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ITEM-LEVEL TAGGING AND PUBLIC TRANSPORTATION

Authors: Andrea de Panizza, Sven Lindmark and Pawel Rotter

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The mission of the JRC-IPTS is to provide customer-driven support to the EU policy-making process by developing science-based responses to policy challenges that have both a socio-economic as well as a scientific/technological dimension.

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Preface

Information and Communication Technology (ICT) markets are exposed to more rapid cycles of innovation and obsolescence than most other industries. As a consequence, if the European ICT sector is to remain competitive, it must sustain rapid innovation cycles and pay attention to emerging and potentially disruptive technologies In this context, the Directorate-General for Enterprise and Industry (DG ENTR) and the Institute for Prospective Technological Studies (JRC-IPTS)[1] have launched a series of studies to analyse prospects of success for European ICT industries in the face of technological and market innovations.[2] These studies, under the common acronym "COMPLETE",[3] aim to gain a better understanding of the ICT areas in which it would be important for the EU industry to remain, or become, competitive in the near future, and to assess the likely conditions for success.

Each of the "emerging" technologies (or families of technologies) selected for study are expected to have a potential disruptive impact on business models and market structures. By their nature, such impacts generate a moving target and, as a result, classical well-established methodologies cannot be used to define, observe, measure and assess the situation and its potential evolution. The prospective dimension of each study is an intrinsic challenge that has to be solved on a case-by-case basis, using a mix of techniques to establish lead-market data through desk research, expert group discussions, company case analysis and market database construction. These are then combined with reflection on ways and means to assess future competitiveness of the corresponding industries. This process has resulted in reports that are uniquely important for policy-makers.

Each of the COMPLETE studies illustrates in its own right that European companies are active on many fronts of emerging and disruptive ICT technologies and are supplying the market with relevant products and services. Nevertheless, the studies also show that the creation and growth of high tech companies is still very complex and difficult in Europe, and too many economic opportunities seem to escape European initiatives and ownership. COMPLETE helps to illustrate some of the difficulties experienced in different segments of the ICT industry and by growing potential global players. Hopefully, COMPLETE will contribute to a better understanding of the opportunities and help shape better market conditions (financial, labour and product markets) to sustain European competitiveness and economic growth.

This report reflects the findings of the JRC-IPTS study on RFID applications in general, and in two specific cases: in item-level tagging and public transportation. The report starts by introducing the technologies, their characteristics, early market diffusion and barriers to take up, and their potential economic impact, before moving to an analysis of their contribution to the competitiveness of the European ICT industry. It concludes by suggesting policy options. The research, initially based on internal expertise, literature reviews and syntheses of the current state of the knowledge, was complemented with further desk research, expert interviews, patent searches, and an economic forecast. The results were reviewed by experts and in dedicated workshops.

1 IPTS is one of the seven research institutes of the European Commission's Joint Research Centre (JRC).
2 This report is one out of a series, part of the umbrella multiannual project COMPLETE, co-financed by DG ENTR and JRC/IPTS for the period 2007-2010 (Administrative Arrangement ref. 30667-2007-07//SI2.472632).
3 Competitiveness by Leveraging Emerging Technologies Economically.

The report concludes that in RFID, a main building block of the envisaged Internet of Things, the European industry is already a major player. From chip manufacturers to label makers to system integrators, European actors hold positions in almost every link of the RFID value chain. However, there are general barriers blocking that prevent RFID from realizing its full potential. These include investment costs which, combined with lack of skills and uncertainty with respect to return on investment, hinder adoption - not least by SMEs. These barriers need to be addressed in Europe and in the rest of the world.

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The authors would like to thank Marc Bogdanowicz (JRC-IPTS) for support and for reviewing several drafts of the report. Thanks also go to Marc van Lieshout (JRC-IPTS/TNO), Ioannis Maghiros (JRC-IPTS), and Florent Frederix (DG INFSO) for their comments and reviews of earlier drafts. In addition, Martin Ulbrich (DG EMPL), Mats Markusson (DG ENTR), Antonios Pavlopoulos (DG ENTR) and Georg Raab (DG ENTR) are acknowledged for their support and comments throughout the project.

The research was presented and discussed for validation in October 2009, at a workshop attended by representatives from the European Commission and industry experts (see Annex B), all of whom offered many valuable comments and viewpoints. In particular, Henri Barthel (GS1) and Michael Jerne (NXP Semiconductors) provided several clarifying written remarks, which improved the accuracy of the final report. The skilful checking and editing of the text by Patricia Farrer is gratefully acknowledged.

Although these contributions were substantial, the responsibility clearly remains with the authors. Andrea de Panizza conducted most of the research for the techno-economic analysis, while Sven Lindmark was project leader and conducted most of the research for competitiveness and policy-related analysis. Pawel Rotter contributed mainly to the research on technological barriers to adoption, notably in the areas of privacy and security, and to that of competing technologies. Andrea de Panizza and Sven Lindmark jointly wrote up and edited the report and organised the workshop.

Executive Summary

Recent technological development in Radio Frequency Identification (RFID) has opened up a rapidly broadening range of applications and deployments which, due to the enabling characteristics of RFID, encompass nearly all economic activities. These applications and deployments have considerable potential for increasing productivity, and offer opportunities for new innovative products and services, and improved public services. RFID is seen as a key building block in the envisaged Internet of Things. European policies are already addressing issues of how to stimulate their development, while at the same time safeguarding health, security, data protection, privacy and environmental sustainability. However, in order to realise the potential of RFID as an engine for growth and jobs, greater understanding of how Europe is positioned in this regard is needed.

Purpose and overview

This report investigates the current and future competitiveness of the European industry in RFID applications in general and in two specific cases: item-level tagging and public transportation. Item-level tagging (when an RFID tag is used to identify a single item) was chosen as a case-study because it represents the most promising application field economically for RFID technology. Public transportation (i.e. passenger transport systems for the general public) was chosen as it is a well advanced RFID technology application field, where some large EU actors are at the forefront; hence, it may be a case from which lessons can be learned for other fields.

The report analyses RFID constituent technologies, drivers and barriers to growth, actual and potential markets and economic impacts. It assesses the EU position, its strength and weaknesses with regard to its industrial position and innovative capabilities, overall and with specific reference to item-level tagging and public transportation. The report concludes with a number of issues relevant for policy making.

The research, initially based on internal expertise, literature reviews and syntheses of the current state of the knowledge, was complemented with desk research, expert interviews among supply and use actors, patent searches, and an economic forecast. The results were reviewed and validated by individual external experts and by groups of experts in dedicated workshops.

Economic importance of RFID

RFID is an auto-identification technology, as are barcodes and contact cards. RFID presents several advantages over these last two: it allows contactless and no line-of-sight information transmission, simultaneous identification, sophistication and integration with sensors, and the modification of stored data. These features support a huge range of applications in, for example, logistics, retail, manufacturing and access control. RFID will be a key building block in the envisaged Internet of Things. RFID applications could have a profound effect on both the industries that produce them and those that use them, and on the competitiveness of European companies.

The potential economic impact of RFID is very large. By 2008, the global market size was already estimated at about €3-3.5 billion, and is expected by some to reach about €15-20 billion by 2018. Much of the increase is likely to be in services. At the moment, the European market stands at about 20% of these figures, and its share is growing. Economic impacts resulting from the usage of RFID – though inherently more difficult to estimate – could be of a higher order of magnitude. These will come in the form of cost reductions/productivity growth and, increasingly, in the form of new products and services.

Roadblocks to RFID adoption

There are still a number of barriers to adoption. Economic obstacles include the investment costs necessary to implement an RFID-based application, combined with lack of skills and uncertainty with respect to return on investment, which hinder adoption, particularly by SMEs. The lack of standard protocols and interoperability may also pose barriers and also, in the longer term, the lack of suitable frequencies. Finally, RFID take up may be slowed down by privacy and health concerns, and by its potential vulnerability to security threats.

EU position and competitiveness

European technology providers, users and research centres have made Europe a major competitor in the global RFID market. From chip manufacturers to label makers to system integrators, European actors hold positions in almost every link of the RFID value chain. In many segments, such as special label-making machinery, they are among the market leaders. Within Europe, Germany leads, followed by France and the UK, Italy, the Netherlands, and the Nordic countries; Austria and Switzerland also have relatively strong positions.

However, the US dominates the market, with large-scale infrastructure projects, first rank companies and R&D programmes, and a strong position in standard setting and patents related to these standards. In Asia, Japan, Korea and Taiwan are already competitive. and China is likely to catch up soon as a result of large domestic demand and industrial policy.

Technology-wise, Europe is also doing well, although it is lagging behind the US in patenting, especially in core RFID technology. Our study suggests that Europe's patenting position is stronger in the application field and is improving in core technologies. The EU's R&D infrastructure is well developed, but is faced with very strong R&D programmes in other regions, including large-scale projects with multi-technology objectives (e.g. Japan, Korea), or government-initiated infrastructure projects in the US.

Policy issues

The most pertinent policy issues relate to the stimulation of RFID adoption. Policy initiatives should include awareness raising, support to pilots and business cases, public procurement and coordination along value chains. RFID policies could be combined with policies in other areas, such as transport and climate change. Particular attention must be paid to SMEs in RFID industries by stimulating their participation in R&D projects and standard-setting forums and to SMEs in using industries by ensuring return on RFID investment, and increasing their awareness and level of RFID skills.

Also, continued R&D support should be provided in a number of areas which are not developed enough at the moment for broad-based implementation of RFID to take place. Currently, these areas are related to tags, readers, and in particular software and systems. And, further standardization should be encouraged.

At the same time, continued attention must be paid to existing and potential harmful effects of RFID implementation. In particular, privacy and security need to be carefully regulated and have also been recently addressed in a Recommendation by the European Commission. The environmental effects, in particular recycling needs, ought to be planned long-term.

Carefully managed, however, there are clearly opportunities for Europe and its enterprises to reap the benefits from RFID.

Case summary: RFID Item-level tagging

In item-level tagging, an RFID tag is used to identify a single item. Item-level tagging represents the most promising RFID application field, as it can be used in a number of industries for very diverse purposes, it encompasses most tag types, and it is bound to become the largest market in terms of value and tag volumes.

The main fields for item-level-tagging applications include retail (tagging of consumer goods), pharmaceutical and medical equipment, postal services, archiving, manufacturing processes, and libraries. Take up in these applications is driven by a range of technological and socio-economic factors. Most pertinent, perhaps, is the range of benefits which RFID potentially provide –increased efficiency, reduced operational costs, reduced time needed for some operations, fewer errors and losses, increased customer convenience and the provision of new services or functionalities. Rapid price reductions, the development of complementary hardware and software technologies and improved customer acceptance will allow item-level RFID tagging to subsequently activate and penetrate new market segments. Notwithstanding the opportunities opened up by item-level tagging, a number of elements may be hindering or delaying it, in particular privacy and security concerns, value capturing, coordination difficulties, and lack of proven business cases along the value chain, cost barriers for SMEs, and possibly the lack of suitable frequencies, standard protocols and interoperability.

The economic impact of item-level tagging is potentially huge. Although the current economic crisis may bring about a downward revision of estimates, global item-level business is expected to rise from about 250 million USD (€180 million) in 2008 to more than 8 billion USD (€6 billion) in 2018 (i.e. from 5 to 30% of the total RFID market), of which almost half is the value of tag production. Correspondingly, the production of item-level tags is expected to grow from about 0.4 billion units to more than 600 billion units yearly (i.e. from 20 to about 90% of the total number of tags). In volume terms, the main engine of growth is represented by consumer goods, which are expected to become largely dominant in tagging flows. This growth is driven by rapid cost reductions and is in turn driving further reductions. The landscape is more varied when it comes to market value: consumer goods take the lead, closely followed by the health sector and manufacturing-related applications. The main actors in the value chain likely to benefit from this market growth are tag and antennas manufacturers, software producers, system integrators and service providers. Other actors affected include those providing complementary technologies (notably, mobile phones for Near Field Communication - NFC), and competing technologies (notably, barcodes). In a broad economic perspective, available estimates show that the existing item-level tagging market for the RFID industry generates only a fraction of its envisaged economic impact.

