanz, Volker	Information Technology Society within VDE (ITG)
Dr. Spiekermann, Sarah	Humboldt-University Berlin
Dr. Schmidt, Stefan	Fraunhofer Institute for Material Flow and Logistics
Dr. Thorun, Christian	vzbv ï Federation of German Consumer Organisations
Ziekow, Holger	Humboldt-University Berlin

VDI/VDE Innovation + Technik GmbH on behalf of the Federal Ministry of Economics and Technology:
Botthof, Alfons
Dr. Bovenschulte, Marc
Gabriel, Peter
Dr. Gaßner, Katrin

1 Foreword by Michael Glos, Federal Minister of Economics and Technology



Modern information and communications technologies account for 40 percent of overall economic growth. As cross-sector technologies they affect the innovative power of nearly all economic sectors and are the driving force behind dynamism and employment. The Radio Frequency Identification (RFID) of products and goods will play an outstanding role in the future. It contributes to more efficiency in the fields of trade, logistics and industry. In addition, it enhances the quality of life, e.g. with regard to consumer goods, in the health sector and in the environmental field.
On this basis, the vision of the "Internet of Things", where intelligent objects and systems interconnect on their own and state-of-the-art sensors serve to register the status of machines or to monitor vital parameters of patients, is already becoming apparent.

In Germany alone, we expect an RFID-related rise in the share of the value added of the producing sector, trade, transport as well as public and private service providers totalling about 62 billion euros by the year 2010 compared with 3 billion euros in 2004.

The planned specialised conference "RFID - Towards the Internet of Things" within the framework of the German EU Council Presidency is to underline the significance of RFID and point out the scope of action in the political and economic fields in order to tap the full potential of this important technology and thus to create a global competitive advantage for Europe. The conference offers political and government representatives, experts and decision-makers from industry and science as well as representatives of social groups a broad - and in this form unique - platform for dialogue at the European level and beyond.

Representatives of industry, associations, government bodies and the European Commission have closely cooperated to contribute to the elaboration of this draft RFID position paper. Our objective was to reconcile the positions of various interest groups and to make first recommendations on a common European strategy and thus to create a sound basis for discussion for the planned conference. We have outstandingly succeeded in doing so. I am convinced that on this basis it will be possible to initiate the right steps for responsible action to tap the potential of this key technology.

I would like to thank all parties involved for the constructive work.

Michael Glos
Federal Minister of Economics and Technology

2 Welcome address of the European Commission by Viviane Reding, Commissioner for Information Society and Media

The European Unionôs renewed ñLisbonò strategy calls for a more competitive Europe and proposes efforts focused on delivering stronger and lasting growth, creating more and better jobs. In this context, beyond setting targets for R&D investment, we must also convert this investment into new ICT products and services as they are the key drivers for productivity growth. In this respect, smart radio tags, technically called Radio Frequency Identification (RFID), is a cornerstone of new ICT-enabled technologies that can boost Europeôs position and give it a competitive advantage. And as we move towards an "Internet of Things", there will be more devices connected online and consequently more online transactions.
It is likely that there will be one billion computers, 5 billion users of mobile communication systems, ten billion appliances, one hundred billion sensors, and one quintillion electronic tags by the year 2020, most of which will be internet enabled.

We all have a role to play in the quest for a ubiquitous information society that serves citizensô interests. To better understand these interests I launched a wide public consultation on smart radio tags in 2006. In response the European Commission has made securing citizens' privacy on and offline a priority, but at the same time tried to balance it with the right approaches of not hampering their potential for business. I welcome that about 70% of the 2190 respondents to the public online consultation were 'interested citizens'.

In particular, the consultation was extremely valuable in that many interesting ideas and important concerns were submitted regarding the challenges that smart radio tags will face. It is clear that all stakeholders should actively engage in a dialogue to develop a "win-win" solution, a situation in which the benefits clearly outweigh any costs, where all concerned parties see an advantage in further deploying this useful and important technology. Businesses are in particular asked to take the serious citizen concerns about their privacy into account when entering the RFID world.

The European Commission will therefore in the months to come develop a common European smart radio tag policy together with Member States, which will also include some clarifications how current EU rules apply to RFID. In addition, I will proactively cooperate with external countries, notably on issues where international agreement is necessary. By the end of 2008, I will reassess the situation to see whether RFID requires also amendments to Europe's regulatory framework. A responsible approach by the industry to RFID that takes out citizens' interests will be the best way to convince me that a "light touch" approach is appropriate here.

Balancing the different national smart radio tag ñspeedsò is another important issue where Member States can clearly demonstrate the benefits of common goals and of pulling together. In particular pre-competitive research must be strengthened and a critical mass of test beds and trials assist us identify new applications that will become affordable and are hence available to all citizens. Europe will foster collaborative smart radio tag research, with the Seventh Framework Programme being instrumental in this regard, and will support the development of pilot projects to test innovative applications of this technology, in domains as varied as property management, import/export logistics, air baggage tracking and control, infectious waste management, health, transportation etc.

We have a choice. We can continue to be buffeted by the harsh winds of a shrinking world, or we can think anew and guide the currents of technological change with a progressive vision that strengthens Europe and prepares our citizens to move confidently to the future. Our progressive vision is a commitment to true opportunity for all, not as an abstract concept but as a practical necessity. To find our way to the "Internet of Things", we need the skills, the insight and the productivity of every stakeholder so as to ensure that the blessings of progress are shared fairly by all stakeholders in return. European values on matters of security and privacy will continue to be guaranteed but we must also encourage the identification of secure solutions that take full account of the emerging ñInternet of Thingsò. This will also be an "Internet for People"; therefore, the handling of RFID-enabled identities will raise critical challenges for sovereignty, individual liberties and economic independence. It will thus be necessary that citizens keep control of how their information is created, used and updated.

We are ready to fulfil our pledge to build a Ubiquitous Information Society, and are committed to strengthen the European and international dialogue on smart radio tags, and the other key technologies that will shape the ñInternet of Thingsò.

The conference is a cornerstone event for raising awareness of RFID and the "Internet of Things" in Europe. Building on the analysis and proposed actions of the recently published Commission Communication on steps towards a European RFID policy framework, it conveys the notion that effective action is needed so Europeans can trust that the various applications of RFID and related technologies are as safe, secure and privacy-friendly as they possibly can be. The document which has been prepared for the conference is thoughtful and provides important recommendations for policy action at European and Member State level. Finally, I welcome very much the initiative of the German Presidency in the field of RFID and would like to express my thankfulness to all conference participants for their engagement.

Viviane Reding
Commissioner for Information Society and Media

3 Introduction/thematic overview

The deployment and implementation of modern information and communication technologies (ICT) are laying the foundation today for dynamic economic growth and the future viability of global competition. ICT has triggered, enabled and accelerated enormous changes. These new technologies are creating an ever-expanding ripple effect on the economy, public administration, science, health care, employment, scholarship and private life. They affect social and individual life. Digital information and services are going mobile and can be called up from any location. The emerging trend towards ambient intelligence (technologies that sense, compute and act) heralds the ubiquitous and invisible use, creation, processing, transmission and storage of information. The "computerisation of the world" is being accelerated by technological and economic developments. Advances in micro- and nanotechnology and in new materials, software and communications technology have moved the technical vision of the "Internet of Things" into the realm of the possible. This includes processor module integration into identification documents and the integration of transponders into cargo pallets that automatically send ID numbers to a reader. Radio Frequency Identification (RFID) allows the unambiguous recognition and correlation of goods, documents, containers, tickets etc., all without direct contact. The use of RFID as a remote keyless entry for cars and trucks is now commonplace. Future tags will gain additional intelligence (for example integrated sensors or data storage and processing capacities) that can make real world objects part of the Internet and vice versa.

When it comes to the effects of ICT, nobody doubts the transformative power of the "IT revolution" that has changed the landscape of industrial production. The advantages of automation and digitalisation in production processes are today common knowledge and widely accepted within companies, trade unions and governments. And now, in the Internet age, ICT plays an increasingly important role in the service sector. Industrial sociologists have called this phenomenon the "industrialisation of services" due to new and mature technologies that enable the transfer of more formal aspects of intellectual work to technical artefacts (rationalisation). This trend is expected to change industrial production to "hybrid production" (fusion of production/product and service) and will also change business models from selling products to selling performance.

RFID is a key component in this process, providing the linkage between the "world of production" (represented by the material good) and the "world of service" (represented by digitalised information). With RFID tags, objects become "smart" and can be networked together and communicate with their environment. RFID technology as a precursor to the Internet of Things will optimise existing processes in various industrial sectors. RFID is also expected to create opportunities for new business models that will take advantage of a global network in which any object can be linked to any context.

What is the Internet of Things?

In the technical trade literature, definitions of the Internet of Things remain surprisingly vague. Most approaches reflect the vision of Mark Weiser ï "Everywhere, always, everything" ï for Ubiquitous Computing. The concept of Ubiquitous Computing ï as well as Pervasive Computing or Ambient Intelligence ï represents a new form of invisible computing. Computers will be integrated into "smart" everyday objects that can communicate and interact autonomously and provide numerous services to their users. The Internet of Things refers to the networks and services that enable communication among these objects. Ubiquitous Computing considers objects as smart agents that act on their own behalf. This striking paradigm shift provides objects with their own digital identity and is a critical component of both Ubiquitous Computing and the Internet of Things.

The Internet of Things is the technical vision for the integration of any kind of object into a universal digital network.

The Internet of Things is a metaphor for the universality of communication processes, for the integration of any kind of digital data and content, for the unique identification of real or virtual objects and for architectures that provide the "communicative glue" among these components. RFID serves as a means to uniquely identify objects. Via RFID, the Internet of Things connects real world items with further data and digital "brains", and, *vice versa,* it supports software systems with sensor and context information accessed by the RFID tags. In the weakest version of the Internet of Things, these objects can be identified but do not "do" anything actively; in the strongest version, objects communicate with each other so that the Internet of Things and Ubiquitous Computing complement each other.

Important fields and industrial sectors for the application of RFID are:

- Manufacturing and production (e.g., the automotive industry),
- Transport and logistics
- Retail and consumer goods
- Public transport
- Health care
- Anti-counterfeiting
- Ticketing
- ePayment
- (National) Security
- Recycling

These sectors can all benefit from RFID as a powerful technology to optimise existing processes, improve reliability, offer new services and realise the advantages of rationalisation. This rationalisation might not finally result in significant job losses, but it will increase productivity, thus keeping and improving the competitiveness of European economies. Furthermore, in the medium term, new production processes and business models will create new jobs that will probably demand higher qualifications and offer higher incomes. The following paragraphs provide a short overview on consumer products and retail, automotive and production, and logistics and health care, some of todayôs most prominent application areas for RFID. The estimations of macroeconomic effects of RFID are based on a study recently carried out on behalf of the German Federal Ministry of Economics and Technology.

Consumer products & retail

As a leading user of RFID, the retail sector is characterised by the fact that it must co-operate with a very large number of partners, the makers of consumer goods. In this competitive and cost-sensitive industry, customer satisfaction and inventory visibility are crucial to growth and profitability. Profits can be increased here in a number of ways, including primarily the reduction of inventory replenishment time, fewer price markdowns, less merchandise spoilage, fewer incidents of theft, and shorter lines at the point of sale. Hypermarkets, large superstores and discounters hold an advantage in achieving such results, while conventional supermarkets, specialty stores and small retail shops are unlikely to profit from them. It is estimated that RFID will enable up to a ten-fold increase in productivity within the next five years. According to the above mentioned study, this will most likely result in a decline in the number of jobs in the retail/consumer goods sector. Sustainable performance in this industry will require staff that is familiar with the technology and is devoted to studying further business process improvement opportunities. Employers will also be required to offer workers training/retraining opportunities to help them retain their employment in the context of technological change and to improve their employability. A successful RFID approach in the retail sector will balance short-term profitability goals with a long-term strategy of business innovation, consistent and effective customer service, and workersôacceptance and support.

Logistics & transport

Logistics will also profit greatly from RFID in the coming years. It is expected that RFID will be widely implemented in transport containers in order to meet the growing requirements of the globalised economy. Due to constantly low margins, the best prospect for increasing profits is to enhance efficiency through automation and rationalisation. Potential for optimisation can be seen both in internal workflows (particularly in the courier, express and parcel sector), and in the inevitable co-operation with partners (other logistics companies, industry and retail). Furthermore, additional services like tracking/tracing can be realised by RFID. The conditions necessary for success include

the integration of intra-company systems that are economic and reliable ï and even more importantly ï universal standards that ensure network-wide exchange and co-operation processes. Industry representatives estimate that if these conditions are fulfilled, the adoption of RFID can achieve significant efficiency gains. Remarkably, despite rationalisation efforts, the numbers of employees in logistics might increase due to the general growth of this sector.

Automotive & production

The automotive industry has been a pioneer in introducing RFID technology. To date, it has implemented RFID primarily in internal company processes. The automotive industry faces several challenges that stem from the complexity of the product, the worldwide decentralisation of production sites, the declining vertical integration of OEMs and the outsourcing of production steps to suppliers, the necessity for customised mass production, and cut-throat global competition. Here too, RFID will optimise existing processes and increase efficiency and productivity; applications will appear mainly in production logistics (vehicles and material), the monitoring systems and processes, full utilisation and availability of assembly lines In the near future, RFID will be implemented in maintenance and service tasks and quality control in order to avoid fallouts during the production process. RFID is expected to yield a five-fold increase in efficiency by the year 2010. Since labour costs play a relatively minor role in the automotive industry, it is unlikely that companies will compensate one-to-one for RFID investment costs through staffing cutbacks.

Many of these findings apply not only to the automotive sector, but also to industrial production processes in general. In order to transfer existing applications to the entire supply chain and thus throughout a ramified partner structure, RFID will have to harmonise with the industryøs existing standards. An additional problem is that investing in the new technology involves considerable risks for the suppliers, which are generally small- to medium-sized businesses; this will be well-nigh impossible as long as their current systems have not yet paid for themselves.

Health care

The pharmaceutical industry views RFID as an appropriate means to protect patients from counterfeit medicines. Due to the increasing number of cheap imitation pills, the threat of using ineffective or harmful medicine continues to grow. RFID can be used for non-ambiguous identification to guarantee that patients receive only approved pharmaceuticals. The European pharmaceutical industry considers RFID as a promising complementary identification solution in the long term, provided that the technology becomes more mature and economically viable.

In a comparable way, there are a multitude of potential applications for RFID in the health care delivery system. Blood donations and blood products can be easily identified *via* RFID at each step of the internal processes in a blood bank, laboratory or hospital. Unlike the traditional barcodes, RFID resists the physical wear and tear of the laboratory environment, such as humidity and mechanical friction, thus ensuring that sample data remain accurate and stay with the sample. In the future, advanced tags with sensors could monitor whether blood samples have remained chilled (maintenance of the cold chain) and undergo adequate treatments. Use of RFID wristbands in the hospital environment has been shown to improve patient safety. RFID can also enable access to pharmaceutical cabinets, trace device histories and prevent the counterfeiting of highly specialised and expensive instruments and tools. RFID can be an integral part of a chronic disease management system at home to improve compliance with medication schedules. In addition, RFID can be used to identify and support the tracing of medical products such as implants and devices.

Besides the aforementioned sectors, RFID has also been implemented in other areas of public and private life. In the public sector, RFID is being used to allow safe, verifiable and non-ambiguous identification, including applications in official documents such as passports, access control, tickets for

events and public transport, etc. RFID is a truly intersectional technology with universal applicability in a large variety of industries. Due to the intersectional character of RFID, it is nearly impossible to calculate precisely the economic effects of this technology. Like many other new technologies, RFID is not an established industrial sector covered by existing statistics. If the diffusion of RFID and its direct and indirect effects are to be measured, new indicators and statistics have to be developed and applied.

Recent studies have shown that, at least until 2010, RFID will remain in most cases an ñinternal technologyò that does not directly affect the end customer. Given the internal character of early RFID applications, customer rights do not seem to be affected by this technology; however, possible privacy issues cannot be disregarded. If every consumer good carries its own RFID tag, a new dimension of customer-based services become possible, including digital shopping assistants, personalised offers and special prices, anti-counterfeiting, facilitated maintenance, etc. Such personalisation via RFID might require deeper analysis from data and consumer/citizen protection point of view and the development of specific guidelines should be considered. This seems to be even truer for the vision of the Internet of Things.

Although the numerous assessments of this technology paint a promising picture for the future, and the technological maturity and economic impacts of RFID have already been realised, important questions still remain open:

- What are the technical hurdles for the broad application of RFID, and what further developments are required for the realisation of the Internet of Things?
- Will business processes be so completely dominated by the use of RFID that even manufacturers, small shops, craftsmen, etc. are forced to introduce this technology?
- Will there be different RFID-based solutions for different applications and industrial sectors or will all RFID applications be operated by one global standard?
- What impact does RFID have on the emergence of new business models, and is it relevant for the labour market?
- How powerfully does RFID affect the privacy of consumers today and in the future?
- Who collects what kind of data, and who will combine and control these data?
- How can Europe be a strong global player in the field of RFID and how can itôs Member States benefit from it?

The following three chapters will address these questions and offer potential solutions. The attempt is made to identify the main obstacles to innovation that must be overcome by the relevant actors in politics, industry, science and society. This policy outlook focuses on the political aspects of innovation that will facilitate the implementation of RFID and make it a success story throughout Europe. The broad roll-out of this technology requires a conscious, responsible, determined and courageous advocacy based on the general agreement of all relevant European stakeholders. In the context of the Lisbon strategy, Europe aims to become the most competitive knowledge-based economy in the world. One key issue of tomorrowôs economies will be a strong and innovative ICT sector with a strong and sustainable impact on the full socio-economic spectrum of the common market. RFID and the Internet of Things are an important cornerstone in this strategy.

4 Challenges for market-driven innovations

RFID technology is considered to be a driver and source of innovation and has attracted international interest. European technology providers, users and research centres have made Europe a leading player in global RFID competition. From chip manufacturers to label makers to system integrators, European actors hold prominent positions in almost every link in the RFID value chain, and in many segments, such as special label-making machinery, they are among the market leaders. Within Europe, Germany is again in the lead, together with France, the United Kingdom, Spain, and Italy.

The United States and Asia (e.g., China, Taiwan, South Korea and Japan) are, however, extremely strong competitors, with large-scale R&D programmes and infrastructure projects either in the pipeline or already under way. These regions have opted for large-scale research programmes with multi-technology objectives (e.g., the ñUbiquitous Cityò in South Korea) or government-initiated infrastructure projects (e.g., the FDA recommendation of RFID to combat counterfeit pharmaceuticals or the Pentagon's broad RFID mandate, and the results of an FDA stakeholder consultation in 2006). These activities and measures offer major incentives for the development of RFID systems and generate demand for RFID solutions in national enterprises.

The European dimension

This chapter describes both technical and policy challenges that have been identified particularly relevant for the successful innovation, adoption and wider diffusion of RFID technologies in Europe. It also outlines possible flanking (accompanying) measures to cope with these.

Strengths	**Weaknesses**
• European RFID user sectors are open- minded and represent global cutting-edge technology applications (e. g., Metro, Tesco) • Excellent research infrastructure and strategic projects • Strong industry with many SMEs all over Europe covering the full value chain	• Many SMEs do not have sufficient equity capital to invest in RFID • Patent situation in UHF • Differing awareness for technological potential and societal issues throughout Europe • Insufficient harmonisation within Europe (different speed in taking up RFID) • Lack of standard protocols • Interoperability issues between vendor products • Still low degree of public procurement and government RFID application
Opportunities	**Threats**
• High potential for efficiency gains in major sectors (e.g., consumer goods, trade, automotive, health care) • Potential for job creation • Important market share within the growing market for European technology providers (esp. RFID tags/readers, production equipment/machinery) • Large potential for improved consumer service and the development of new markets • Industrial initiative for security and privacy can stimulate generation of new markets • Development of Privacy Enhancing Technologies (PET) • Importance of a wide stakeholder dialogue has been realised, first experiences already exist	• Strong competition from technology providers in US and Asia • Low-cost (dumping) overseas competitors • Highly fragmented competitive environment • Speed of RFID application ñroll-outsò in competitive markets such as Asia and US • Short window of opportunity for market entry • Lack of interoperability, different speed of implementation within the EU and with respect to major competitors like the US and Japan • Absence of seamless value chains • Lack of consensus on societal issues and concerns

European SWOT Analysis for RFID

Based on the European Strengths, Weaknesses, Opportunities and Threats (SWOT) Analysis, the following chapters address central challenges and proposed measures to deal with them.

Challenge: Common European framework for RFID innovation

The European Commission and the Member States have realised the opportunities inherent in RFID. This is underlined by various projects in Framework Programme 6 (FP6), the expected importance of the upcoming R&D projects in FP7, and through major initiatives at the national level (e.g., within the NextGenerationMedia and Microsystems programmes in Germany). RFID is currently a topic on the European Technology Platform on Smart Systems Integration (EPOSS; www.smart-systems-integration.org). Sixteen European collaborative R&D projects are currently being organised into a strategic cluster (Cluster of European RFID Projects (CERP); www.rfid-in-action.eu/cerp). Commissioner Reding presented a paper entitled ñRadio Frequency Identification (RFID) in Europe: steps towards a policy frameworkò to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions at CeBIT 2007.

Nevertheless, policymakers must continue to create a more stimulating and supportive environment for European firms working on RFID. Clear policy could help resolve central issues such as usersô and investorsô need for legal certainty, harmonisation of frequencies, establishing standards, showcasing of good practices in implementation strategy and business models. There is still no coherent technology and industrial policy regime for translating R&D findings into feasible, economically viable, and socially and ethically acceptable applications. A unified approach at the European level could go a long way towards meeting these challenges and easing the innovation constraints on the wide-scale deployment of RFID, thereby enhancing the future international competitiveness of the European market. The Member States appreciate successes of the consultation process, and they welcome the heightened visibility of RFID, and therefore the European Commissionôs recognition of their roles and responsibilities.

Proposed measures: On the European level, a benchmark study could be carried out to compare Europeôs own RFID technology policy and those currently adopted by the Member States of the European Union. Secondly, the approaches favoured by the United States and Southeast Asia should be discussed. Based on the outcome of this comparative study, the European Commission and the Member States should take bold steps towards harmonising and strengthening RFID technology policies and their corresponding research programmes. In addition, technologies like polymer electronics, security engineering and sensor networks should be prioritised and the establishment of large, joint multi-technology projects with a pronounced applied bias (beacons) could be overall objectives.

In particular, publicly sponsored RFID infrastructure projects involving several Member States (such as the ePass; www.pointprotect.de) should be tapped for the broad testing and introduction of technologies in beacon projects. Furthermore, EU Member States should commit to several ñflagship projectsò. In order to accelerate the utilisation of RFID technology, national governments as well as the European Commission should consider the implementation of RFID (e.g., public procurement in access control, document tracing and other security-related process systems).

Fields of application ï market drivers, chances and challenges

RFID applications are already in place in such diverse fields as manufacturing processes, highway toll management, building access badges, mass transit, and library check-out. In addition, thanks to the increasing attention drawn to RFID and the rapidly improving maturity of the technology, a growing number of companies are investigating how their business processes would benefit from RFID.

In some cases, RFID has become a top priority for firms involved in manufacturing and production (e.g., the automotive industry), transport and logistics, retail and consumer goods, access control and security, health care, and governmental administration.

The growing interest in RFID is attributable to the fact that it enable its users to efficiently collect and distribute, store and analyse information on traced objects, notably on inventory, location, business processes and security controls, just to name a few.