Europe's competitive position in item-level tagging is much the same as it is in RFID in general, though it suffers more from Europe's weak position in UHF spectrum and standards. Policy needs to continue to address these weaknesses.

Case summary: RFID for public transportation

The use of RFID is already established in public transport systems. Initially, most projects were very large in terms of investment, organizational issues, visibility and numbers of users. Now, however, the technology is within the reach of smaller projects. The main RFID application in public transport is in ticketing, i.e. to give the public access to means of public transportation such as buses, ferries, trams, subways and trains. In this application, RFID substitutes traditional paper and magnetic stripe tickets, but also goes beyond the functionality of these.

The economic impact of RFID for public transportation includes effects on the supply industry, on public transportation companies and on their customers. RFID enables the realisation of more efficient and effective systems by reducing boarding time and, in some cases, by providing additional information to travellers (time of arrival, time of departure, delays in time schedules, etc.), offering management information about the traffic patterns in public transport, reducing fraud, and extending the range of services public transport operators can offer, if necessary, in combination with other service providers.

The current world-wide RFID market for public transportation can be estimated at about 100-250 million Euros annually. Main barriers to further diffusion include the systems' complexity and initial investment costs, organisational difficulties, political decision making, systemic risks and privacy-related concerns. However, the market is expected to continue to grow in the years to come, due to progress and cost reduction in RFID technology, and the fact that it has features which are superior to its main alternatives (paper tickets, magnetic strips and contact smart cards).

Although, in the long run, this application will become relatively less important than other fast growing RFID applications, the spread of RFID for transport ticketing is deemed strategic from a public perspective. Indeed, besides the direct economic benefits to transport providers, it is a powerful tool for better managing and integrating public transportation offers locally, expanding them to other services (e.g. bicycles) and moving from local to regional or national network integration. It may also facilitate the break up of local monopolies.

The European competitive position in public transportation is stronger than in most other areas, with respect to both production and usage, and does not suffer from any particular weakness in technology or standard-setting. In fact, the implementation of RFID applications in public transportation could serve as inspiration for how public initiatives can be used to create other European lead markets with this technology.

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Introduction

Applications of radio frequency identification (RFID) systems are one of the fastest growing Information and Communication Technology areas: the total RFID market value is expected to grow fivefold from 2008 to 2018, from an estimated value of €3.5 billion to €18 billion.[4] Technological developments and cost reduction open up a rapidly broadening range of applications and deployments which, due to the enabling characteristics of RFID, encompass nearly all economic activities. Rapid average returns to investment hint that the direct economic impact of RFID take up will largely exceed its market size. The expected socio-economic impact, however, is even larger, taking into account the fact that RFID can be a vehicle for positive externalities such as mortality reduction in hospitals, or time saved and enhancements in service quality for consumers.

In view of the above, European policies are already supporting RFID research and diffusion, and at the same time the safe-guarding values of health, security, data protection, privacy and environmental sustainability. Still, it needs to further its understanding how Europe is positioned to realize the potential of RFID engine for growth and jobs. This report aims to provide support such policy making.

This report investigates the current and future competitiveness of the European industry concerning applications of RFID in general and for the cases of item-level tagging and for public transportation.

The case of item-level tagging (when an RFID tag is used to identify a single item), was chosen because it represents the most promising application field for RFID technology. It can be used in a number of industries and for very diverse purposes, and is bound to become the largest RFID market in terms of value, and all the more so for tag volumes. Public transportation (i.e. passenger transport systems for the general public) is an advanced field of RFID technology application. RFID has already been implemented in transport networks in several large European cities, both as a replacement for traditional tickets and subscriber cards and for network management and vehicle tracking functionalities. There is still room for further diffusion of RFID in public transportation, and this is also a field where some large EU actors are at the forefront. As it is one of the first applications, it may also constitute a case from which lessons can be learned for others.

The research for this report was conducted in 2008-2009, using a mix of qualitative and quantitative data, and both primary and secondary sources. It built on internal expertise and earlier research at JRC/IPTS (e.g. Maghiros et al 2007). RFID in general is also a fairly well documented area, and a considerable effort has been devoted to reviewing and synthesising the current state of knowledge. The two case studies and the European competitive position in RFID, less documented, had to be investigated using desk research, interviews, as well as patent searches, build-up of company data bases and economic forecasts. The results have been reviewed and validated by external experts: a validation workshop took place in October 2009, with a selected group of representatives from RFID manufacturing industries, service providers, users, certifying bodies, consultants and policy owners (Annex B). Conclusions from that workshop have been integrated in the report.

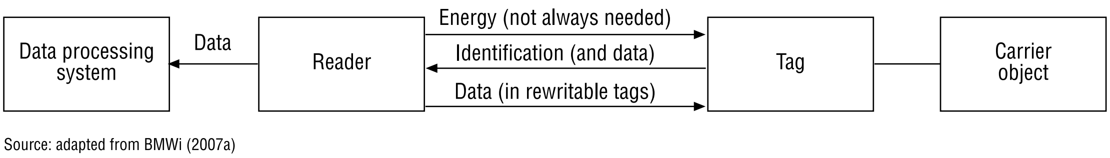
4 See OECD (2008a) for a collection of estimates of RFID market. IdTechEx (2008a), estimates the total market (including software and services) to USD 5.29 billion for 2008.

1 Setting the RFID Scene

1.1 What is RFID?

Radio Frequency Identification (RFID) is a technology that enables contactless data transmission with tagged objects for identification and other purposes. RFID systems consist of three elements: a transponder (tag) placed on the object to be tracked, an interrogator (reader) which sends queries to tags and obtains data in response, and a data processing system, including necessary software.

Figure 1-1: Components of an RFID system



Source: adapted from BMWi (2007a).

Typical RFID tags consist of an antenna and a microchip packed together. However, the simplest (and potentially cheapest) tags are chip-less, while other (extended capability) tags have a larger information storage capacity and can include sensors and/or batteries. Powered tags, called *active tags*, can operate at much longer distances than other (*passive*) tags.[5] They can also simultaneously collect data from other tags, continuously record sensor data, store data, etc. On the other hand, they have a shorter life-time (due to battery autonomy), and they are larger and more expensive. (See Annex A for an overview of passive and active RFID technologies.)

Readers vary in size from that of a coin to a laptop, and their cost varies enormously, from tens to hundreds or even a thousand Euros and more, if they have to communicate with active tags over long distances.[6] RFID systems can be distinguished according to their operating frequencies (from 125 kHz to 2.4 GHz), which in turn also influences parameters such as: reading range, interference from metal and water and the need to direct antennas. To sum up, there is a wide range of configurations available, which are suited to diverse applications (Table 1-1). Taxonomies of RFID systems can be drawn up with respect to their operational properties, as well as to their *closed* vs. *open* nature (when inter-operability by different actors along the value chain is required). RFID printers typically encode labels by first writing the code to the tag and then printing it on the label as a barcode.

Software systems referred to as 'middleware' (or sometimes as 'edgeware') represent the link between RFID hardware components and the enterprise software controlling the production process. Filtering data and event handling are their key functions.[7]

System integration comprises installing hardware on-site and linking it to backend IT systems. Creating an interface between RFID

5 Intermediate categories include semi-active or semi-passive tags, with a battery which is used only when interrogated.
6 OECD (2008b).

7 BMWi (2007a).

Table 1-1: Taxonomy and features of RFID tags

Frequency		Low (LF)	High (HF)	Ultra High (UHF)		Microwave (MW)
		125, 134-135 kHz	13, 56 MHz	EU 865-868 MHz;	US 915 MHz	2.4 GHz
Operating principle		Induction		Radio		
Energy supply		Typically passive		Active and passive		
Range typical (<max)	**passive**	20 cm (<1,2m)	20 cm (< 1.5m)	3-6 m	6-8 m	2m (<10m)
	active			100 m		
Need to aim reader?		No	No	Sometimes		Yes
Typical tag shape		Glass tube, plastic housing, smart cards, smart labels	Smart labels, industrial	Smart labels, industrial		Large format
Bulk processing		Rarely impl.	<100/sec	<500/sec		<500/sec
Data transfer rate		Slow	Medium	Fast		Very fast
Effect of	**water**	None	None	Negative		Negative
	metal	Negative	Negative	None		None
Typical application areas		Access control, anti-theft, industrial, animal, laundry cleaners, gas readers , car immobilisation	Laundry cleaners, asset management, ticketing, tracking, library, passport, payment	Palette tracking, container tracking		Road pricing, container tracking, production control.
Comments		Non-ISM band				

Source: adapted from BMWi (2007) and OECD (2008b)

systems and ERP (Enterprise Resource Planning) software also requires significant expenditures on software engineering, as well as in-depth IT consulting or process-oriented management consulting. The integration of RFID systems into ERP systems usually depends on the user's individual design wishes and thus requires customised software development.[8]

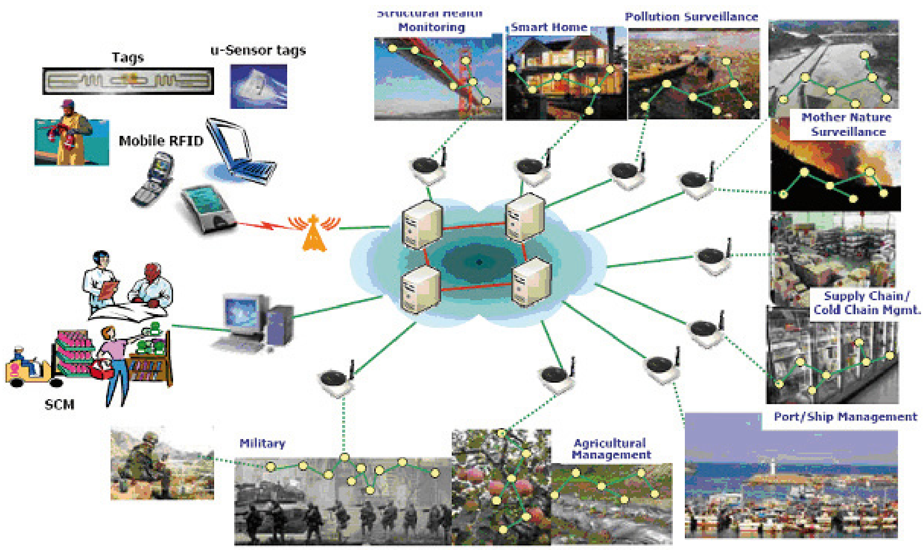
Finally, it should be mentioned that RFID tags and readers are often components of a broader RFID system, which in turn, is a component of an enterprise information technology infrastructure. The efficiency of RFID systems depends on the capacity of the organisation's IT network to transport the flows of RFID information efficiently, where middleware components connect the RFID core systems to the back-end. Even more importantly, getting the full benefit from RFID requires that information flows are well managed and that the best use is made of them. This often entails some organisational changes.

1.2 Why is it deemed so important?

RFID technology is undergoing rapid development, rendering it very promising in terms of the range of economically accessible applications. As a result, according to IdTechEx (2008a) estimates, from 2006 to 2007 the number of new tags grew 70%, from 1 billion annually to 1.7 billion. Indeed, with respect to other widespread auto-identification technologies such as barcodes and (magnetic or chipped) contact cards, RFID has several advantages: information from tags can be transmitted without any contact, tags can be read in bulk (simultaneous identification) without being in the line of sight of the reader; they can be quite sophisticated and integrated with sensors, and data stored can be modified. Given the above, applications of RFID are manifold – from asset management

8 BMWi (2007a).

Figure 1-2: Ubiquitous sensor network – everywhere, everything with RFID tags; sensing ID and environmental information; real-time monitoring & control via network



Source: Kim (2006).

and monitoring, to supply chain parts and goods control and inventory, to fraud and theft control, to payment systems, and the authentication of people and objects – and encompass nearly all economic activities (Table 1-2).[9] Lastly, RFID will ultimately constitute the means to uniquely identify objects in the envisaged *Internet of things*, where any object could be integrated into a universal digital network (see European Commission, 2008, 2009d, and ITU 2008) based on Ubiquitous Sensor Networks (USN: everywhere, everything with RFID tags, which could eventually network amongst themselves to increase range; sensing ID and environmental information; real-time monitoring and control via network – see Figure 1-2).