The field of *manufacturing*, for example, is one important domain in which RFID demonstrates a high potential for improvement. Early adopters are using the technology to monitor and control operations on the plant floor. Here, RFID enables more automated data capture enhancements than traditional barcode technology does. The major advantage of RFID technology in comparison to the traditional barcode is the fact that information on RFID tags can be read without a line of sight, which allows processes like justï in-sequence production. Also, the amount of information that can be stored on the tag or accessed in the backend system far exceeds the capacity of traditional barcodes. RFID can offer a more detailed view of production processes, and product genealogy can be recorded in greater detail. Nonetheless, one should not assume that RFID transponders will replace barcodes overnight. It is more likely that both technologies will exist in parallel for a long period of time. RFID technology, however, definitely has some clear advantages over barcodes, such as data collection in real time without physical or line of sight contact, multi-tag reading, resistance to dirt and other potential damage, expanded storage capacity for data, data-storage and data-alteration capacities.

Getting better insights in the running operations in the plant enables numerous improvements for manufacturers. Fine grained information about operation on the plant floor allows for more flexible planning and for the identification of potential optimisations in the process. Additionally, the collected data can help to narrow recalls for faulty products as well as to enhance the product quality and process safety. This can be facilitated through additional checks for plausibility as well as for quality and correctness of the operation. Furthermore, RFID technology can improve the data consistency and availability by storing information right at the corresponding object. Dependent on particularities in the production lines, RFID can enable improvements that could not be achieved by traditional auto-id technologies.

The same holds true for the domains of *transport and logistics*. Here as well, RFID can enhance workflow visibility and enable better system control and optimisation. In addition to these advantages, RFID improves safety and security operations. Especially in branches like air traffic control or container handling, information regarding the safety and integrity of items can be monitored with RFID directly on the item. Since manipulations will be detected immediately, RFID here may also increase the efficiency of inspections. Additionally, RFID is a solution for minimising the risk of loss or damage to goods. RFID enables the localisation of items (e.g., containers on a port yard), as well as the transmission of information about the itemôs status and location, which permits constant monitoring. Furthermore, RFID can lead to improved methods of asset management of items. Applications like these are highly promising in respect to increasing efficiency and accuracy (e.g., as a basis for cost-sharing methods).

RFID will also be a vital part of a more flexible automation of transport processes, since RFID can actively assist in routing and resource allocation for a particular item along the supply chain. In summary, RFID offers a broad range of improvements towards a robust, secure and efficient logistics process design.

In the *retail* sector, retailers and vendors of consumer goods can profit from RFID, and customers can as well. The aforementioned improvements of the supply chain can be directly transferred to the retail

sector, but only if low-cost technology, polymer transponders and printable integrated circuits become available. The RFID label itself can be easily integrated into the package manufacturing processes by simply printing the label onto a carton. Customers will benefit from a higher level of convenience; for example, RFID could direct a customer with a mobile personal device by pointing the way along the aisles to selected products. Cases of warranty and returns can be simplified, too, since all required information is stored on the returned goodsø label.

Challenges and open tasks in adoption and diffusion of RFID

For many of the application fields mentioned above, RFID technology is fully mature and ready for widespread implementation. For others, some challenges remain, and European stakeholders are called upon to join forces to overcome remaining obstacles. These challenges, which vary from application field to application field and from business case to business case, include difficult Return-On-Investment calculations, performance issues, the absence of widely accepted standards and standard solutions, and privacy concerns.

Therefore, the adoption of RFID is still at an early stage and remains far from fulfilling its full potential for both markets and citizens. A major obstacle for the introduction of RFID in some application areas is the absence of standard solutions. Existing RFID applications are often purpose-built and tailored to their specific application context. Today, in some areas, there are no best-practices scenarios with detailed technical guidelines. Thus, potential adopters often have to develop implementation analyses and their technological realisation from scratch, and cannot draw on standard solutions for their industry. Standards exist for other application fields, but target markets remain unaware of them, creating a need for more information and dialogue among stakeholders.

Moreover, in the case of RFID applications in supply chain scenarios, one remaining challenge is the organisation of the supply chains to facilitate the exploitation and sharing of the full potential of RFID by collaborative data exchange. In many existing RFID applications, the captured RFID data is used to optimise the local logistics or manufacturing processes. However, local optimisation may not be optimal for the whole value chain. If partners in the value chain would exchange production data, they could optimise for the whole chain (e.g., by creating globally optimised schedules).

Sharing information in order to globally optimise value chains poses challenges on both the technological and organisational level. A global optimum may not be equivalent to a *pareto* optimal situation that each participant would support. For instance, costs and benefits of such an information exchange may be unevenly distributed. Such inequities could be avoided by applying cost-sharing models and compensation payments. Detailed collaboration models tailored to different industries need to be developed in order to facilitate global optimisation and to fully exploit the potential of RFID.

To enable collaboration, the market needs new software services offered by IT service providers that deliver far more functionality than todayøs EDI connections. These services must ensure confidentiality of handling, tracking and tracing data in cross-enterprise supply chains and offer optional interfaces to the future EPCglobal network. The Electronic Product Code (EPC) is a coding scheme for RFID; in many contexts, the EPC is standard for the identification of objects. The main driver for the implementation of the EPC is the organisation EPCglobal, which was founded by GS1 and GS1 US.
RFID solutions on the reader/antenna layer can only generate value when the transmission of reader data along the supply chain is guaranteed and when integrated companies can rely on confidentiality; that is, they must be sure that their competitors, which are integrated in the same network, will have no access to their supply chain data. The lack of such services enabling collaboration is currently a greater barrier to the deployment of RFID applications than any technical RFID problem.

In addition to its organisational challenges, collaborative data exchange must be supported by suitable technological means. In general, RFID data can be communicated by following the ñdata on networkò or ñdata on tagò paradigms. This means that data is either provided via databases with network interfaces, or that data may move on RFID tags through the subsequent value chain. Both alternatives have advantages and disadvantages that depend on the particular application. In data on tag solutions, information is transferred consistently without any additional network support. Furthermore, the information is always quickly accessible along with the referring object. In contrast, data that is exchanged via a network can be accessed independent of the corresponding objectôs physical location. This facilitates near real-time propagation of business events and allows quick reactions to exceptions. Additionally, the integration of data from the whole value chain into one networked system may better allow identification of potential optimisations in processes carried out.

Proposed measures: All European stakeholders involved in the economic and scientific debates about RFID must continue the process of standardisation and ensure that all interests are duly recognised when drafting standards. Industry must be the first to organise production processes and value chains. The European Commission and the Member States should follow this process carefully, while giving the market the opportunity to let standards evolve without premature competition interventions. Instead, the major task for all stakeholders ï especially for participants in the commercial and/or governmental value chains ï is to educate themselves about RFID technology, foster the exchange of best practice examples (especially with respect to SMEs), and to encourage collaboration and co-operation across industry sectors.

In order to stimulate large-scale European pilot projects, the European Commission launched its ñCompetitiveness and Innovation framework Programme (CIP)ò, which supports the emerging digital economy based on the convergence between network services, media content and new electronic devices.

Public policy institutions must assume a more active role in specific application fields (e.g., health care, food logistics). Policy can also play an active role when it comes to public procurement or ñlighthouse projectsò that can stimulate RFID innovation and diffusion. Finally, policy interventions would become necessary if market and industry structures develop that hinder open and fair competition.

Challenge **Making RFID more accessible for SMEs - Speeding up technology diffusion amongst users**

Potential users that could benefit from RFID technology often lack the necessary knowledge and do not hear about success stories of RFID applications (product and process innovations, service schemes). This is true in particular for small and medium-sized enterprises (SMEs), which lack the resources to take on high risks (including the risk of bad investments, disruption of established processes, etc.) or the extra capacity to try out new technologies.

At the moment, RFID projects still entail large effort for system integration. The main reason is the discrepancy between the rapid speed of technological development in both hardware and software and the slow acquisition of practical know-how by technology providers and users. This is why small and medium-sized enterprises in particular are wary of RFID projects, which results in RFIDôs slow penetration of the European market as a whole. Since small and medium-sized businesses play a leading role in the European economy, this could reduce Europeôs overall international competitiveness.

It is particularly challenging for small and medium-sized companies to acquire the information necessary for the assessment of RFIDôs potential in their own processes and the realisation of successful RFID implementation. Identifying profitable good practice cases requires both a solid understanding of the technology as well as comprehensive knowledge about the application domain and related business processes. For each good practice case, the context conditions must be taken into account for selecting the right RFID technology (e.g., the appropriate communication frequency). Currently, a wide range of RFID tags is available on the market. The tags vary in such aspects as memory capacity, physical robustness, supported communication protocol and radio frequency. The best solution for a certain application depends on the particularities of the application environment. In addition to basic information, advice and best practice cases, specific training for SMEs has the potential to improve their ability to integrate RFID into their business processes.

Several Member States have already started programmes and initiatives to increase the exchange of best practices and to make the benefits of RFID available to small and medium-sized businesses. In Germany, federal government initiatives such as Next Generation Media, PROZEUS, and a national research focus on micro-systems technology have all helped to make RFID more attractive to SMEs. Business associations such as BITKOM, AIM and the VDEB or initiatives like the road show ñRFID in Small and Medium Sized Companiesò, organised by the Electronic Business Network, have made a strong case for the use of RFID systems. Comparable projects have been undertaken in some other Member States. The European Commission supports several RFID projects, such as BRIDGE (developing tools enabling the use of industry-driven standards for EPC to support the development of RFID applications), SToP (RFID- based solutions to stop counterfeiting), Indisputable Key (resource optimisation in the timber industry), SMART (unique product identification in supply chains) and CE RFID (improving the competitive conditions for RFID technology in Europe), all of which give specific attention to the needs of SMEs.

Proposed measure: In order to further support small and medium-sized companies in exploiting the benefits of RFID technology, they could be assisted in identifying profitable applications. Existing professional networks should be enlarged and/or used to impart practical RFID know-how. This also includes the proper representation of SMEs in RFID standardisation bodies.

Geared in particular to benefit and meet the needs of small and medium-sized enterprises, good practices should also be showcased in order to highlight the prospective applications of RFID technologies and related business schemes. Good practice guidelines, along with descriptions of pitfalls, would help to avoid project failures and would widen the profitable utilisation of RFID. Typical use cases and technological setups could be developed for major industries and serve as baseline patterns on which adopters could base their applications. These guidelines may also serve as the foundation for standardisations of RFID-enabled business processes. Manufacturers, for instance, could use RFID from inbound material if suppliers labelled their shipments with RFID tags. These kinds of supply relations could be established flexibly if RFID standards were available for the respective industry.

Challenge: Avoiding distortion of competition

In many (complex) products there are already technical means which make it impossible for third party producers to add their parts to a system. Of course there are critical applications like replacement parts in cars or airplanes, in which OEM parts must be used ï in this case, (cheap) imitations poise obvious risks. But in non-critical contexts, the market should permit alternatives for products and services. It might be that RFID technology could aggravate the mentioned trends and could be misused to impede competition and segregate markets. Similar to the regional coding system used by the DVD industry, RFID could limit product functionality to certain geographical areas. And in the context of the Internet of Things, this sort of RFID application might function as a restrictive

mechanism comparable to the Digital Rights Management software used today in Internet content management.

Proposed measure: DG Competition and national competition authorities should carefully monitor whether RFID technologies are used to impede competition. If RFID is misused, authorities should enforce competition law. Where existing competition law is not sufficient to ban abusive practices additional legislative measures should be considered.

Challenge: **Patent issues**

The patenting and licensing of innovative technologies is an everyday process, and it is one of the prerequisites for technological progress. Companies certainly want to get a return on investments made in their R&D efforts. However, patents should not lead to long-standing trade disputes that create insurmountable cost barriers for technology adopters, especially SMEs. On the one hand the formation of patent pools, such as the RFID Consortium in the US, is an appropriate way to share patents and make innovations like RFID accessible to a greater number of interested businesses which will prove to be beneficial for the technology as such. But nevertheless on the other hand patent situation could become a real problem, if European RFID industry depends from US-companies holding patents.

Proposed measure: Encourage European industry to co-operate with patent pools in the United States. Especially within the UHF bandwidth, there is a risk that European companies will be prevented from market entry by U.S. competitors due to the patent situation. European companies should participate in the existing U.S. patent pool. Also, co-operation among European companies could be fostered by the formation of European patent pools.

Challenge: Harmonising frequencies

Global frequency harmonisation, streamlined regulations for allocation procedures and technical conditions will all help facilitate the introduction of RFID applications. RFID deployment in international logistics chains, and in other applications that aim at global markets, require a coherent approach to spectrum management. While wavebands for industrial, scientific and medical RFID applications (so-called ISM frequencies) have already been allocated worldwide, there is no harmonised frequency band for RFID applications that operate in the UHF band as in logistics. In Europe, a harmonised standard (EN 302 208) and a CEPT (European Conference of Postal and Telecommunications Administrations) recommendation (CEPT/ECC Recommendation 70-03 - Annex 11) exists, but implementation in the EU is still spotty.

The European Commission adopted a decision "on harmonisation of radio spectrum for radio frequency identification (RFID) devices operating in the ultra high frequency (UHF) band" (2006/804/EC) in November 2006. The purpose of this decision is to harmonise the conditions for the availability and efficient use of radio spectrum for RFID devices operating in the ultra high frequency (UHF) band. Member States shall designate and make available, within six months on a non-exclusive, non-interference and non-protected basis, the frequency bands for RFID devices, subject to the specific conditions laid down in the annex to this decision.

In addition, the European Telecommunication Standards Institute (ETSI) is already working on a revised ETSI standard in order to facilitate a large-scale RFID implementation. It is important that Member States and the European Commission safeguard this process and ensure the prompt implementation of a revised standard.

In the medium term, it will be important to consider a strategy for further spectrum for RFID (e.g., the "digital dividend", frequency bands that will become available due to the introduction of digital broadcasting technologies).

Proposed measure: Harmonising frequencies requires further policy action. The Member States should therefore work together with the European Commission towards a speedy implementation of the CEPT recommendation in the entire CEPT region. It will also be important to develop both medium and long-term strategies for further spectrum for RFID devices. The Member States need to ensure a timely implementation of a revised standard, as soon as it is adopted.

Challenge: Governance – Upholding European interests in the global network

Europe must ensure that the upcoming Internet of Things is based on a platform generally available to all organizations, public or private, that need such services in order to track and trace objects as they move through supply chains and to share supply chain information about moving objects on a cross-enterprise or global basis.

Companies that are part of global networks or value chains will be able to find out where products or transport items (e.g., containers) have been in the supply chain, and whether the transport is on time or delayed.

There are several solutions that could provide such functionality. For instance, one could rely on a centralised address resolution model like the one proposed by EPCglobal. It may also happen that different providers will set up specific systems for specific user groups or industry sectors. A recent step towards a diversification of services is the tracking of luggage via RFID which is offered by Geneva based SITA, an IT service provider for airlines, in cooperation with registry expert Afilias. The Afilias Discovery Service (ADS) can potentially not only be used for luggage tracking but as well for replacement parts etc. If cross-communication is needed it may be achieved by establishing specific interfaces between the systems or guiding standards which allow interoperability. Similar problems have been solved in the Electronic Data Interchange field where global approaches have been adapted to geographical needs.

a) The EPCglobal Network Architecture

Key components of the EPCglobal Network are the electronic product code (EPC, the globally unique identifier of an object), EPCglobal Information Services (EPCIS), and an Object Name Service (ONS). ONS points to the address of one or more EPCIS, or generally to a server or application where the EPC information can be found. The goal of EPCIS is to enable disparate applications to leverage EPC data via EPC-related data sharing, both within and across enterprises. Ultimately, this sharing is meant to enable participants in the EPCglobal Network to gain a shared view of the disposition of EPC-bearing objects within a relevant business context. EPCIS are hosted by the given EPC's issuing authorities, which is usually the manufacturer of the product concerned. The originating manufacturer also administers access to the EPC-related information stored within EPCIS.

The root ONS is provided by EPCglobal to its subscribers. It is designed to be a central service in order to avoid fragmentation of EPC-related information across the network due to geography, sector or technology. Currently, the U.S.-based firm VeriSign, which also manages the Internet's central Domain Name System (DNS), operates the service on behalf of EPCglobal. Other ONS nodes currently operate on distributed servers in Asia, Europe and the United States.

b) Some questions raised about the EPCglobal operator model

The EPCglobal operator model is not yet operational. Should, however, the model be put to operative use for consumer products and retailing in trade and other sectors, as the only alternative to exchange information between partners, special care should be taken to ensure that the system is not

dependent on a single enterprise under non-European jurisdiction. Clearly, any misuse of the system should be prevented, such as the denial of ONS services to certain subscribers or unauthorised tracking of goods flows. The same is true for the Afilias Discovery Service and other potential services.

From a European standpoint, this raises particularly critical questions about unilateral reliance on and confidence in a central operator model; similar questions have been raised in Asia as well. Innovation and industrial policy therefore has a firm interest in organising the transparent and non-discriminatory technical operation of the EPCglobal network with European participation.

Aside from the question of control over the root ONS, the technical basis of this infrastructure must be carefully evaluated. Since the ONS is based on the Domain Name System (DNS), the ONS also inherits the weaknesses of DNS technology. This means, for example, that requests (requesting IP and requested EPC) are visible to any router along the way. In the absence of appropriate confidentiality measures, industrial spies (located anywhere in the world) could intercept communication and gather intelligence about local firms such as material flows or inventory lists. Every core service used in a global Internet of Things needs to offer sufficient levels of privacy and security, for example, by masking sensitive information and traffic flows.

Proposed measure: The European Commission should thus work towards a localised, dependable and interoperable setup of look-up mechanisms and systems like the ONS which allow a decentralised operation and a competitive approach.

In this context, the EU Commission should promote an Internet of Things supported by user-driven, globally accepted standards that facilitate collaboration across industries, commercial sectors and geography, and avoid the establishment of diverse, incompatible systems that inhibit collaboration in global supply chains.

5 Technology and application roadmaps

In the short term, and particularly in the medium term, RFID will be one of the most relevant technologies for optimising processes. Promisingly, the fast pace of RFID development is driven primarily by users such as logistics and the automotive, aeronautical and pharmaceutical industries, all of which are working to adopt RFID. The tracking and tracing of goods in logistics processes and the subsequent optimisation of the entire supply chain are main applications of RFID. For the pharmaceutical industry, reducing drug counterfeiting is a main goal. Other industries apply RFID to improve the monitoring of production processes and for asset management. RFID can be used even in health care to improve the quality of care and patient safety.

There are already a wide array of RFID products on the market and several solutions for a large variety of application fields. Despite many years of development, RFID technology still faces a number of unsolved problems. Though the price of individual tags has lowered in recent years, they are still too expensive for several mass applications. Research in polymer technologies is under way, as organic materials are much cheaper and in some aspects easier to handle. But polymers are far from being able to displace silicon tags. Further research is needed to develop sensor technology, optimised power supplies and mobile displays. In terms of software, the issue of reader integration and transmission of RFID data to associated software systems is resolved, but semantically enriched applications such as data filters and the aggregation of complex data remain a challenge. In addition, real time processing must be supported. The manifold demands needed to monitor a supply chain require open systems with appropriate architectures. Also, the Internet of Things is a vision that requires security concepts and methods in managing very large databases.

The European dimension

Challenge: Competitiveness

One main issue concerns how to accelerate or enable risky developments in R&D for RFID technology. Certainly, public monies have already helped stimulate private investment in industry. This can be seen in examples of collaborative R&D projects through policymakersô public initiatives such as non-monetary incentives, funding, procurement policy, regulatory exertion of influence, etc. However, co-ordinating the allocation of scarce monies will remain a challenge for European competitiveness.

Proposed measure: A concise European R&D policy on RFID needs co-ordination between all stakeholders. This is inspired by the policy strategy process of Germanyôs EU Presidency, which has considered both national policymakersô(BMWi, BMBF, stakeholders) and the European Commissionôs input and ideas to fine-tune a common strategy.

The European stakeholders must consider:

- The role of the technological platforms (RFID within EPoSS or/and ARTEMIS)
- The RFID policy initiatives of the Portuguese, Slovenian and French Presidencies of the EU Council
- The RFID policy initiatives of the European Commission
- The objectives of the 7th framework programme
- Policies within EUREKA or 169/171 initiatives
- Objectives and measures of national policymakers
- Policies supported by stakeholders not directly represented, including NGOs and think tanks.

The development of basic hardware technologies and smart micro systems

Challenge: Low cost systems

Existent tags are still too expensive for the mass introduction of RFID tags into industrial and retailing logistics processes. This is especially true for the item tagging of low-priced products. Currently, RFID chips are silicon-based. Silicon chips are expensive because of their cost per interconnected chip plus antenna, their complex manufacturing process and raw material costs. The use of polymer electronics for RFID tags promises a cost reduction by approximately one order of magnitude

Sub Task 1: Assembly and manufacturing solutions

Optimising the production process of tags is one option for reducing tag costs. Reel-to-reel production of high-quality tags is still problematic as it entails developing very thin and therefore flexible chips; in some cases multiple chips must be assembled for one tag. Replacing pick-and-place assembly with self-assembly methods is another means of optimisation.

Sub Task 2: Polymeric electronics and new materials

There are currently several efforts under way to develop polymers that could, at least in some applications, replace silicon. Polymers promise a substantial reduction of cost. As a base material for integrated circuits, polymers also provide material flexibility, and printable electronics are foreseen. The need to develop organic materials that can be used as substrates for displays or diodes is great. However, producing these materials and electronic parts on an industrial scale poses both technological as well as economic challenges.

Sub Task 3: Integrated tag application processes for RFID users (Inline Ability)

To reach lowest system cost and greatest flexibility, the production of RFID tags must fit easily into the manufacturing processes of the application industry. A fully polymeric, print-on-demand solution is one possibility. Other solutions foresee a õfrom reelò assembly of silicon-based RFID tags. But there are also imaginable advanced technologies for the on-demand production of silicon-based RFID tags..

Proposed Measures: It is recommended that a common initiative be developed for advanced RFID technologies to support future product developments in Europe. To meet future technology demands, small and medium-sized enterprises in particular need support through such an initiative. Requirements such as common technical standards demand the co-operation of European states. A European network of RFID developers, device manufacturers and technology providers is needed to develop a common industry-based R&D strategy for Europe.

Research and development in materials, production processes and layout are important for polymer RFID tags. For complex RFID tags, further research on 3D-integration techniques, such as chip stacking or embedding is needed. The integration of nano-ICs, sensor chips, actuator components, displays or power supplies requires the development of new reliable components. To reach a high degree of miniaturisation and minimized thickness, advanced technologies for thin components are to be developed.

Challenge: Energy autarkic systems

Active and semi-active RFID tags need energy in order to perform computing processes (such as the storage of sensor data) or to amplify the transmission power. Because most tags are not connected to a constant power supply, they require a battery or a capacitor. A long energy supply life span is crucial for many applications. They must, for example, accompany products and function for the appropriate product life span. In maintenance scenarios where tags are applied to parts of a building or to machines, exchanging tags is expensive and time-consuming.

Sub Task 1: Integrated, miniaturized energy storage

Energy storages have to be small because of the limited space provided by the tags. Active tags with batteries could face additional restrictions at end-of-life, because the batteries would then be covered by the EU-wide Batteries Directive. Research topics focus on both technical solutions and computational energy control, that is, integrated foil batteries, energy saving algorithms and energy saving power management.

Sub Task 2: Energy harvesting

Energy harvesting comprises approaches that gain energy from their environment. There are currently different approaches under development that use, for example, light as solar cells, mechanical energy as vibration or thermal generators (ñThermo generatorsò). There are specific fields in contemporary science that deal with downsizing problems, robustness and application-specific adaptation.

Proposed measure: A strong effort must be made to develop advanced and cheap power supplies that have to be complemented by highly energy-efficient devices. Aspects such as re-usability, use of resources and recycling must be integrated within the R&D agenda right from the start.