On the other hand, the spread of RFID faces some techno-economic hindrances (system costs, interferences, reading effectiveness), and it is also controversial. There are concerns about safety, security and privacy, in relation to electromagnetic fields, and unauthorised data access and modification by third parties with a wide range of consequences and traceability of individuals.[10]

The analysis of RFID can be approached by focusing on the different parts and features of RFID systems, and on the segments of the RFID industry – from chips and antennas to software and integration – or on diffusion and impacts across industries and fields of application.

All these distinct, overlapping analytical perspectives are characterised by a relevant degree of uncertainty: will a *one cent tag* become available, when, with what features, and what will be the adoption rate? Considering the direct costs of RFID systems, sophistication is naturally reflected in tag prices, which at present range from a few cents to several euros. Some applications in given industries are already well established, while others will become feasible

9 For a review of present applications by industry, see OECD (2007); OECD (2008a).

10 After submitting the draft to public consultation, the EC recently published a *Recommendation on the implementation of privacy and data protection principles in applications supported by radio-frequency identification* (European Commission 2009a) and some accompanying working document on its impact assessment (European Commission 2009b, 2009c).

Table 1-2: Overview of RFID applications in the Private and Public sector

	Application examples in the Private sector	Application examples in the Public sector
Asset utilisation	• Container management (*e.g.* small load carriers in the automotive sector) • Loading equipment management (*e.g.* for gears in the automotive supplier sector) • Management of dollies at airports • Fleet management	• Waste management: Container management • Health: Location of medical equipment at hospitals
Asset monitoring and maintenance	• Machine maintenance • Tool box maintenance (*e.g.* for the maintenance of aircraft) • Maintenance of parts built in aircraft • Smart home applications	
Item flow control in processes	• Tagging of parts along the supply chain to correlate information on the tagged item to process steps • Goods movement control • Quality control of goods • Tracing drugs in the pharmaceutical value chain • Tracking finished goods for the purpose of diversion control	• Health: Tracking of medication from the pharmacy to the hospitalised patient • Health: Tracing blood bottles • Administration: Document management
Inventory audit	• Real-time location system for finished vehicles in the automative sector • Automation of warehouse management • Automated sorting and counting of inventory • Checking of ingoing and outgoing goods • Baggage handling at airports • Livestock tagging	• Defence: Ammunition management • Education: Lending system in libraries • Exhibition in museums • Science: Tagging animals and plants for research purposes
Theft control	• Car keys (immobilisers) • Electronic Article Surveillance (EAS) systems • Tracking products along the supply chain to minimise theft	
Authentication	• Persons: – Company badges – Ski passes – Event ticketing – Sports: recording time during a competition • Objects (counterfeiting control): – Proof of authenticity of spare parts (*e.g.* in the aviation sector) – Proof of authenticity of drugs – Proof of authenticity of luxury goods	• E-Passports, identity cards • Health: Patient authentication for the monitoring of medication in hospitals • Leisure/sports: recording time during a competition • Traffic: Tolling systems • Traffic: Speed control • Transport: Access control cards for public transport
Payment systems	• Tolling systems • Contactless cards for financial transactions	• Transport: Payment cards for public transport

Source: OECD (2008a)

only below a certain price threshold, which is a matter of volumes as well as of investments and technological achievements.

1.3 RFID market dynamics

Estimates of the actual and prospective dimensions of the global RFID market vary considerably, depending on what is included in the estimate (only hardware or also software, maintenance and marketing services as well), and on underlying assumptions on technological breakthroughs. The most credited amongst the latter are represented by chip-less and especially printed tags for low-cost high volume applications, and by Ubiquitous Sensor Networks (USN), especially for high performance active tags.

The most prudent estimate (Gartner, 2008) sets the market for RFID hardware plus software at about 1.5 billion USD for 2008 and 3.5 billion USD in 2012, while all inclusive pre-crisis estimates[11] evaluate the RFID market at about 5-5 billion USD (€3-3.5 billion) for 2008 and up to 25-28 billion USD in ten years time, thus doubling each five years. More recent estimates (June-July 2009) on the impact of the economic downturn on RFID investments set global RFID market growth at between 5% (IdTechex) and 10% (VDC Research) for 2009, with an uneven pattern among applications and market segments, and forecast that a yearly growth rate of 30%, estimated in 2008, will only be achieved from 2011-2012. As confirmed by the panel of industry experts during the IPTS validation workshop, though, figures on the expected market value in ten years time should be taken with extreme caution.

In 2018, according to the IdTechEx (2008a) detailed projection, the share of tags will stay at about 45% of the total RFID market value, while the combined service, software and network components would grow from 28 to 38% (and even more according to our panel of experts). For 2008, it is estimated that more than half the total expenditure on RFID systems was made in East Asia (mainly due to the Chinese national identity cards programme), about one quarter in North America, and about one fifth in the EU (approximately one billion USD. Another indication of the actual spread of the technology can be drawn from the number of RFID case studies reported in the IDTechEx database (to date the most comprehensive available): according to these data, Europe seems to be well positioned in terms of usage. In March 2009 the five largest European RFID-using countries (France, UK, Germany, Italy and the Netherlands) together made up about one quarter of the total case studies, worldwide.[12]

In the years to come, however, EU expenditure is forecast to gradually catch up, reaching one quarter of total expenditure by 2018. Market dynamics by components and regions are reported in Figure 1-3. Percentage shares are portrayed on the left, and values in billions of US dollars on the right.

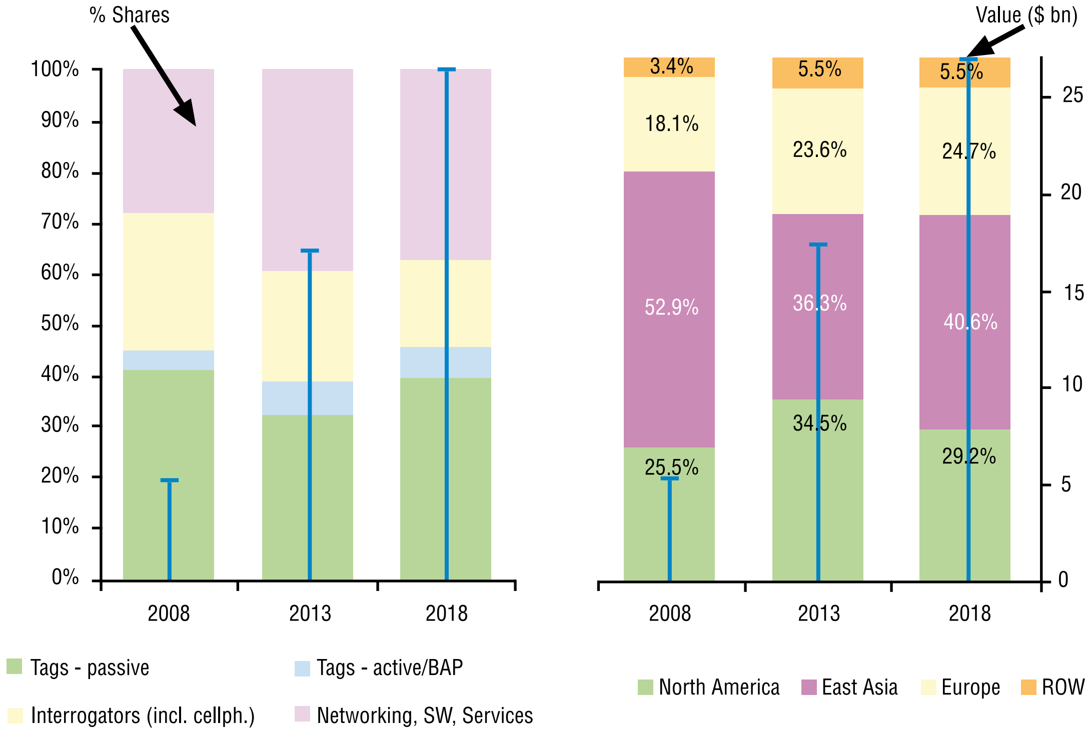
The volume of RFID tags, in the same period, is projected to grow from about 2 billion to 670 billion units yearly, while their average price is expected to decrease up to 100 times. Forecasted trends for tag prices and diffusion by application are reported in Figure 1-4, where logarithmic scales had to be used to portray the dramatic dynamics of volumes and unit values.

It is expected that the spread of RFID tagging across application fields will also change greatly. Currently, several applications are present on a relatively small scale in terms of volume and more than 50% of market value originates from smart cards, used for financial and authentication purposes (including public transport ticketing). At the end of the forecasting period, however, due to

11 IdTechEx (2008a), Baird (2007), RNCOS (2008), ABI (2008), VCF (2008; 2009). See also the comparative table reported in OECD (2008a).

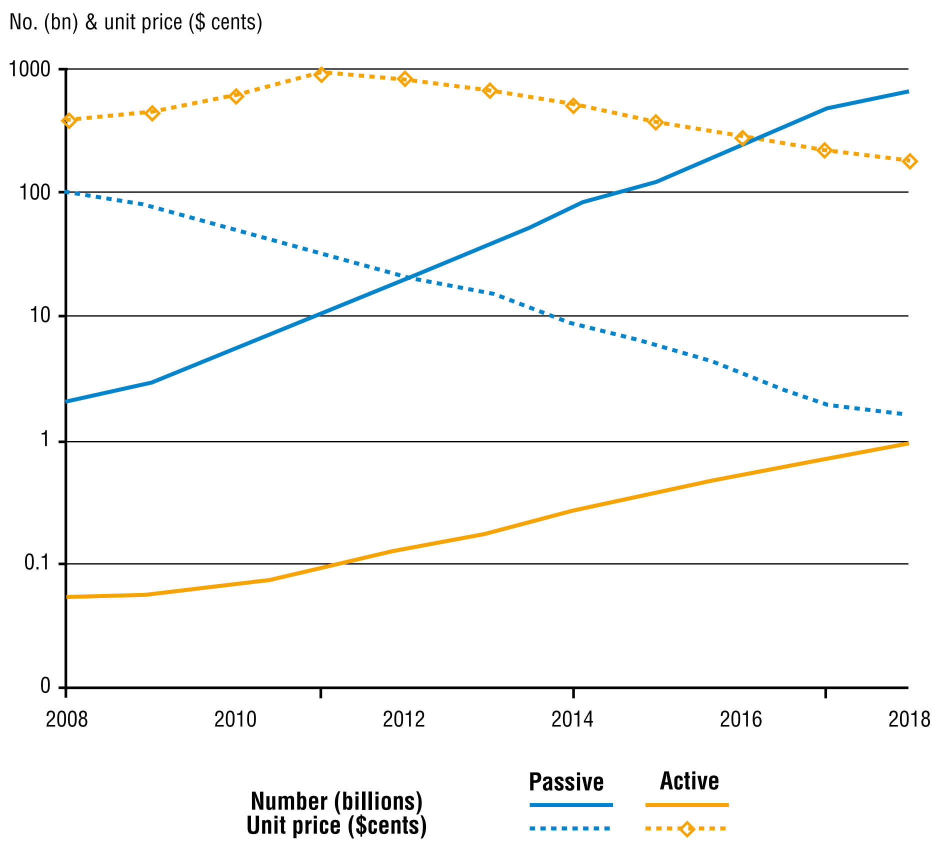
12 See http://www.idtechex.com/knowledgebase/en/breakdown.asp [accessed 2009-03-26].