Challenge: High functionality systems/ Tags with extended functionalities

To ensure high functionality at reasonable cost, applications with a high added value require future RFID tags to be highly integrated. Minimal size and low power consumption will enable mobile and (semi-) autarkic operation. A rigid, non-obligatory miniaturised packaging concept will ensure a high degree of RFID reliability during operation. The integration of mechanical, optical or biological functions will extend functionality considerably. Smart Displays as a human interface will be adapted to the shape of the product. These future RFID tags must be capable of operating in different environments such as industrial applications, where electronics have to operate at high temperatures, or in harsh environments. Several sensor principles have already been established, but challenges remain in developing further improvements, integration principles, downsizing to a molecular level, immunity against environmental influences, or the development of multi-sensors. There remains a lack of reliable sensor principles in the field of chemical or biochemical sensors.

Rigid displays are still established. RFID tags need displays with very low power consumption, such as bistable displays with no backlighting, where only switching power is needed. Organic LEDs (OLEDs) are a suitable solution for flexible substrates and there are some initial solutions available on the market. However, several technological problems remain that need to be resolved for broad application. Research in the field of keypads is needed to fit the needs of special production processes (such as high temperature or high pressure) with the desired features (such as feedback for the user).

Proposed measure: Opportunity for European industry is seen in the development of such complex smart RFID tags designed and produced by optimised technologies with high flexibility and a short time-to-market cycle. This requires the fast and efficient development of new integration technologies for RFID tags with extended functionalities.

Challenge: Development of smart micro systems

The range of products in the semi-passive RFID area is still small. Semi-passive tags can be combined with sensing functions, as well as processing, decision-making, intelligence, storage and communication capabilities. The current demand for sensor tags is immense, as they are required for several applications in which monitoring product status is important, for example, during the transport of goods. Mobile sensor modules enable the monitoring of temperature, humidity, or shock. They therefore make for very good tools in monitoring the cold chain. When applied in the cold chain, the sensor modules, together with the transponder chip, log the status of a product and communicate requested data for automatic quality controls. Tags can also support maintenance processes by

enabling the monitoring of machine status. In order to develop smart micro-systems, active tags are to be combined with sensing functions, as well as processing, decision-making, intelligence, storage and communication capabilities.

Proposed measure: Support the development of robust smart micro-systems that can be programmed according to the logic of a specific application. This will be the basic building block for further development towards an Internet of Things.

Suggested roadmap for hardware components

Field	Tasks			
Energy Supply	batteries	integrates batteries	thermo generators, solar cells	micro-fuel.cells, mechanical energy harvesting
Keypad		on rigid substrates	on flexible substrates using polymers	
Display		on rigid substrates		on flexible substrates using polymers
Actuators		noise	vibrations	complex actuators
Sensors		physical sensors	chemical sensors	biochemical sensors + GPS + microphones
Signal processing	data storage	+ physical data sampling + processing	chemical data sampling + energy management	+ navigation + ad hoc network ability
Materials/ Use of Polymers	prototype tags	tags for selected HF applications	tags for selected UHF applications	cheap Tags for HF applications
	today	**< 3 years**	**< 5 years**	**>5 years**

The timeline refers to scientific developments of prototypes not to market-ready products.

Challenge: Reader technology

Today, readers are developed primarily to work with one frequency. Data exchange between different RFID systems could be enabled by the introduction of multi-frequency readers. Thus, a common standard for a special RFID technology may no longer be important because multiple RFID technologies could be used in parallel for the same process. Moreover, such solutions might reduce costs as a consequence of the introduction of several different readers. Some companies have already started with products that support multiple standards. Where this is the case, the frequency remains the same but different standards are supported. Reader technology also differs according to the type of signal modulation that has to fit between tag and reader. Just like multi-frequency and multi-standard readers, ñadaptive readersòcan ease RFID-enriched processes.

Readers have to be small under some circumstances. This could be a key condition in production processes where readers are integrated into machines. Another demand on the horizon is seen in RFID readers for mobile phones.

In order to avoid signal collisions, reduce reader-to-reader interference or improve control over the precise localisation of tag identification, several applications need to limit the range of an antennae. Highly directional readers are therefore needed.

Proposed measure: Existing readers have to be developed further so that neither their technical specifications nor costs represent a significant barrier in enabling new applications of RFID technology.

Networks of RFIDs ï Communication, Protocols and Security

Challenge: Development of sensor networks

By means of increased data storage and processing, and sensing capabilities, information RFID systems have the potential to integrate contextual information (e.g., location, temperature) about mobile objects. The next expedient step towards sensor-embedded tags is smart tag networking, which includes possible inter-tag communication in wireless networks.

The supervision and monitoring of industrial plants, assets, buildings, or even private apartments bears great potential in reducing the cost of production processes, improving product quality, easing maintenance processes and tracking equipment. Modules in sensor networks will be enabled to communicate among each other. Current sensor network technology offers open, peer-to-peer networks in which the sensor modules are nodes in a network. New nodes can be added flexibly and are identified by the network. This may lead to self-organising IT networks where the smart objects and the readers gain much more autonomy and responsibility.

The challenge in developing sensor networks is associated with several other challenges for RFID technology (i.e., the downsizing of sensor nodes, long-life batteries and application-specific embedded software). The software challenges are manifold and include the self-configuration of ad-hoc networks, localisation, context-sensitive services, appropriate middleware, and tools for network administration. If future RFID or sensor networks, like the Internet today, become connected to and used by ICT systems for home applications, business and critical infrastructures worldwide, a new set of challenges regarding security, privacy and safety risks could emerge.

Proposed measure: Intensify research and development concerning communicating tags and micro-systems including architectures, protocols, intelligent energy-saving tags, and develop autonomous systems.

Challenge: Reader communication

One of the most important features of RFID technology consists of the ability to identify multiple objects within very short time periods. Increasing the reading rate would lead to more effective logistics processes. Therefore, new anti-collision protocols have to be developed.

Wherever readers must cover larger areas, a large number of readers must be in use. Sometimes readers are integrated into WLAN access points as tools of localisation functionality for hospitals. In such cases, management support for the readers themselves is of high importance.

Proposed measure: In order to fully benefit from the advantages of RFID, the reader infrastructure should be improved so that existing bottlenecks can be overcome.

Challenge: Real-time communication in distributed RFID systems

There are two main approaches discussed here to developing RFID architectures: the data-on-tag paradigm is contrasted with the data-on-network paradigm.

In the data-on-tag paradigm, the data adheres to the object. Together with data processing capabilities, the tagged object itself acts as an agent. This also includes the possibility of working in offline mode, which allows for the decentralised pre-processing of business tasks in, for example, the transport and logistics sectors. Tasks addressed here include theft-protection and local routing of items and goods in areas where a stationary RFID-infrastructure would be difficult to implement. Such pre-processing could also decrease the amount of communication necessary if any information has to be accessed at a backend system. Nonetheless, managing a large number of independent data storage units on tags is very difficult and causes itself challenges in terms of communication and maintenance.

In the data-on-network paradigm, the entirety of data processing is executed by the backend system. The objects identify themselves by their unique number only. The backend system provides the entire operational semantics.

In the current absence of experience, it is assumed that actual implementation will constitute a combination of these approaches depending on the application. The implementation and assessment of decentralised monitoring with real-time capability is currently an innovative research task. However, there are several technical problems with such complex networks (reliability, security, configuration issues), that have yet to be dealt with in practice. Current IT systems like enterprise resource planning systems or production planning and control systems are not well prepared to fit into the paradigm of decentralised systems. Even if the tags and the readers provide their information in real-time, the IT systems are still based on batch or user-driven processing. The task will be to define appropriate ICT architectures for decentralised RFID systems.

Proposed measure: Intensify research and development concerning simulation, modelling and the realisation of production systems that integrate RFID tags for decentralised control.

Challenge: Development of new IT security and privacy mechanisms

In forthcoming RFID systems, IT security will become a major issue. Many applications require secure data on the tags and the safe transfer of data across the air interface. Cryptographic algorithms are often too expensive for RFID in terms of both computing time and memory usage. Therefore, standard cryptographic algorithms must be adapted to the restricted hardware and energy resources of RFID systems. Moreover, Privacy Enhancing Technologies (PETs) could help citizens to prevent unnecessary and/or undesired processing of their personal data, and to protect their privacy by eliminating or reducing the amount of data processed. The European Commission has adopted a Communication on Promoting Data Protection by Privacy Enhancing Technologies, by which it considered the benefits of PETs, laid down its objectives in this field and set out clear actions to achieve its goal by supporting the development of PETs and their use by data controllers and consumers (COM (2007) 228, 2.5.2007, Communication on Promoting Data Protection by Privacy Enhancing Technologies). On the other hand, an attack on IT systems by means of RFID devices has to be prevented.

Proposed measure: Developing privacy enhancing technologies has to be seen as crucial to the successful implementation of RFID in many application areas. This is especially true for applications that address consumers and citizens directly. The European Commission, the Member States and industry should seek to improve the development of PETs and related technologies at an early stage, taking into account the specific requirements within the different application areas.

Business models, open architectures and privacy

Challenge: Open systems to support business-to-buisness processes and public services

Currently, processes that involve several companies or institutions are supported by proprietary and closed systems. Open systems are needed that support the entire process. Examples include systems that control the supply chain and systems for public services, such as the electronic passport or e-ticketing.

For these systems, RFID serves as a means of obtaining real-time information, such as location, about goods or objects. This information can be used to optimise logistics processes such as delivery planning, the transfer and tracking of goods, traceability and security. By adding sensor functions to

tags, automated quality control of goods becomes possible.

Processes that span institutions require compatible infrastructures, interoperable systems and an agreement on the kind of exchanged data. For many goods, information exchange is already implemented on the basis of EDI standards, but superordinate processes have yet to be sufficiently addressed.

To facilitate global and inter-company information exchange for RFID-equipped items, three major components have to be specified and put in place:

a) The information on the chip (in the simplest way, a unique identification number),

b) A lookup for corresponding applications and databases by means of the unique identification number and

c) An aggregation and interpretation of object-related data in a time or location context in order to create added value from these data (e.g., tracing of objects along a business process).

It is of vitally important for Europe that these components are developed openly, consider different technical solutions, have interoperable interfaces and are operated by various service providers or organisations. If the application context is of a high public interest or becomes a public good, the components may even be developed and operated by public authorities.

The EPC network as suggested by EPCglobal is one possible instance of implementing the three aspects mentioned (cf. chapter 4). The Internet is currently the primary technology available for the common global use of data and communication technology. No other technology scales comparably. Nonetheless, the Internet does not determine in detail the kinds of protocols, security tasks and architectures in use. Internet technologies offer an appropriate basis for open RFID ICT systems. Service-oriented architectures can be realised and process languages as BPEL can map business processes. One challenging vision is the communication among objects that become smart and gain more control over processes. They coordinate processes in order to react faster and more adequately in given situations, they improve the utilisation of resources and they adapt to user requirements.

Proposed measure: Develop models that demonstrate how the three RFID components described above are interoperable and can be operated in a competitive environment. Because open systems and global value chains ï particularly in the Internet of Things ï require the co-operation of all partners, projects that develop solutions for such problems must integrate all relevant representatives. Trust between co-operating companies and establishing trustworthy connections are crucial aspects here.

Challenge: Development of semantically enriched middleware, business models and service structures

Data capturing with RFID and sensor tags can help to narrow the gap between the physical and digital world. However, creating value from the additional data requires that information be transformed into business-relevant information. This approach requires an intelligent system for processing data from multi-functional tags and sensors. Intelligent micro-systems have to be complemented by an intelligent software architecture that allows application-specific usage of the data. This comprises not only the filtering of raw sensor data, but also includes semantic enrichment, routing information to where they are needed and triggering actions in response to events.

Within closed loop scenarios, such data processing could be realised in an extended RFID middleware. In global value chains, at least some of these processing tasks may be outsourced to service providers in the network. Such services could facilitate cross-organisational collaboration and may create new business models. For instance, event registries may inform subscribers of critical situations in certain processes. RFID and sensor data may be provided via the network as well and linked to planning applications of partners in the value chain. This kind of data exchange may lead to

more optimised value chains and create business opportunities for both data providers as well as data recipients. However, this kind of collaboration needs to be supported by a suitable architecture.

In addition, information security in the Internet of Things will create plenty of opportunity for new business models, examples ranging from services for Error and Fraud Detection, global service mediation and trust management, to a new generation of penetration testing that involves attacks on confidential information by data mining.

Proposed measure: High priority should be given to the development of flexible and secure software architectures that facilitate multi-dimensional and cross-organisational data exchange, which is seen as a basic need for the creation of new business models. In this context, special focus must be put on the future requirements of an Internet of Things.

Challenge: Development of application-specific guidelines

The discussion of RFID is dominated by a primarily vague, generalised and collective application context. In reality, however, there is no standardised RFID ï its technical needs and requirements, effects and impacts are quite different for different application areas. The health care sector needs solutions that differ from solutions in production. The levels and qualities of potential risks regarding privacy and security are thus also specific. A general guideline might result in over-regulation in one area, while failing to provide the basic needs in another area.

Proposed measures: Privacy and security should be built into RFID information systems before their deployment. To enable the implementation of capable security mechanisms, and to ensure the same level of safety, security and privacy in similar applications of RFID systems, national governments should support the development of guidelines for RFID systems. These guidelines have to be application-specific due to the fact that, for example, RFID in production processes has to fulfil other conditions than in logistics or in health care.

Challenge: Continuous examination of specific IT-security and privacy-related risks

The highly interconnected environment of a global Internet of Things is about to inherit information security risks from the classical Internet. It will also create new security challenges due to the new quantity and quality of data processed, and the integration of the Internet of Things into core business processes and applications.

This creates research demands in device, network service and database security for highly dynamic systems on a global scale, ranging from new cryptography for resource-constrained devices, new security protocols for key and certificate management, authentication and authorization, as well as research in database security and privacy-preserving data mining that addresses questions like ñHow much data may be shared without leaking confidential business information in the face of powerful inference algorithms?ñ

In an Internet of Things, a lot of sensitive data will be created. Further elaboration is needed on the means by which data owners (individuals, businesses, states) can control their digital traces and identities. Further work is needed on the procedures and roles of the actors in managing unique identification numbers and, consequently, the electronic identities these numbers represent.

It seems essential that security and privacy are an integral part of the design of any future global and inter-company information retrieval network. Therefore, a model should be acceptable to both parties, that is, individuals owning the objects and the other stakeholders (e.g., companies in the supply chain who would need to offer access to possibly sensitive information). The stakeholders' requirements regarding security and privacy should be taken into consideration and technical solutions should be devised for managing possible conflicts of interest.

Proposed Measures: RFID systems and related security and privacy risks are a moving target - they

require continuous monitoring. Therefore, a close and continuous examination of (new) specific security and privacy-related risks is necessary.

Challenge: Standardisation of security mechanisms

Although progress is being made in the international standardisation of RFID, many sectors ï especially security and privacy mechanisms ï still lack international standards, which could pose a considerable obstacle to the implementation of industry-wide applications.

Therefore, it is necessary to ensure that European standards meet European requirements (in particular privacy and security) to identify standardisation gaps and to provide a framework for the development of interoperable security mechanisms..

Suggested roadmap for software and communication components

The table entries below indicate the development status of software that are between first prototypes and readiness for marketing.

Field	**Tasks**			
geographic localization	GPS	WLAN localisation	localisation via antenna arrays	localisation in sensor networks
communication	bi-directional communication (tag/reader)		sensor networks	smart environments
infrastructure and services	RFID middleware	Semantically enriched RFID middleware	decentralised control of logistics and manufacturing systems / software agents	Internet of Things
security	standard cryptography	light-weighted cryptography and identity management adapted to RFID		physical uncloneable functions / physical one-way functions
	today	**< 3 years**	**< 5 years**	**>5 years**

6 Societal Issues

RFID technology can address important issues in society. At the same time, RFID technology raises several concerns that should be considered seriously to ensure its acceptance among citizens, whether they be consumers, voters, employees or patients. There are two major concerns: Firstly, RFID could increase existing tendencies of profiling, surveillance etc. which are already known from other technologies. Secondly, RFID might enable completely new and undesirable usage scenarios due to the invisible and contactless reading of data. Therefore the future perspective of RFID should be to develop solutions that strike a careful balance between the fulfilment of technological expectations and ensuring genuine societal benefits with minimal disadvantages for the individual or society.

RFID offers great potential for addressing important issues in society. RFID can help find solutions to some of the future's pressing challenges, and it can improve the lives of millions.

- The safety of drugs and medication can be improved by powerful anti-counterfeiting technology.
- Patient care can be optimised through personalisation, improved medication dosage and through improvements in hospital administration, thus avoiding medical malpractice and adverse events.
- Mobility and accessibility for the handicapped can be optimised with the help of RFID, as part of the effort in ICT technologies aimed at mastering the challenges of demographic change in an ageing society.
- Consumer safety can be improved though better traceability, ensuring proper handling and storage of perishable foods.
- In mobility & transport, RFID-based keys permit easy access to vehicles. RFID-based ticketing solutions for public transport will make life easier for millions of commuters.
- In leisure & sports, RFID will make the use of ski passes, tickets and libraries more simple and convenient. It will help make sports more accurate and precise, for example, by measuring the "out" in football or tennis.
- In shopping, RFID will enable database models that provide additional product information, helping people with allergies or diabetes to make the right food choices.
- In sustainability, RFID can optimise recycling processes and help monitor the environment.

Whether a consumer is out shopping or just enjoying his or her free time – wherever there is a need for speed, efficiency and fast service – RFID technologies will create new possibilities for everyone. But these new possibilities will have direct and indirect effects on every single user. In the following paragraphs, the key societal issues concerned with the (broad) use of RFID will be discussed and focus on a European perspective..

Challenge Informing citizens about RFID

Due to the fact that the mass roll-out of RFID technology in consumer applications has yet to become a reality, the benefit of RFID technology is barely visible for the public. It is therefore necessary to inform the public openly of this new technology. A balanced and realistic debate about the benefits and risks of RFID is needed. This debate must strike a balance between the pitfalls of exaggerating potential benefits on the one hand and overemphasising potential dangers on the other. Such a debate will cover a large variety of concerns, spanning ethical issues concerning implanted chips to the requirements for specific education, and the protection of privacy and consumer rights.

Most current RFID applications do not have a direct impact on citizens. When RFID technology is used for production purposes, this technology does not have a bearing on the privacy of citizens. It is also important to note that the potential dangers of privacy infringement differ greatly from application domain to application domain. One of the challenges for the debate on RFID is therefore to clearly

differentiate between different application fields, making sure that the use of the technology is not compromised where privacy is not an issue and clearly highlighting problems where privacy, freedom from paternalism, or competition are at stake.

Proposed measure: Informing the public and ensuring transparency in RFID applications are important prerequisites to broad acceptance of RFID among citizens. The EU, national governments, companies, consumer organizations, data protection authorities, trade organisations and information initiatives should conduct user education and information activities with the goal of achieving informed and responsible user behaviour. This is a common task, which should have high priority and be initiated quickly.

Information of the public and transparency in RFID application are important prerequisites for citizens acceptance. Essential for the broad acceptance of RFID applications is the education and information of the user through the EU, national governments, companies, consumer organizations, data protection authorities, trade organisations and information initiatives with the goal of achieving informed and responsible user behaviour. This is a common task, which should have high priority and soon be commenced.

Challenge Increasing citizens safety and security through RFID based applications

RFID solutions are supposed to contribute to safety and security. A clear potential is seen in the protection against counterfeit medical products, which is, according to the World Health Organisation, a threat for millions around the globe. For this reason, international bodies and national government agencies, such as the U.S. Food and Drug Administration (FDA) are discussing the use of RFID to protect patients from counterfeited products. RFID transponders can be easily integrated into medication packaging. Medication is thus clearly labelled and patients can be protected from potentially life-threatening fake medicines. The technology can also prevent financial and business losses that companies suffer as a result of counterfeit products. In addition, RFID simplifies returns management and improves processes along the entire logistics chain. RFID-labelled products ease pharmacistsôadministrative tasks.

RFID can also improve consumer protection in the food industry. RFID transponders can be used by animal breeders to tag cattle. With these transponders, exact information about each animal, including lineage, pedigree, breeding, feed and veterinary care, can be tracked ï from birth to the slaughterhouse. In addition to this data, information about processing and the supply chain can be included on the RFID transponder that is part of the meat packaging. Transponders with temperature sensors enable the cold chain to be monitored seamlessly. In addition, RFID can help to supply consumers with more information about daily products (such as ingredients or possible allergens) and strengthen consumer trust in brand products such as clothing or electronics by protecting consumers and manufacturers alike from counterfeit products. RFID also guarantees company-wide traceability. Should a quality problem arise, recall announcements can be issued precisely and quickly. This benefit applies not only to fresh products such as meat, but also to cars and other technical equipment.

There is another societal issue of great relevance: RFID provides several benefits in daily life for disabled persons. Blind persons, for example, can ñreadò their surrounding if it is tagged. That is relevant for the individual surrounding (i.e., private home) in the same way as it is for the work place and even public spaces (e.g., streets and shops). This potential should be used to strengthen the integration of disabled persons.

As with all new technologies, companies, institutions and countries intending to employ RFID technology for consumer safety and security purposes must carefully assess benefits, potential risks and the costs involved, and then choose the technology that best suits their current needs. Considerations must include not only the economic dimension of risk, but environmental consequences as well. For example, whether or not the radio communication used for RFID causes harmful radiation affecting the health of consumers or employees must be clarified.

It must also not be forgotten that technical infrastructures will never be 100% failsafe, and they can result in unintended effects.

Proposed measure: All stakeholders should engage in a common approach and use feasibility studies to assess in which application domains RFID can be used to benefit and empower the public, and how to apply RFID technology without negative effects on citizens. This could also entail the use of a different technology or employing two technologies at the same time in order to ease the cost of RFID implementation, and to ensure a smooth transition with full interoperability of current systems (as exemplified in the parallel use of RFID and barcode technologies). In addition, the process of RFID implementation should be accompanied by means of technology assessment monitoring potential risks caused by the technical infrastructure.

Challenge Balancing the different approaches for data and consumer protection

Data protection legislation in Europe rests on the premise of collecting, processing and storing as little personal information as possible ('data minimisation' principle). When personal data is collected, processed or stored, individuals need to give their unambiguous consent if the data collection is not required by a special law. For individuals to make well-informed decisions, they should be informed of the purpose of the collection of their personal data and be able to consent to this freely. In addition, data collection, processing and storage should be carried out in a transparent manner.

Due to the functionality of automated interaction, RFID applications and even more advanced visions like the Internet of Things make data collection and processing the rule rather than the exception; it is not clear how citizens will express their consent in a ubiquitous environment. While not all RFID application scenarios encounter these problems, it is imperative that practical ï nevertheless privacy-friendly ï solutions are found for these cases in which personal data or any information relating to an identified or identifiable natural person is used.

Following a critical view on RFID, additionally to creating new challenges for data protection and privacy regulation, there are already some hints, that the wide use of RFID could result in new needs for data protection legislation. Even today, many citizens are not able to assess the processes affecting their data ï this is partially based on the situation of legal uncertainty in some areas (existence of legal 'grey area').

The mentioned developments do not necessarily represent a call for a specific RFID data protection legislation. Where loopholes exist, they must, however, be identified and closed. In the broader context of multimedia progress, data protection legislation might need to be updated to provide frameworks for new applications that make (automated) data collection and processing the rule.

Both on the European level and within the Member States, several initiatives are already underway to discuss these issues. The Article 29 Data Protection Working Party and the European Commissionôs Directorate General for Information Society and Media have conducted public stakeholder consultations that included privacy and data protection issues. In the United Kingdom, major retailers have agreed upon a Code of Conduct for the implementation of RFID in the retail sector. EPCglobal

has issued binding guidelines for all its members, calling for the labelling of products containing RFID, extensive consumer information and the possibility to deactivate RFID tags at the point of sale. These principles address, to a certain degree, the demands made by data protection officials and consumer organisations for guidelines regarding the use of RFID: addressing questions of consumer information and RFID labelling; deactivation; and no discrimination if consumers wish not to use RFID check-outs.