Figure 1-3: RFID market value by component and region (2008-2018)



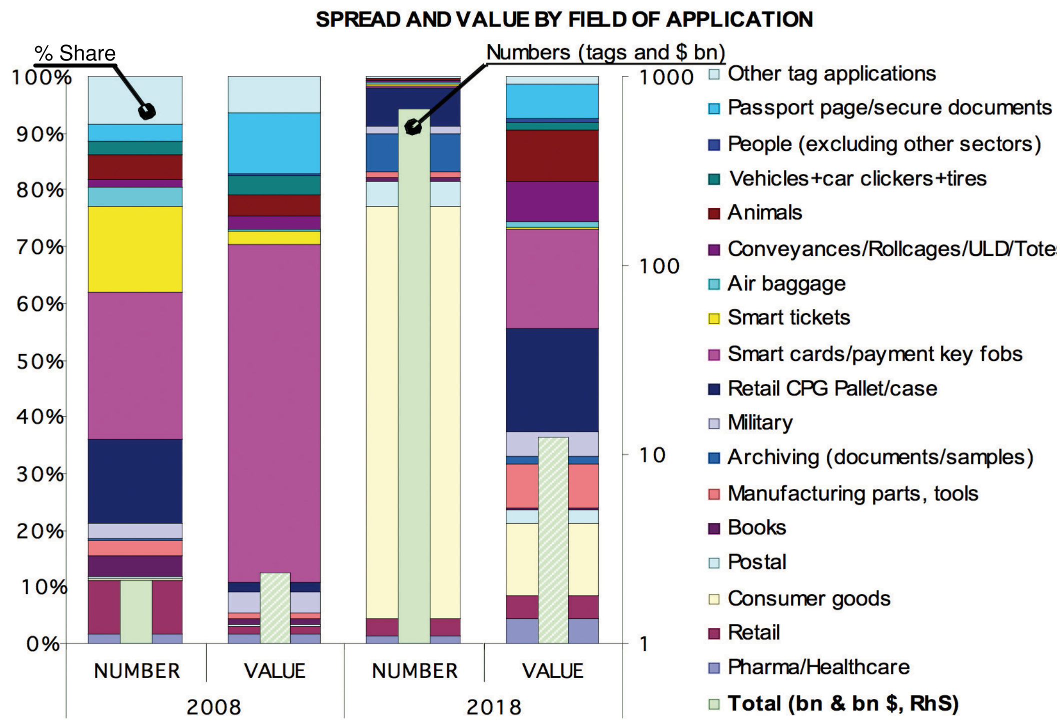
Source: based on data from IdTechEx (2008a).

Figure 1-4: RFID active and passive tags diffusion and unit prices, 2008-2018



Source: authors' calculations based on IdTechEx (2008a); unit tag prices per type are weighted on market value.

Figure 1-5: Tag diffusion and market value by application field (2008-2018)



Source: authors' calculations based on IdTechEx (2008a); unit tag prices per type are weighted on market value.

much more pervasive deployment of RFID across the economy, most of the (very large) volume of tag production will be for consumer goods item-level tagging, while market value will be more equally shared amongst different application fields.

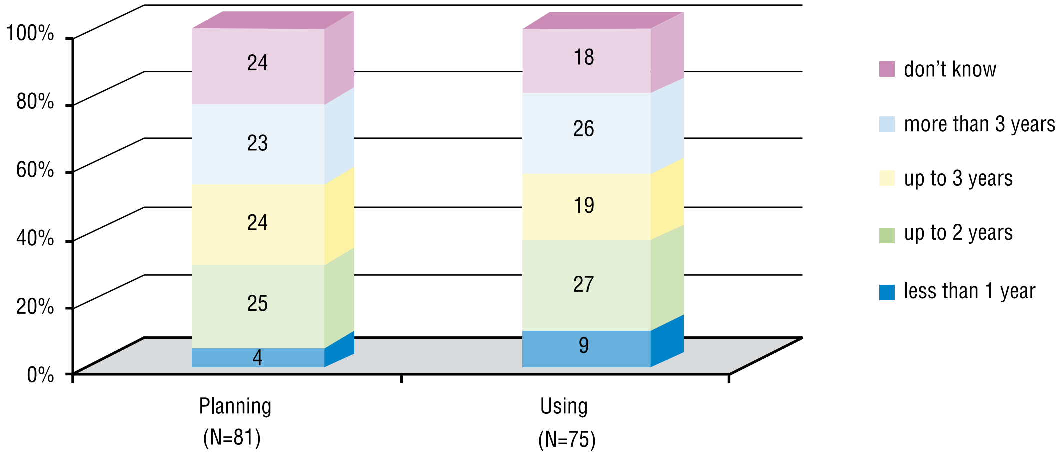
Thus, the two applications selected for further investigation in the current report are: (1) RFID in public transport as this is one of the most important RFID applications of today; it is already used in most large EU cities, it has further room for diffusion and is a field where some big EU actors are at the forefront; and (2) item-level tagging as this is the most promising application for tomorrow; it can be used in a number of industries and for very diverse purposes, it encompasses most types of tag, and is bound to become the largest RFID market in terms of value, not to mention tag volumes (Figure 1-5).

At present, payback time to item-level tagging investment for successful applications is often estimated to be between a year and 18 months. For instance, a survey conducted in mid-2008 on 185 organisations (ABI, 2009) revealed that 36.7% of potential investors were expecting returns within the first year, and another 25% within 18 months: these shares were significantly higher than 2 years before.[13]

These figures, however, do not fully take into account failures and economic losses (which, indeed, in the past few years were also relevant for RFID producers). From another recent survey on (overall) RFID adoption in four industries across seven EU countries (IDC 2008), the ex-post median payback time on investment was between 2 and 3 years (still making it advantageous), with wide variations in returns and some (equally positive and negative) differences with respect to plans (Figure 1-6).

13 See also the results of a survey by IIG-Freiburg, reported in Deutsche Bank (2009).

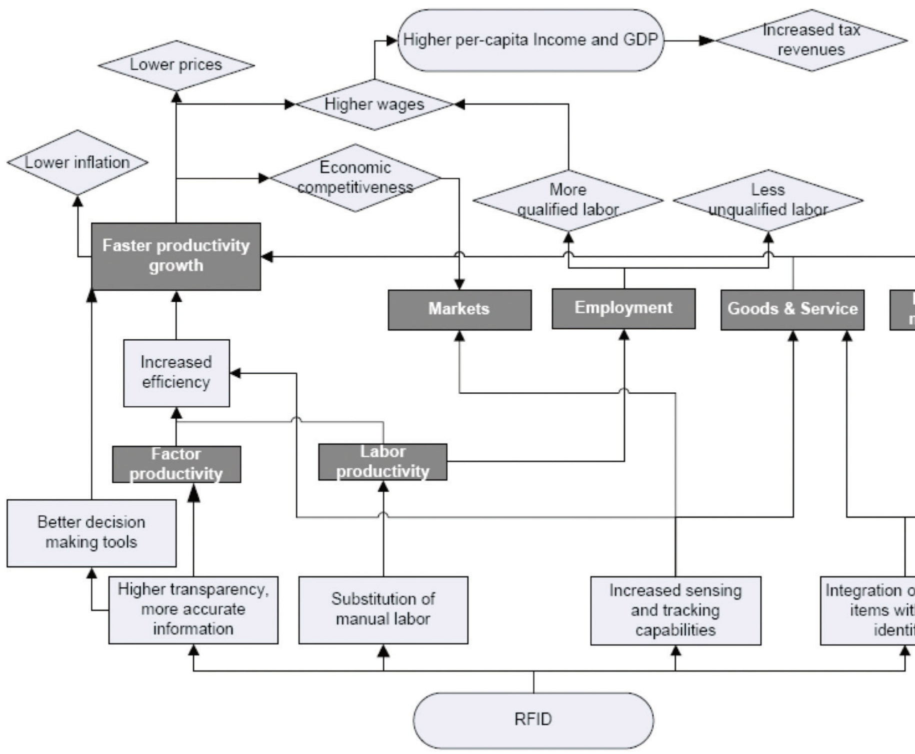
Figure 1-6: Estimated payback period of RFID Investment



Source: adapted from IDC (2008).

Note: firms surveyed across Retail, Transportation, Discrete/Process Manufacturing, Hospital Activities in France, Germany, Ireland, Italy, Poland, Spain, and the UK.

Figure 1-7: Economic impact and developments due to the use of RFID



Source: Schmitt & Michahelles (2008).

On the other hand, the RFID market in itself is expected to represent only a fraction of its overall economic impact, most of it being due to the take up by industries. A conceptual framework for the latter, proposed by the BRIDGE project, is depicted in Figure 1-7.

Table 1-3: Portion of value added due to RFID technology take up in German industries

	YEAR	Manufacturing				Trade		Transport storage & communication	Health and social work	TOTAL
		Transport equipment	Textiles & apparel	Chemicals	Machinery & equipment	Commercial / Wholesale	Retail (except motor v.)			
Gross value added (Eur bn)	2004	73.1	37.4	45.6	67.2	89.5	84	116.4	141.2	654.4
	2010	71.4	34.4	55.4	85.5	133.5	88.1	148.1	148.1	764.5
Percentage of RFID pioneers	2004	10%	5%	5%	2%	10%	10%	7%	1%	--
	2010	40%	20%	15%	15%	40%	40%	25%	15%	--
RFID pioneers' value added (Eur bn)	2004	7.3	1.9	2.3	1.3	9	8.4	8.2	1.4	39.8
	2010	28.6	6.9	8.3	12.8	53.4	35.3	37	22.2	204.5
Percentage of output "influenced" by RFID	2004	10%	5%	10%	2%	10%	10%	5%	1%	--
	2010	35%	30%	20%	20%	30%	30%	40%	20%	--
Portion of v.a. "influence" by RFID (Eur bn)	2004	0.7	0.1	0.2	0.03	0.9	0.9	0.4	0.01	3.2
	2010	10	2.1	1.7	2.6	16	10.6	14.8	4.4	62.2

Source: OECD (2008a), based on BMWi (2007).

Frameworks, such as the BRIDGE one above, by definition tend to portray relationships between stylised facts optimistically. They are, nonetheless, useful as they allow us to highlight the main dimensions impacted by RFID adoption.

In the German economy, according to a recent estimate by BMWi (2007, as reported in OECD 2008), RFID adoption by enterprises will achieve weightings from 20 to 40% in their respective industries by 2010, with an expected impact on their value added of more than €60 billion (Table 1-3).

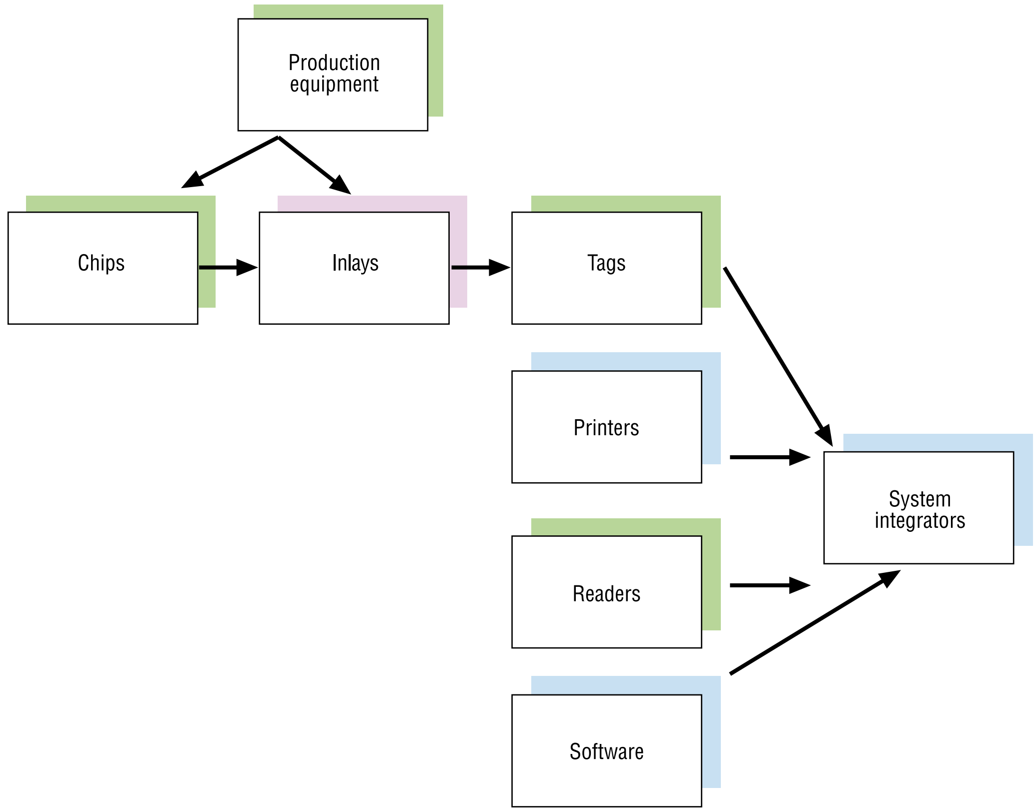
1.4 RFID value chain

When seen from the production side, the structure of the RFID industry includes actors which operate only in specific segments of the value chain – be they research, or manufacturing, reselling, middleware production, or consultancy – as well as enterprises which are present in several different stages.

Particularly relevant among the latter, due to the composite nature of the technology, are firms offering the *integration* (of hardware components, power and data exchange networks, workplace environment) necessary to make RFID systems operational (Figure 1-8).

Several large ICT corporations have a foot in RFID, but several specialised SMEs are also active. The degree of market concentration differs according to the application and the elements considered. In very general terms, services tend to be more fragmented and bound to local economies than, for instance, chip manufacturing, which is also undergoing a process of concentration. Some estimates (Baird, 2007, RNCOS, 2007) to be considered with caution, position EU production of RFID systems and services at a comforting 40% of the world market in 2010.

Figure 1-8: RFID value chain



Source: adapted from e.g. BMWi (2007a).

1.5 RFID technological (patenting) dynamics

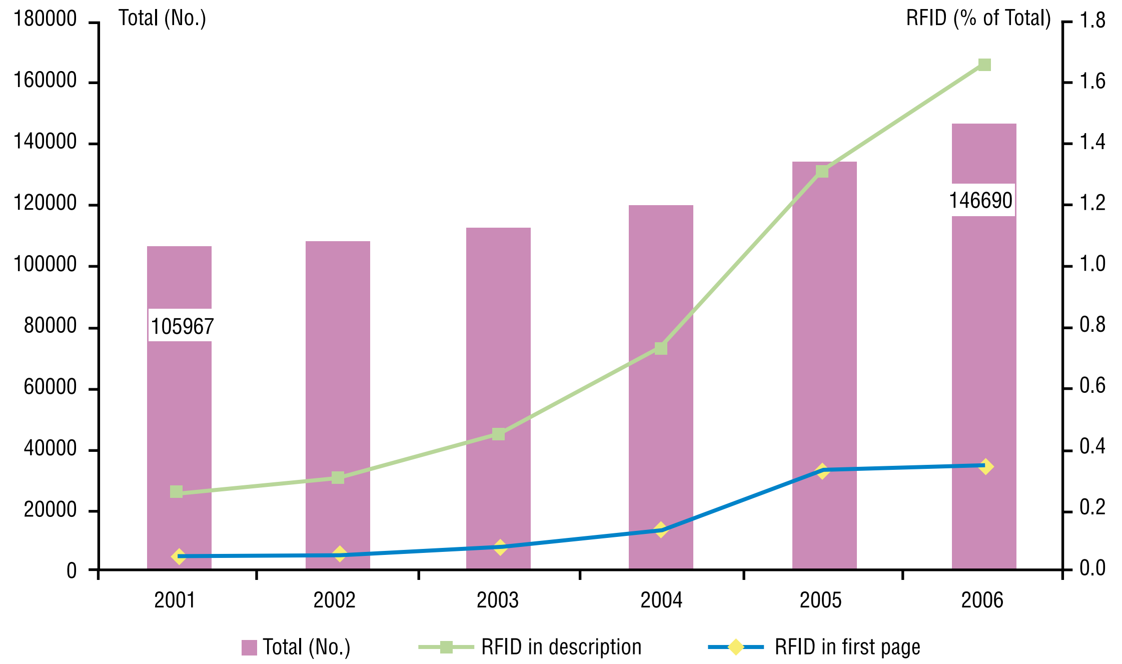
An indication of the importance of RFID research can be obtained through the assessment of inventive activity, as measured by patent output. To this purpose, we screened all international patent applications submitted to the World Intellectual Property Organisation under the Patent Cooperation Treaty (PCT) for the text "RFID". The search was performed both on the first page in order to get a count for likely RFID inventions (narrow definition), and in the full description so as to include inventions which include some RFID devices, though not necessarily as their chief objective (broad definition).

This exercise clearly reveals an increasing relevance of RFID-related technologies in patenting activity. The overall flows of patent applications from 2001 to 2006 grew by about 40% to 147,000 and applications related to RFID in both the above definitions increased more than nine-fold, so that their shares reached, respectively, 0.35 and 1.7% of total (Figure 1-9).[14]

As will be seen in Section 3.2.1, underlying these aggregate figures there are wide differences in the contributions of individual countries/ regions and of with respect to RFID direct and RFID *enhanced* applications, and their dynamics.

14 We consider the results proposed in the exercise robust, although it has to be noticed that it provides a partial coverage only of patents related to RFID (and, obviously, does not consider patent value). According to a research on the market conducted by the RFID Consortium (see below in text), quoted by the RFID Journal (http://www.rfidjournal.com/article/view/4785/2), there would be "more than 13,000 published patents and applications for patents involving RFID", and "the consortium has identified approximately 70 firms that hold at least 15 patents or applications".

Figure 1-9: International PCT applications: totals and percentages of RFID patent filings (2001-2006)



Source: authors' computation on WIPO's PATENTSCOPE database.[15]

1.6 Barriers to RFID adoption

This section discusses some general barriers to RFID adoption identified when reviewing the literature. These are economic (mainly in the form of low return on investments for SMEs and lack of proven business cases), usage related, lack of skills, privacy issues, technological issues including security, and also insufficient standardisation and spectrum. These barriers are also addressed with specific reference to the case studies.

Costs (for instance, RFID costs are higher than bar code costs) are often referred to as a significant barrier. They include tags, readers, middleware and integration costs. Integration costs include both the reader and the overall the integration into the firm's software infrastructure. The importance of middleware costs depends on whether companies develop their own middleware or whether they can rely on middleware which is already on the market. While tag costs are expected to decline further to allow ubiquitous RFID use – the 2008 average market price of a standard UHF RFID tag ranges from €0.10 to €0.15 for volume purchases (although cheaper tags at €0.05 have become available) – it is fundamental to evaluate the total cost of ownership of a full RFID solution. This includes software, IT services and in-house efforts to manage RFID programmes over time. The share of hardware spending on the total RFID investment is declining, while the share of IT services and software spending combined is rapidly increasing.

The issue of costs is strictly intertwined with that of investment profitability. Lack of strong evidence of return on investment (**ROI**) for RFID projects is a major barrier to RFID adoption. This is a critical issue for companies of all sizes, but mostly for small companies. Indeed, these typically have a limited operational scale and a confined geographical presence, which may result in narrow opportunities

15 Note that WIPO bears no responsibility for the integrity or accuracy of the data contained herein, in particular due, but not limited, to any deletion, manipulation, or reformatting of data that may have occurred beyond its control.

for benefits. In addition, the restricted availability of financial resources is a limitation for small companies. There are, in fact, many indications that **SMEs** in particular are still reluctant to adopt RFID, as they perceive it as unprofitable or too risky.

There is also a lack of proven lack of business cases in the RFID value chain, mainly for the SMEs, whose access to using RFID is hampered by the unavailability of generic architectures (building blocks) and lack of a fair sharing of costs and benefits in the value chain.[16]

Barriers on the **user** side are often generic and relate to many situations in which new technologies are implemented. Employees often lack required skills (and motivation) at different implementation levels. **Privacy** concerns are also an important issue, extensively treated in the previous IPTS report on RFID (Maghiros et al. 2007), and recently addressed by the European Commission (European Commission 2009a, b, c). Finally, business reengineering difficulties are a further internal organisational barrier.

Extra-organizational barriers (Coordination or **value-chain barriers**) include questions regarding who pays for and who benefits from RFID and the absence of seamless value chains. To date, in most cases, suppliers have to bear the costs of RFID tags as well as the cost for their internal hard- and software infrastructure. As a consequence, suppliers pay the majority of the costs and purchasers often benefit the most. Alternative cost-sharing models could solve this issue but are currently not in use, according to the interviewed experts. The large amount of data produced also leads to problems in data sharing between supply chain partners and in data integration.[17]

Technological barriers lie partly in reliability of tag/reader systems, due to RF interference with metal and liquid and/or to reading difficulties (rates and range). Integration with inherited IT solutions and the lack of technological readiness on the part of implementing organisations might also represent an issue. Additionally, there are **security** problems in this domain, which will be further discussed in the case studies.

Lack of a **global standard,** which makes interoperability difficult, proved to be another barrier for private firms when they started to look at RFID a few years ago. As discussed in Section 1.7, RFID standards are available and the resolution of standardization issues is progressing, but some parts are still not fully standardized. Furthermore, heterogeneity of existing standards due to different, sometimes competing standard organisations poses a problem. There may also be a standardization creep which drives up the cost for high-volume tags. Related to the issue of standards, spectrum congestion and limited frequency availability are mentioned as barriers, especially in Europe. Furthermore, the IPR situation could hinder band exploitation and the diffusion of technological solutions.

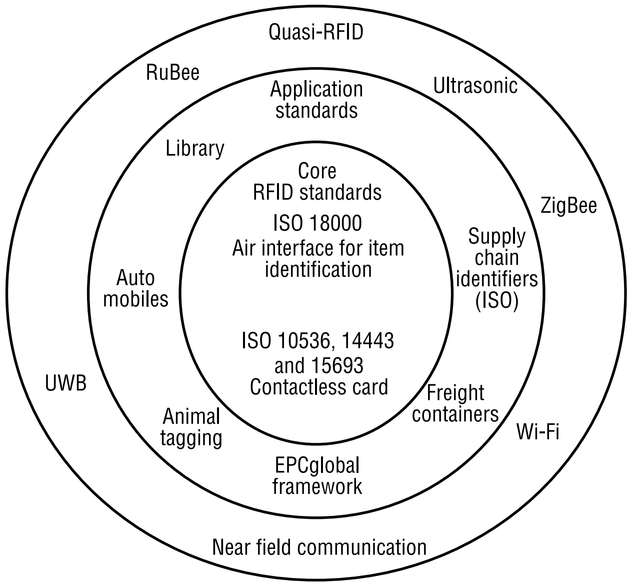
Finally, perceived negative side-effects of RFID act as barriers to adoption. For instance, consumer reluctance to embrace the technology and its services, due to unsolved or inadequately addressed data security and privacy issues, acts as a barrier, though this is not regarded as a major issue by all the industry participants.[18] Other potential barriers are related to effects on health and the environment (recycling issues).