In Germany, there is an ongoing dialogue between consumer organisations and major companies on possible elements of self-regulation for the use of RFID, which was initiated by a series of round-table discussions chaired by the Federal Ministry of Economics and Technology. In addition, there are already guidelines for the application of RFID in the area of the end customer, as for example, those suggested by the International Chamber of Commerce or the United States of America Center for Democracy and Technology.

By the end of 2007, the European Commission will issue a recommendation to set out the principles that public authorities and other stakeholders should, due to the ECôs perspective, apply in respect to RFID usage. In addition, appropriate provisions in the forthcoming proposal for the amendment of the ePrivacy Directive and will be considered as well, taking into account input from the RFID Stakeholder Group, the Article 29 Data Protection Working Party and other relevant initiatives such as the European Group on Ethics in Science and New Technologies.

Proposed measure: The discussion on RFID and its privacy implications is ongoing. While examining privacy issues raised by RFID, European stakeholders should identify possible loopholes in privacy legislation via a joint approach that includes industry as well as data protection authorities and privacy advocates. in discussion. Issues to be addressed include whether data protection legislation must be updated to establish frameworks for new applications that make data collection and its processing a widespread rule; and whether updates are needed to cope with the new challenges posed by the Internet of Things. Currently, a special RFID law seems counterproductive, since data protection legislation should remain as it is now: technology-neutral. Since RFID technology could be applied in law enforcement, it is necessary to identify ñthird pillarò stakeholders that is, police and judicial co-operation in criminal matters, at an early stage and involve them in these discussions.

Self-regulation should be used to supplement regulatory measures, particularly in areas that are too specific to be addressed by legislation. RFID implementation in the retail sector, for example, is one area suitable for self-regulation while simultaneously following the principles embedded in the Data Protection Directive 95/46/EC. Codes of conduct could address the following concerns: (a) Information and awareness: the public should be informed about the application of RFID technology; (b) Labelling: RFID tags and readers should be labelled; (c) No secret profiling: personal data should be collected, processed and stored only if consumers are aware of and have consented to this; (d) Deactivation: the tags should be easily disengageable at the cash-out ï until now there is no consensus between consumer organizations and industry, if deactivation should happen per default or at consumers' request; (e) No discrimination if consumers wish not to use RFID-based services; and (f) Anonymous shopping: option of paying with cash at check-outs. In addition, the industry should develop technologies that by design help consumers to better protect their privacy, i.e. Privacy Enhancing Technologies (PET). PET could strengthen consumersô confidence in the proper use of RFID and reduce the collection and processing of data.

Lastly, the European Commission should foster continuous dialogue between business, policymakers and data and consumer protection organisations on developing further the regulatory framework for RFID at the national and the European levels. Irrespective of a possible European Code of Conduct, national efforts to develop in co-operation systems of voluntary obligations should be given explicit support. A shared consensus can be found much more rapidly at the national level than at the general

European level. National systems of voluntary obligations can also consider special circumstances directly. Such systems could serve as the model and basis for a European Code of Conduct, which could in turn easily include the implementation of technical solutions (Privacy Enhancing Technologies) to minimise privacy and data protection risks.

Challenge The ethical application of RFID

There are profound concerns that some RFID application scenarios are not compatible with the dignity of natural persons. Firstly, RFID could increase activities such as profiling and surveillance, which are already associated with other technologies. Secondly, due to the invisible and contactless reading of data, RFID might allow for entirely new and undesirable usage scenarios. This is especially true for implanted chips. Whether used in an employment context, access control or member fees for clubs, they prompt ethical debate. Should RFID tags be used someday to tag people rather than animals, should parents use RFID technology to control children, or should the elderly be tagged to monitor their location, important questions about the role of consent and dignity will undoubtedly be raised.

Proposed measure: National governments and the European Commission should develop guidelines for the range of applications that are compatible with human dignity and ethical principles. A pro-active approach is important because changing practices is very expensive and difficult once technologies have been developed and their infrastructure established. Creating guidelines thus lies in both the public and industry's interest.

Challenge Guarantee a qualified workforce

RFID technology suppliers, system integrators and users are increasingly concerned about the lack of practical knowledge needed to develop, implement and operate RFID systems among engineers, technicians and IT specialists . Knowledge regarding in particular the principles, possibilities and limits of radio technology use for RFID is absent. This phenomenon is typical of broad roll-outs for high-tech applications, and can be compensated by adapting existing job qualification programmes, and by adding the subject of RFID to the appropriate academic curricula. To date, the need for a special professional or academic curricula for RFID is not foreseen. The relevant authorities should put more effort on treating the subject pragmatically and with flexibility. This entails making RFID an aspect of existing academic careers, and allowing future engineers to specialise in RFID technology. Given that RFID is expected to face wide-scale implementation in Europe and the world within the next five to ten years, easy solutions for opening universities further to RFID technology have to be found.

Proposed measure: In the academic context, the goal of guaranteeing a qualified workforce should be realised in line with the "Bologna Process" and by amending existing technical curricula. For professional training and education, a commonly accepted and criteria-based RFID certificate could be defined to guarantee a consistent standard throughout various industrial sectors and EU Member States. With its own motivation and demand, industry (i.e., companies, industrial associations, trade unions) should be the driving force behind this process. The need for a qualified workforce is apparent today. Industry must assume responsibility and should be supported pro-actively by public authorities to avoid a bottleneck.

Challenge Employee protection rights and RFID

If RFID applications affect the sphere of the employee, protection of personally related data and the right of control over personal information must be protected as well. To date, however, separate treatment of this aspect would entail postulating future uncertainties, as there are currently few relevant cases of RFID applications affecting the sphere of the employee in the production process.

Statements regarding possible harmonisation with employment rights can, at present, be made at a hypothetical, highly abstract level only, which renders their utility questionable.

On the other hand, employees in medicine, security-relevant areas and some service sectors already face the use of RFID-based wristbands as a means of documenting access to special rooms and areas. In such cases, data from employee tracking/monitoring can be easily archived; how to safeguard the fundamental right to privacy in this situation must be discussed.

Should RFID applications one day have a widespread effect on employment relations, the resulting needs would be by no means novel or specific. RFID applications could simply be another justification for needs such as data protection and personal control over information, which are already known as an aspect of the everyday and widespread use of information technology in employment relationships.

There have been concrete efforts and plans to create guidelines and establish a legal foundation for regulating issues such as data protection within the framework of employment relationships for quite awhile. RFID applications could be located within this rubric as one of several manifestations of information technology, which is an aspect of employment relationships recognised by labour law. The International Labour Organisation (ILO) in Geneva has engaged in a substantive dialogue with stakeholders on which effects can be expected from the use of advanced technologies in the retail sector workforce, and on which measures are best suited to address these challenges. This approach could prove successful for other industry sectors as well.

Proposed measure: A European legislation initiative could be initiated by Member States and taken up by the European Commission in the event of severe insufficiency. In a first step, European stakeholders should continue their successful social dialogue, elaborating on whether the legal framework is sufficient to uphold workersô rights as new information technologies are implemented at the workplace. Also, within the European Union, the Member States should foster the exchange of best practices, for example, on how issues have been resolved between employers and workers at the company level.

Challenge Public awareness and open-mindedness

Empirical studies show that citizens are interested in using RFID-based technologies, but that they are concerned about RFID technologies being applied in ways that encroach on their sovereignty and privacy. This implies that when RFID applications are designed to be used by consumers, specific consumer concerns have to be taken into account. The technology should be developed in a way that reduces the risk of RFID being used against consumers. End users are eventually those who will decide the success of RFID-based applications in item tagging, which is most relevant for consumer products and retail.

User education and information aimed at developing responsible user behaviour is essential to the broad acceptance of RFID applications. The EU, national governments, companies, trade organisations and information initiatives should give this common goal high priority and begin soon.

It is very importance that this effort be open to public interests and concerns. Analysis of the the relationship between the public and technology in recent decades shows that the public has built up an acceptance of technology continuously. The public wants technology and progress, but not necessarily at any price. In order to gain public acceptance of RFID, key stakeholders must demonstrate the benefits, opportunities and risks posed by RFID. People will select ñtheirò technology. Knowing this in advance is, for industry, preferential to investing great sums of money in technologies that are rejected later. An empirical study conducted throughout Europe ï possibly in the form of

special edition of the Eurobarometer survey – could be used to learn more about public perception of RFID, and the degree of knowledge, expectations, fears, prejudices and general tendencies in assessing this technology. A common survey might also identify differences within Europe – perceptions in RFIDís main drivers (i.e., France, UK, Germany) might differ from those in countries that currently represent the RFID periphery (e.g., the new Member States still in transition).

It is questionable as to whether, beyond this, it is feasible and constructive to produce guidelines for handling RFID correctly. RFID is a basic technology for a large number of quite different applications. To reduce the management of RFID applications to a few general rules is neither realistic nor sensible. In addition, there is currently scant relevant experience with RFID applications that directly affect the sphere of the citizen, and on which a practical guideline could be based.

Proposed measure: Bridging the current gap between the lack of experience and future relevance could be promising. Creating an elaborated approach to explore this "blind spot" through a joint initiative might be valuable, particularly if combined with information and discussion debates.

Challenge RFID and sustainability

The principle of sustainability and the responsible use of natural resources are essential for future generations. Modern technology will play an increasing role in helping this effort succeed. First of all, the increasing efficiency of processes due to RFID will most likely reduce energy and material use, which will in turn allow for an improved use of resources. In this context, it is assumed that there are no rebound effects; that the sheer number of RFID tags and resources needed for their production will not outweigh RFIDís positive effects. The effects of larger amounts of RFID tags in other waste streams, and the effects of a shift to semi-active and active tags in mass applications have not been investigated yet. It must be assumed that current RFID tag technologies have to be treated as electronics – thus necessitating separate treatment – rather than as compatible with household waste or packaging. Currently, the disposal of RFID tags together with domestic waste does not cause large-scale problems as a small amount of the materials used in passive RFID technology can be burnt in modern incinerators. More problems arise in connection with recycling processes. Transponder materials might have to be separated from others during sorting processes. For example, copper could add impurities to glass and tags could impede plastic bottle or paper recycling because of tagged medication packaging. Implications depend very much on materials that are used for future RFID technology. However, RFID can help optimise recycling processes by providing detailed information on equipment components, such as electronic equipment. Given the unlimited possibilities of tagging nearly everything with RFID, existing recycling processes must be adapted to the widespread use of RFID, as tags pose specific challenges to contemporary glass, paper and plastics recycling.

RFID manufacturers and the waste management industry are called upon to address these issues early on. Possible measures include environmentally friendly transponder design (especially with regard to their material composition) and adaptation of current disposal and recycling processes to deal with transponders appearing in refuse. The goal should be to recycle transponder materials whenever possible. In terms of environmental policy, it is desirable to begin this adjustment process at an early stage so that resources will be used frugally in RFID systems, too. But the development of environmentally friendly RFID technology by European technology vendors is also beneficial from the vantage point of industrial policy, because like other environmental technologies, it can uniquely position vendors of the Member States in the international market. It is thus in the public interest to initiate this development process and to moderate it if needed. Governments could supplement this with appropriate technical studies and expert discussions to raise awareness and to entertain potential implementation approaches that would take economic aspects into account.

Monitoring pipelines or the storage and transportation of hazardous goods with RFID technology can help prevent potentially fatal or environmentally catastrophic incidents. Furthermore, the future Internet of Things might help to monitor the environment, providing information about and early warnings of natural disasters (floods, volcanoes) or global phenomena (global warming).

Proposed measure: The Member States and the European Union should encourage further research in the field of RFID and sustainability, focusing on the question of how ICT can be employed to provide for a sustainable future. By way of this, more research on recycling RFID tags is also necessary and includes developing further polymer tags that will be much easier to recycle than the silicon-based tags currently in use.
Generally, RFID tags and future components of an Internet of Things have to fulfil the WEEE directive 2002/96/EC on waste electrical and electronic equipment and the RoHS directive 2002/95/EC on the restriction of the use of certain hazardous substances in electrical and electronic equipment.