1.7 Standardization and IPR issues

RFID partly rely on standards, which ensures that components from different manufacturers are interoperable. The main organisations driving standardisation in the RFID field are the International Organization for Standardization (ISO) and the industry consortium EPCglobal. The two cooperate, so that ISO standards (mostly of a general type dealing with air interface) are fully

16 Pavlik and Hedtke (2008).
17 Juniper (2005).
18 Pavlik and Hedtke (2008).

Figure 1-10: RFID standards, from the core to the boundaries of the concept



Source: OECD (2008b).

endorsed by (Electronic Product Codetm) EPCglobal which, in turn, is part of the GS1 (Global Standards) Consortium. However, it is worth stressing that ISO is an official international standard setting body, while EPCglobal is an industry-based association which, at the beginning of 2008, had more than 1,400 member companies in both producing and using industries, most of them (54%) from the US or Canada, one quarter from the EU, and less than 20% from the Asia-Pacific region.[19] EPC standards are freely and publicly available. The participation in the GS1 standard process requires membership that is subject to membership fees. GS1 membership provides access to the required numbering capacity enabling companies to identify uniquely their products, locations, assets and other entities.

There are a multitude of standards in the RFID field (Figure 1-10), including air interface standards, application standards, standards for test methods, data management standards, data structure standards and sensor standards.[20] Air interface standard issues are perhaps the most important (core) for RFID. Indeed, these define parameters for the tag/reader interface or radio link (air interface), i.e. operation frequency, coupling types, modulation, methods, data coding, etc. The two most important standard families here are the ISO/IEC 18000 series and the EPCglobal series (from GS1, EPCglobal).[21] These standards are developed in collaboration. The only GS1 EPC global air interface standard published so far is known as Gen 2. This standard is compliant with ISO/IEC 18000-6 type C. A collaboration has been established between the relevant GS1 EPCglobal and ISO working groups (ISO/IEC JTC 1/ SC31/WG4).

It is beyond the scope of this report to dwell further on these standards, although most analysts agree that there is a need to further internationally-accepted standards in the field of RFID.

Another issue which may become problematic is that of IPRs covering essential features in the

19 Data provided by EPCglobal, reported in BRIDGE (2008,a). In the EPCglobal governing board, 8 out of the 19 members are from the US, including a representative of the US Ministry of Defence, 6 from the EU (all from Germany), 4 from Asia (2 Japanese, one Chinese, one Taiwanese), and 1 from Brazil (information available from EPCglobal website).

20 See Wiebking et al. (2008).
21 Wiebking et al. (2008).

standards. To this respect, patents may turn out to be a cost driver and blocking factor in the implementation of EPCglobal standards. For instance, US Intermec claims that it holds essential patents for the Gen2 specification and has set up a licensing programme. Some known producers – including Zebra, Symbol and SAMSys – have joined the programme, while others such as Alien and NXP have purposely avoided doing so.

Also, a number of producers have joined together in the US-based RFID Consortium (http://www.rfidlicensing.com) to create a patent pool for RFID systems in the UHF range.[22] The RFID Consortium roster of current members includes 3M, France Telecom, Hewlett-Packard, LG Electronics, Motorola, ThingMagic, Inc., and the Zebra Technologies Corporation. Notable non members include the Intermec Technologies Corp.[23] and some other very large enterprises which usually do not use patent pools, and instead defend their intellectual property rights themselves.[24] Preliminary operations to go on the market (including a certification by the US Department of Justice) took almost four years, during which time some members left and new ones joined, but now the RFID Consortium can offer licenses for its pool of patents for passive UHF RFID.

Another body operating in the same field is the US start-up RPX, which focuses on "defensive patent aggregation". It purchases patents on behalf of its member companies in order to protect them from the growing number of non-practicing entities (or "Patent Trolls"), that acquire patents specifically to sue businesses they allege are infringing these patents. Cisco, IBM, LG Electronics, Panasonic, Philips (possibly now NXP), Samsung and Seiko-Epson (all of which sell hardware, software or services involving RFID), and also Shortel, TiVo and Vlingo (http://www.rpxcorp.com/facts.html) have signed on as members of RPX.

22 BMWi (2007s).
23 See http://findarticles.com/p/articles/mi_zddvs/is_200508/ai_n14906258/print
24 http://www.vialicensing.com/patent/UHF_RFID_index.cfm

1.8 Summary and conclusions

This chapter investigated RFID in general. RFID is an auto-identification technology, as are barcodes and contact cards. With respect to the latter, RFID has several advantages: it allows contactless and no line-of-sight information transmission, simultaneous identification, sophistication and integration with sensors, and the possibility to modify stored data. These features allow numerous applications in e.g. logistics, retail, manufacturing and access control. RFID may also constitute a building block in the envisaged Internet of Things. RFID applications could have a strong impact on both the industries that produce them and the industries that use them and on the competitiveness of European companies.

The potential economic impact of RFID is very large. By 2008, the total market size was already about €3-3.5 billion and is projected to grow to about €15-20 billion by 2018. In particular, robust growth up to about 40% of the total market value is expected in the software and services part of the value chain. Europe holds about 20% of this market and its share is expected to grow over the coming years' More important, economic impacts resulting from the usage of RFID – though inherently more difficult to estimate – could be of a higher order of magnitude. These come in the form of cost reductions/productivity growth and, increasingly, in the form of new products and services.

There are still a number of barriers to adoption. RFID raises privacy concerns and is vulnerable to security threats. Economic barriers include the investment costs necessary to implement RFID-based applications which, combined with lack of skills and uncertainty about return on investment, hinder adoption by SMEs. The lack of suitable frequencies, standard protocols and interoperability may also pose barriers, which – as we shall see in the coming chapter – are especially relevant for the case of item-level tagging.

2 RFID Applications: Item-level Tagging and Public Transportation

This chapter considers the current and prospective development of RFID technologies in the tagging of individual items and in public transportation.

Item-level tagging is when each RFID tag identifies one single item or a box which contains several items which cannot be tagged, or items which would be senseless to tag individually. The potentialities of item-level tagging will be considered across economic sectors and production stages, with specific reference to the retail trade, which is deemed to be the most promising application field in business. The tagging of animals and people will not be considered as *item level*, nor will any of those cases in which the (information contained on the) tag is an essential part of the item itself be addressed, as it is for smart (payment/access) cards, electronic ID cards and passports, and the like, which are partly covered in the case of public transportation.

In *Public Transportation*, RFID can be used in a number of fields, from baggage tracking to passenger tickets and smart-cards, to the tracking of vehicles and of individual mechanical parts. In the following section, we focus on the main application to date, i.e. ticketing (mostly through item-tag objects, and smart cards), considering its potential interaction with other technological applications.

For each of the two case studies, the analysis will address current and potential RFID technologies in use, competing and complementary technologies,[25] market size and overall socio-economic impacts, with specific reference to the EU where possible. For the sake of readability, the two cases are treated separately.

2.1 RFID item-level tagging

2.1.1 Uses and tags types

In most cases, an RFID tag usually contains only an identification number, which is used as a pointer and indicates a corresponding record in a database. When this is so, RFID in item-level tagging is employed as a kind of barcode, although with improved characteristics. For example, unlike printed barcodes, RFID tags do not require line-of-sight during their reading. RFID enables multiple scanning (e.g. the whole truck or basket at once) allowing the automation of industrial processes like manufacturing, archiving documents, automation of postal services and faster customer service in retail.

In contrast to barcodes, tags may contain a wealth of information on product details and history or, if combined with sensors, the history of storing conditions, mechanical shocks, etc. This further enlarges the range of potential uses in production, retailing and, after purchase, by consumers themselves, for example in ICT domotic applications.

There are countless potential applications which could extend pervasively into a number of fields, with item-level tags constituting the basis for the *Internet of Things*.

Most tags used in item level are of the UHF (Ultra High frequency) or of the HF (High Frequency) type:

25 Adapting the classification proposed by Maghiros et al. (2007), we distinguish between technologies which compete with RFID as they are mostly alternative to it, and technology which mostly complement it, as they may provide additional functionalities to RFID systems (enhancing) and/or form a part of them, and, for instance, provide communication between reader and backend (enabling).

Table 2-1: Features of UHF and HF tags used in item-level tagging

Tag type	Advantages	Disadvantages
UHF	– Better multi-tag reading (about 1000 tags) – Theoretically possible use of existing pallet readers – Costs may be slightly lower than for HF tags	– Potential issues with frequency spectrum – Not compatible with NFC. There are no mobile phones which could read UHF tags
HF	– Lesser royalties issues – Compatible with NFC (Near Field Communication) , supported by many models of mobile phones	– Slightly more expensive due to more complicated geometry of antenna – Multi-tag reading limited to tens – Limited range, which is however possible to enhance

Ultra Wide Band tags (UWB), which do not have specific frequency but send short pulses of energy in different parts of spectrum (so they do not interfere with other devices) can also be used. They allow the precise location of items, but are expensive active tags, useful for niche market but not for massive deployment. The European Commission has recently taken steps towards approving appropriate legislation for the use of UWB.[26]

2.1.2 Competing and complementary technologies

The main competitor of RFID for item-level tagging is the well established optical *barcode,* the main advantage of which is that it is still much cheaper and much more common, and investments are already in place. The main disadvantages of barcodes with respect to RFID are:

- Line-of-sight is required and only one tag can be read at once. Therefore full automation is not possible.
- If a tag is bent, it is difficult to read it.
- Number represented by a barcode is too short to identify uniquely each product. However, a relevant progress was made with 2D barcodes (Figure 2-1).
- It is not possible to couple it with sensors, nor to add information on it.

A hybrid technology is represented by *Sound acoustic wave* (SAW) tags, where the identification number is represented by the structure of a tag surface (acoustic wave reflectors). Radio waves coming to a tag are changed to acoustic waves, which after reflection are changed back to radio waves. SAW tags are expected to be significantly cheaper than traditional RFID (no need for an electronic chip), and perform very well on metal surfaces.

However this simplicity comes with a price and SAW technology has important limitations. The identification number is coded during manufacture and no information on the tag can be modified. SAW tags cannot be complemented with sensors, and cannot collect information. In tag design there is no place for privacy protection methods, neither for anti-collision protocol, which makes it difficult to read many tags at once.

SAW technology should not only be seen as a competing technology, but also as a complementary one. In future systems, SAW and electronic tags may co-exist, and be scanned by the same readers. Finally, it could be noted that SAW is not a completely different technology from RFID. Although tags are based on different physical phenomena and have different capabilities, the functioning of a SAW tag is very similar to a simple chip-based tag, and SAW may be considered to be a kind of RFID.[27]

Visual tags are another concept of tagging physical objects. A visual label is a 2-dimensional

26 http://www.morerfid.com/details.php?subdetail=Report&action=details&report_id=2660&display=RFID

27 Whether we consider SAW as a kind of RFID or not, it depends on definition of RFID. For example, according to Garfinkel & Rosenberg (2005), the term RFID is "generally used to describe any technology that uses radio signals to identify specific objects", so SAW technology falls into this category.

Figure 2-1: The possibilities of 2D barcodes

An air ticket electronic boarding pass

The text "*RFID - Techno-economic analysis and the EU Competitive Position: the case studies of Item-level tagging and Public Transportation*" with different types of coding

Aztec

MicroPDF417

Data - Matrix

And how it would look with a 1D barcode (note: the figure is reduced in length by 75%)

RFID – Techno-economic analysis and the EU Competitive Position: the case studies of Item-level tagging and Public Transportation

Source: codes created with tec-it barcode generator http://www.tec-it.com/online-demos/tbarcode/barcode-generator.aspx?LANG=en.

binary pattern, which contains a unique identification number, related to a website showing the description of the object to which it is attached. One example is *thinglink* – a free open standard; any user may create a number of unique labels, which will never be re-used. Any individual who wants to tag an object can receive (free of charge) a unique pattern which he/she can print and stick to the object or directly write (scratch/burn) on it. Then anyone who wants information on the object may take a photo of the label (with any camera, e.g. built into a mobile phone) and retrieve a link to the corresponding website. Giving a unique code and corresponding unique website to each of such objects allows people access to a description by a producer and also to participate in an information exchange on blogs, personal websites, etc. Visual tagging is cheap, does not require large investment costs, is easy to use and could therefore be a better option than RFID for SMEs. On the other hand, it is unlikely that it will replace RFID in retail, as it has all the main disadvantages of a barcode, except that of a short identification number. However, it could be used as a complementary technology, which would allow everyone to create tags pointing at websites easily and for free.