7 Intersection analysis

Regarding the developments and challenges as described in the previous chapters, the major opportunities and challenges of RFID in Europe can be subsumed in five theses that provide the rationale for the political options and recommendations in the following section.

RFID is an important building block for the future Internet of Things
RFID is one of the major building blocks for the envisaged Internet of Things. Besides the known applications in logistics, retail, manufacturing and access control, increasingly more new RFID applications for a networked world will emerge, including, for instance European citizen cards, food chain traceability, protection against counterfeit pharmaceuticals, etc. Citizens, companies and the public sector will benefit alike from these new applications in the networked world.

RFID strengthens the competitiveness of European users
European users are among the forerunners in both private and public RFID applications. Whereas RFID is mainly a means for rationalisation in the short term, in the long term, this technology will generate new business processes, services, and products. This fits well into the strategy of most European companies, which are not competing at low prices but with high-value products and customised services. Thus, RFID strengthens the competitiveness of European companies, and helps safeguard and create employment in Europe.

RFID is a major opportunity for Europe ICT industry
Analystsôand scholarsôreports show that RFID has the potential to become one of the boom markets in ICT. Growth rates are impressive and will lead to a billion Euro market for RFID hardware, software and services. In all segments of the value chain, European RFID technology vendors and service providers are well-positioned to participate in this development. Most importantly, medium-sized companies ï which are the backbone of employment in Europe ï have a fair share in this evolving segment of the ICT market.

Challenges in international RFID competition must be met
International competitors from the United States and Asia who benefit from, respectively, the large U.S. domestic market and the emerging, potentially even larger Chinese domestic market, pose strong challenges to Europe in the RFID market. To keep apace in this race, the European Union must meet certain challenges. Europeôs most prominent obstacles include the limitations and existing fragmentation of radio regulation in Europe, the sometimes too-restrained participation of European stakeholders in standardisation, and the existence of potential blocking patents in certain technology areas.

RFID needs fair rules for privacy and governance
The potential ubiquity of RFID is a challenge for both privacy and governance. The potential invisibility of RF identification demands a comprehensible and reliable approach to the preservation of data protection, workersôrights and consumer rights in those RFID applications that may be used to track people or to build personal data profiles.
Other aspects of RFID governance that are most important for RFID users and technology providers comprise the free and non-discriminating access to standards, to licenses, and to the services of future RFID networks.

8 Political options and recommendations

As one of the key technologies of a networked world, RFID holds great promise for the European economy, both for RFID users and for providers of technological products and services. With regard to international competition, the economies of some Member States are currently well positioned to exploit these opportunities.

Nonetheless, actors in policy, the economy and society will need to meet a series of challenges in order to actually reach the potential of RFID technology. With this in mind, the following recommendations address national governments, industry and business associations, and advocates for data and consumer protection in the Member States. For a number of these recommendations, it is advisable to co-ordinate closely with the European Commission, in particular with regard to the recently published Communication of the European Commission on Radio Frequency Identification (RFID) in Europe: steps towards a policy framework.

Technology Development for Small and Medium-Sized Businesses
Most RFID users today must spend much time and effort working toward feasible solutions that can be adequately incorporated into existing processes and system environments. These are typical start-up problems of new technologies, which melt away with growing experience in dealing with the technology and which large companies can absorb with relative ease. But for small and medium-sized companies, the many incalculable factors ï both technical and financial ï of introducing RFID represent a major barrier. However, letting these companies be forced out of sectors where RFID is adopted contradicts the interests of a pro-small business economic policy.

Small business should be engaged early on through RFID centres of excellence. Industry associations and economic policy should actively work toward facilitating the early entry of small and medium-sized businesses into RFID projects. Possible steps toward this end include offering practical, industry-specific informational materials and events, and carrying out pilot projects that can serve as models. RFID centres of excellence would be one way of offering and facilitating this. For reasons of efficiency, they should be built as extensions of existing structures.

Further on, companies and their industrial associations are called upon to develop and introduce fair models for cost allocation in cross-enterprise supply chains, where needed. This will allow even small and medium-sized businesses to participate in RFID-supported processes.

Data Protection and Consumer Awareness
Protection of individualsôdata ï whether in the role of consumer, patient or citizen ï has been a matter of heated public controversy. An antagonistic confrontation between advocates for data and consumer protection on the one side, and RFID users on the other, could cause undesirable setbacks for RFID applications. In itself, improving citizen education on the potential benefits of RFID is unlikely to be sufficient in defusing this confrontation. In this respect, the European Commission has recently established for two years a RFID Expert Group with a balanced representation of stakeholders. This group will provide an open platform allowing a dialogue between consumer organisations, market actors, and national and European authorities, including data protection authorities, to fully understand and take co-ordinated action on the concerns that have been raised.

There is still some controversy over the future adequacy of current data protection law to responsibly regulate RFID applications that affect citizens. There seems to be a consensus, though, to establish a framework for the range of RFID applications that are compatible with human dignity and ethical principles. Furthermore, there are concerns that RFID might create new challenges for privacy legislation due to its ubiquity. This ubiquity could lead to data being connectable to such a degree that

it would no longer be reconcilable with the existing principles of data protection ï transparency and ñdata minimizationò (i.e., collecting no more data than necessary for a given use). Consequently, parliaments and governments of the Member States and the European Commission should review data protection law at regular intervals to ensure that it is still adequate to the rapidly increasing interconnectedness of IT systems, mobile devices and everyday objects (the Internet of Things, Pervasive Computing) and to amend regulations as needed to meet new needs. However, given that RFID tagging of individual products is still in a very early stage, there is no urgency to immediately draft and pass an RFID-specific data protection law. The previous approach of avoiding technology-specific data protection regulations should be maintained.

Furthermore, self-regulation could be used to supplement regulatory measures, in particular in areas that are too specific to be addressed by legislation. Those directly involved, industrial and governmental RFID users and advocates for data and consumer protection are called upon to coordinate their interests on data protection for the RFID systems in the relevant application areas. This could take such forms as commitment by RFID users to a code of conduct. Also privacy should be built into the technology by using privacy enhancing technologies.

Spectrum Harmonisation

Europeôs sluggish implementation of already determined spectrum allocations is a hindrance to introducing cross-company and trans-national RFID applications, especially in comparison to standardised spectrum regulation for RFID applications in other parts of the world. A further aggravating factor is that there is partly significantly more UHF bandwidth available than in Europe.

The EU Member States and the European Commission should ensure prompt implementation of the solutions for efficient usage of Europeôs available UHF bandwidth. ETSI is currently developing a revised standard to facilitate a large scale uptake of the technology.

In conjunction with the Member States and the European Commission, CEPT should develop a long-range strategy for making more spectrum available for RFID applications e.g. spectrum from the digital dividend (conversion from analogue to digital television) or from abandonment of little-used radio applications. This long-term planning should also be expanded to the microwave range, where new RFID applications such as sensor networks will probably settle over the long run. It will also be important that in the processes for allocation and reallocation of spectrum resources the enormous economic and social benefits of RFID applications are taken into account.

Standardisation

In addition to spectrum harmonisation, the international standardisation of data formats, air interfaces and communication protocols is an essential prerequisite for creating an RFID market that is open to all. These standardisation processes are being driven mainly by large companies and public institutions. Small to medium-sized RFID users and technology providers often do not take part in these processes because of the great effort, time and costs they require. However, their outcome directly impacts these companiesôparticipation in standardised business processes and their access to markets.

Support for the involvement of small and medium-sized businesses in standards organisations is recommended. A pro-small business economic policy has a direct interest in small and medium-sized companies having access to national and international RFID standardisation activities. This may mean that they participate directly, or that they bundle their interests through joint representatives. The national governments should provide targeted subsidies to encourage participation of small businesses in RFID standards organisations.

Particularly in the UHF range, there is a risk that overseas competitors will use patents to impede the market entry of European companies. It is thus desirable that European companies become more deeply involved in the existing patent pool in the United States, and/or that they create their own European patent pool that would then co-operate with the American pool.

Governance

It is likely that the many mass applications of RFID will be based on IT infrastructures which connect the unique number of a tag with specific information in background systems. For global networks, global information services are required. The most prominent example in this field is the ONS of EPCglobal hosted by the US company VeriSign. Due to the anticipated great importance of such a network, European users have a major economic interest in ensuring non-discriminatory access to the network in the future, once it actually goes online and is widely used. One conceivable technical solution would be to develop a decentralised structure of operators for the EPCglobal Network overseen by an international steering committee with European participation. The Member States should work with the European Commission toward developing a decentralised operating model for the EPCglobal Network ï for example, by supporting appropriate R&D projects.

The requirements outlined for the ONS have to be fulfilled by alternative RFID networks ï like the Afilias Discovery Service ï as well. In general, the development of competing RFID infrastructures is desirable since it counteracts the formation of monopolies in the field of global information services.

Research and Technology Policy

Today's competitors in the field of RFID, the United States and Japan, as well as future competitors, South Korea and China, are spending large sums to accelerate their sponsorship of research and technology, and they are also push-starting major RFID projects.

For this reason, Europe's research and technology policy should carry forward and expand its present activities in order to further enhance the current strong position of European RFID users and technology providers. The various funding agencies should network their activities more closely with each other to achieve synergy effects among the individual projects and to avoid redundant initiatives. It is also desirable to have flagship projects ï that is, large collaborative projects using multiple technologies and with model character but a limited application field. In coordination with the European Commission, flagship projects should be started at the European level to support formation of a European RFID market.

Education

RFID technology vendors, system integrators and users sometimes complain today about a lack of practical knowledge among engineers, computer scientists and technicians, which hampers development and implementation projects. In particular, this refers to inadequate knowledge of RFID's possibilities and constraints due to its basic radio technology. This is a typical side-effect of new and newly-adopted technologies, which typically must be mitigated by adapting occupational training and continuing education, and by augmenting university curricula.

It is recommended to include RFID-specific topics in occupational training and university education. The main contacts here should be the organisations involved in redefining occupational profiles and requirements. In order to support technological diffusion with appropriate, timely training programs, however, it makes sense to use training modules ï and when possible, with certification ï driven by industrial needs and coordinated with chambers of commerce and industry. This will empower employees to act in their professional capacity. In addition, universities and technical colleges should make sure that engineering majors devote more attention to RFID's fundamental principles of action in the future.

Environmental Protection

Like other electronic products, RFID systems are also subject to legal regulations to protect health and the environment. These limit the use of unhealthy materials, require a closed disposal system for certain groups of products, and set thresholds for the impact of radio transmission equipment. Currently there is no evident short-term need for any regulatory action that would apply only to RFID systems.

In the long view, though, the impact of the expected mass-scale use of transponders in everyday objects may pose a challenge to existing disposal and recycling processes in the future. This initially will affect the integration of transponders in recyclable materials such as paper, glass, plastic and aluminium. If they cannot be separated, the transponder materials will decrease the purity of recyclables and thus potentially diminish their quality. In addition, mass-scale adoption of RFID could also significantly increase the proportion of undesirable or valuable materials (such as copper and aluminium) landing in the residual waste.

Closer Coordination of RFID Activities

A number of national and European institutions are functionally in charge of individual aspects of RFID. It appears favourable to establish an inter-institutional RFID committee. The duties of this RFID committee would be to ensure a constant information flow between the individual departments within Europe that deal with RFID, and to co-ordinate issues that cut across departments. Such issues include data and consumer protection and the inter-linkage of research and technology policy with regard to RFID systems and applications.

9 Outlook and next steps

The next steps of the process for a broad roll-out of RFID and a responsible and sustainable application of this technology has to be developed by the conference ñRFID: Towards the Internet of Thingsò, 25th/26th of June 2007 in Berlin. The strategic perspectives of the discussion during this conference will be documented in order to fill in gaps in the draft version of the European Policy Outlook RFID and will be used to sketch further action of the EU member states, the European Commission, industry, organisations and the various stakeholders involved in RFID policies.

In cooperation with