It is rather unlikely that any of today's competing technologies will seriously threaten the development of RFID, as none of them can offer similar capabilities. However, alternatives to RFID like visual tags could become popular in some areas, mostly because of lower cost, simplicity and/or privacy concerns related to RFID. On the other hand, most analysts agree that RFID is likely to

Table 2-2: Comparison RFID and competing technologies

	Barcode	Visual tags	RFID (& SAW)
Cost	Low.	Low. Can be produces with any printer. Existing mobile phones equipped with digital camera are sufficient as readers (only software is needed).	High. For massive item-level tagging the main barrier is cost of a single tag (lower for SAW). Price of readers and backend is also relatively high.
Convenience and speed	Average.	Similar like in barcode or lower.	Very high.
Security and privacy issues	Practically there are no concerns.	Practically there are no concerns.	A number of concerns.

replace barcodes in the future, although a rather long period of "double tagging" is also envisaged. From an industrial perspective, it is interesting to note that the US *Symbol Technologies* (which now belongs to Motorola), once world leader of barcode scanners, successfully moved as a key player into the business of RFID systems, while *Verisign,* also US-based and responsible for operating the registers of .com and .net top internet domains, has recently been chosen to attribute unique numbering for EpcGlobal standard complying tags.

Investment in a new RFID system often requires a lot of complementary investments. Complementary technologies include those which provide communication between an RFID reader and backend, and which support the backend. The main enabling technologies are network technologies to which RFID can be added.[28]

Complementary technologies which could enhance the use of RFID include: powerless extensions of memory and security; battery-based added functionality (e.g. sensors), boosted communication range, and combined RFID readers/tag. Enhancing technologies also include the information systems which process the events, in particular what is provided through RFID middleware.[29]

2.1.3 Market size and potential applications by sector

Item tagging is by far the most promising field of application of RFID technology: according to Gartner,[30] item-level tagging will represent about 40-45% of total RFID revenues in the coming years. According to IdTechEx, item-level business will rise from about 250 million USD in 2008 to 8.3 billion USD in 2018 (i.e. from 5 to 30% of the total RFID market), with the value of tag production alone passing from about 100 million to more than 4 billion USD. Correspondingly, the production of item-level tags is expected to grow from about 0.4 to more than 600 billion units yearly, i.e. from 20 to about 90% of the total number of tags.

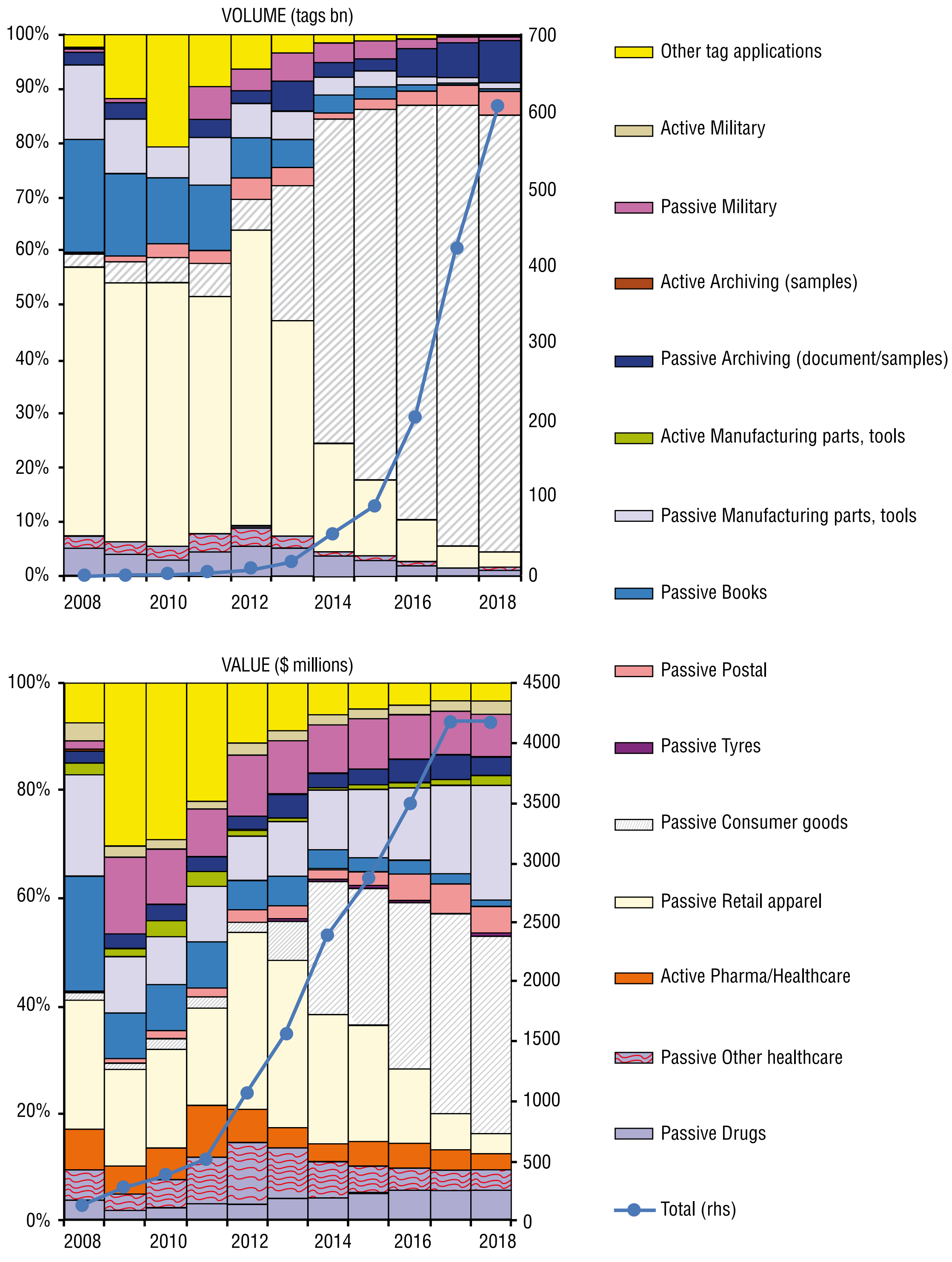
The volume of tags is expected to take off in about five years from now, and then grow at a brisk pace up to 2018. Market value, instead, is expected to accelerate earlier and then stabilise, due to emerging, cheaper technologies such as printed tags.

28 These can be differentiated in Local Area Networks (LAN), Wide Area Networks (WAN) and Personal Area Networks (PAN). LAN encapsulates technologies and standards such as Ethernet, WiFi, Ultra Wideband, and Zigbee. Examples of Wide Area Networks include GPRS, UMTS and WiMAX systems, while an example of a Personal Area Network is the well-known Bluetooth protocol, which can achieve data rates of 1 Mbps at short distances (<1 m), as is mainly meant to connect devices wirelessly to each other.
Mobile phones may play a role of competing technology when SMS is a means of payment; however, this does not apply to item-level tagging.

29 Maghiros et al. (2007).

30 IPTS telephone interview with Gartner analyst.

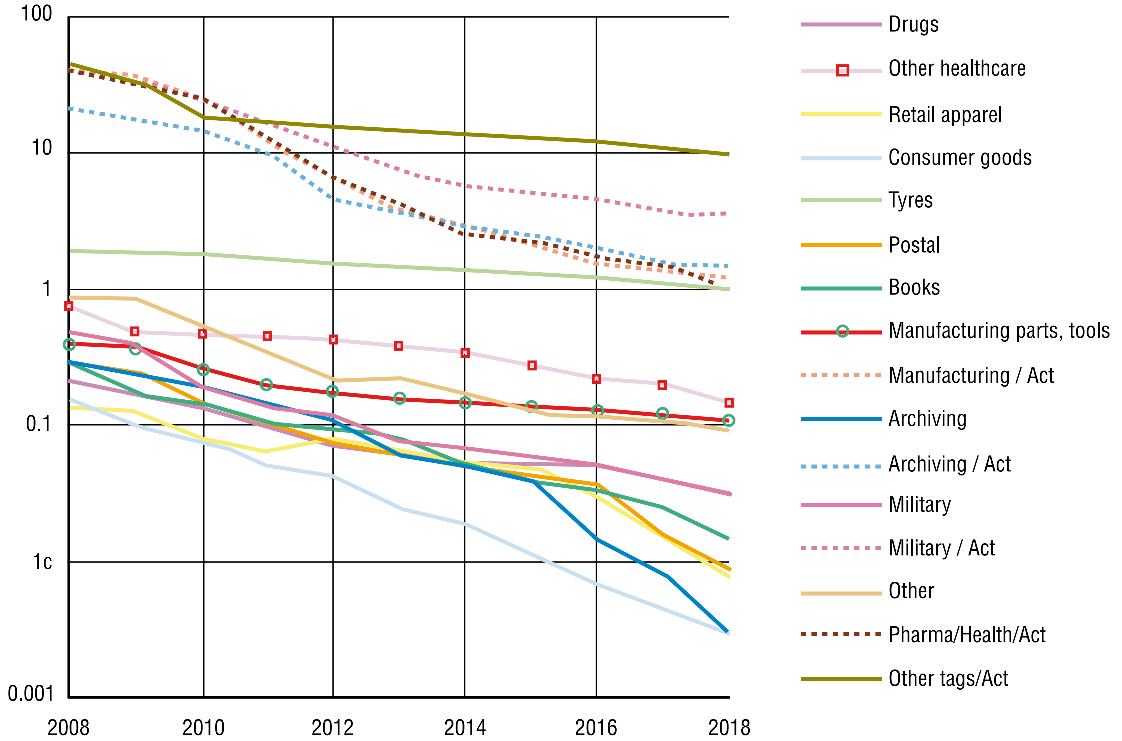
Figure 2-2: Item-level tagging volume and value, by application and type of tags



Source: authors' computation on IdTechEx (2008b).

From an industry perspective, the situation in ten years time would be very different from that in 2008. In volume terms, the main engine of growth is represented by consumer goods, which are expected to become largely dominant in tagging flows. The landscape is more varied when it comes to market value, with consumer goods taking the lead, but closely followed by the health sector and manufacturing-related applications and, at a distance, by more expensive military-related demand. These dynamics are reported in Figure 2-2. The first picture, portraying volumes

Figure 2-3: Item-level tag average unit prices, by type of application (USD)



Source: computed from IdTechEx (2008b).

in percentage shares by sector and tag type (passive, active), and overall volumes in billions of tags yearly (right hand scale), shows that the acceleration in adoption is mostly due to the tagging of consumer goods, while the importance of apparel, books and manufacturing parts fades away. The second picture does the same for values (percentage shares and millions of US dollars).

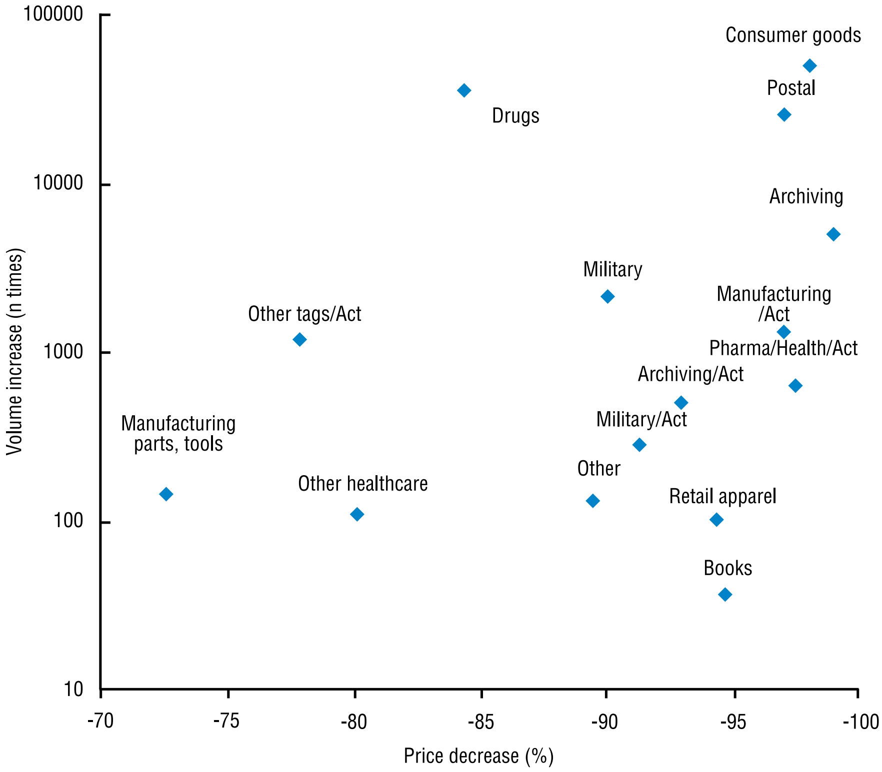
Indeed, where the intrinsic value of the item justifies it and/or when the tag is to be reused, sophisticated and expensive tags may be required and afforded. In other cases, however, high volumes of low-edge tags are required, such as most consumer products in retail. Hence, the figures above reflect differential hypotheses on the elasticity to price of tag demand and on price evolution, by (representative) type of application. The latter is portrayed in Figure 2-3, which predicts the broad and persistent, or even increasing variety of average unit prices – from less than 0.15 USD to 45 USD at present – within a framework characterised by a generalised rapid price reduction.

These dynamics incorporate assumptions on the push on prices exerted in one direction by volumes and technological development, and in the other by the growing sophistication of tags. Hence, the price of the simplest tags (most easily printable) with potentially high volumes, as is the case with tags for consumer goods or archiving, would shrink by 98-99%, while prices of increasingly complex active tags and/or those for specific applications with little numbers are expected to decrease "only" by 70 or 80% (Figure 2-3).

Some of these assumptions are less robust than others. In particular, it is not certain that technology will give us tags for 0.3 cents of a dollar each in ten years time. This implies that the mass extension of RFID to consumer goods is also uncertain to an extent.

The elasticity of demand to price reduction is also supposed to differ widely across applications, taking into account differences in potential volumes and prices altogether (Figure 2-4).

Figure 2-4: *Item-level tag unit price and volume dynamics by application, 2008-2018*



Source: authors' calculations based on IdTechEx (2008b).

In broad terms, the assumption is that price decreases would open rich new markets for other applications, determining a relatively (log) linear overall relationship between unit prices and volumes. At present, however, the market is grouped into two price induced clusters of up- and low-end applications. These dynamics can be seen by comparing the situation of 2008 and 2018, as in Figure 2-5, which portrays unit prices and diffusion by application, together with bubbles of varying sizes which represent individual applications' market values.

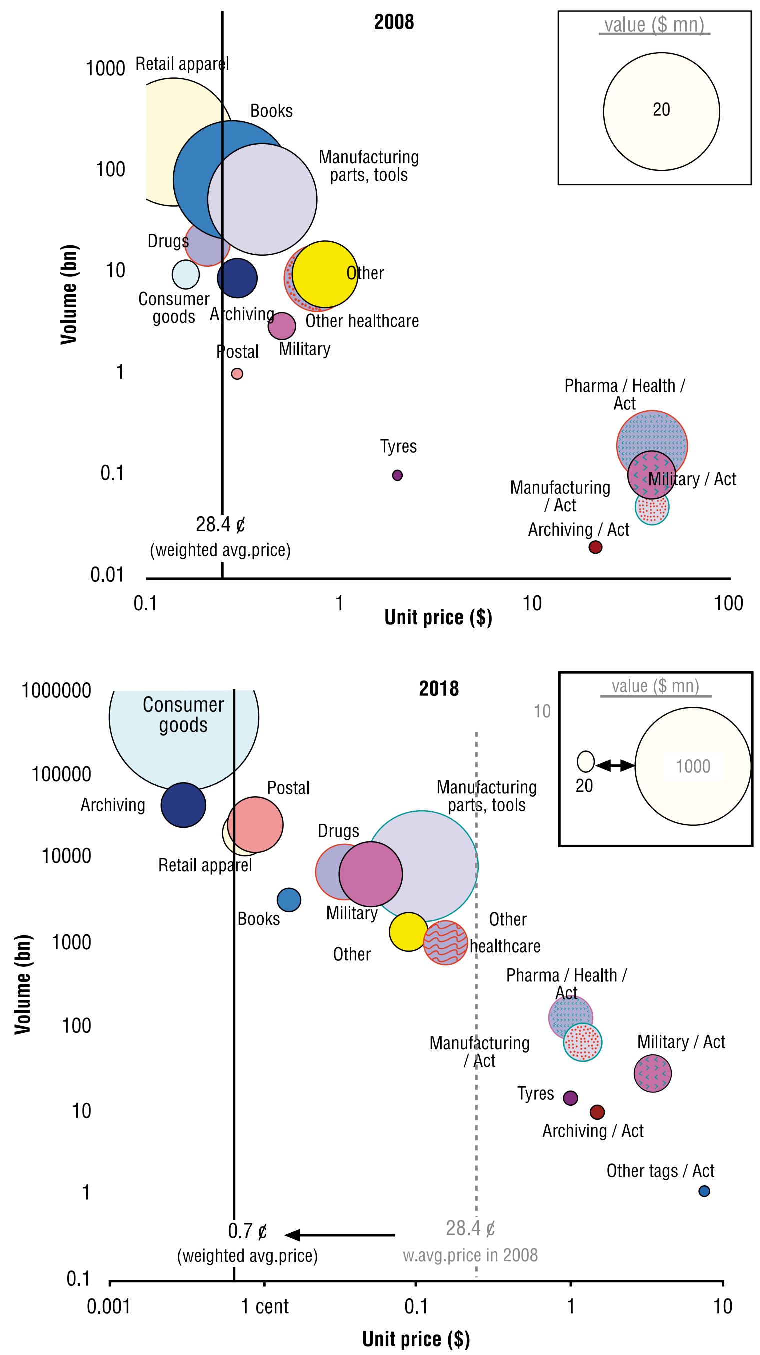
The main application areas for item-level tagging and their potential benefits are expected to be in:

- *Retail*. Tagging consumer goods is the main application of item-level tagging and large retailers, such as Wal-Mart. METRO, TESCO and Marks & Spencer, are early adopters. The deployment of RFID is deemed to bring about substantial improvements in logistics, increasing efficiency and opportunities for stock management, inventory and packaging, to increase availability of products on shelves, reduce time that customers need to spend in queues and let them easily access additional information on items. RFID will also enable additional services even after the product has been sold, like, for example, automatically setting the right washing machine programme, or oven cooking times.

- *Pharmaceutics and medical equipment*. Tagging medicines started 8 years ago, mostly with a view to error prevention.[31] Nowadays, the biggest push comes from producers' associations, which use tagging mainly to

31 According to statistics, 1 out of 20 patients suffers from adverse drug effects and many cases can be avoided by item-level tagging of medicines (Maghiros et al. 2007, chapter 11.2.3). Future envisaged applications in this field might reach smart dust on pills, preventing them from freeing active principles in undesirable conditions (e.g. interaction with other medicines), or revealing patient's ongoing treatments to physicians in hospital emergencies.

Figure 2-5: Item-level market in 2008 and 2018: unit prices, volumes and values (bubble size)



Source: authors' calculations based on IdTechEx (2008b). All applications average price is weighted by market value.

reduce the huge market for counterfeited products. Tagging surgical tools prevents surgeons from leaving them in patients' bodies. Expensive medical equipment can also be immediately located if it is tagged.

- *Postal services*. Tagging packages and letters facilitates the automation of sorting and therefore makes the process more efficient. Although some years ago, item-level tagging of packages apparently was still not profitable (e.g. in DHL's pilot programme in 2004), decreasing the price of tags should make it affordable in the near future.

- *Archiving*. Tagging documents helps not only with their immediate identification but it may also speed-up the process of document searching. Hand-held readers or even readers built into shelves in office (smart shelves) can help locate the desired documents instantly.

- *Manufacturing*. Tagging parts facilitates the automation of the manufacturing process. Assembling machines can automatically recognize and locate the item they need. However, since the precision of location is limited, RFID will complement other sensing technologies, like machine vision.

- *Libraries*. Tagging books and journals speeds-up loans and returns. It is enough to put the book and reader's card close to the reader to make an assignment. It eliminates errors and facilitates fast searches for books, even if they have been put in the wrong place, just as it does in the case of tagged documents. At the same time, tags attached to books can serve as protection against theft.

In all these fields, it has been claimed that item-level RFID tagging allows for the automation of several business processes and eventually leads to:

- Improvements in efficiency,
- Decrease in operational costs (in long-term perspective),
- Reduction of time needed for some operations,
- Reduction of errors,
- Reduction of losses and theft,
- Increasing in shops' information and customers' convenience,
- Enabling of new services or functionalities.

In Box 2-1, we given an example of the drivers of item-level tagging and the possibilities it brings in the case of retail, where it can be used in a number of applications. Retail is also acknowledged as the most promising in terms of market values. Although the details and importance of criteria considered by the decision makers are different for different applications and implementations, general factors which favour the deployment of RFID are similar across sectors and applications.

2.1.4 Broader socio-economic impacts

For the above reasons, item tagging is acknowledged as potentially the economically most important and most pervasive application field for RFID technology. Even if the forecasts presented prove overoptimistic, item-level tagging could be adopted in a variety of applications throughout the economy, and has remarkable potential for both the daily business of a number of industries and for consumer habits.

As outlined in Chapter 1, item-level RFID tagging increases labour productivity, by optimising production flows, and reducing operational costs, errors and losses (including theft and human life), and enhances the quality and variety of services offered.

In a broad economic perspective, available estimates show that the item-level tagging market for the RFID industry is only a fraction of its envisaged economic impact. Gross gains from RFID adoption for the German economy alone were estimated at about €62 billion by 2010, of which more than half would be in item-level prone industries (BMWi 2007a; see above, Table 2-2). With respect to the potentially richest applications of retail trade, the most detailed study available for the USA (Barua et al, 2006) quantifies the benefit to sellers from pallet and item-level tagging at nearly 68 billion USD from 2007 to 2011, and suggests that the return on past investment for retail and healthcare applications would be 900%.

The highest benefits would derive from reductions in *i)* labour costs (46 billion USD, mostly from check-in and order filling, and

Box 2-1: Applications and benefits of item-level tagging: the example of retail

Typically, the operations of a retail store (such as a supermarket), include staff identifying missing items on shelves, listing them and then bringing them from storage if they are available. This process has aspects which could be improved, or even automated. The main existing technology – barcodes – can only facilitate this to a certain extent. It may also be a reason for low levels of customer satisfaction. Often, it cannot detect in time when items are out-of-stock. If an item is not found on the shelf, customers abandon their purchase, so the store loses sales and customer loyalty.

Item-level tagging allows for a real-time real-level low cost inventory, and dramatically decreases the occurrence of the above incidences. Information on inventory status updated in real-time facilitates real-time automatic replenishment: purchase orders can be automatically generated when the numbers of a certain product drop below a certain level. Introduction of item-level tagging gives an opportunity to deploy so-called smart shelves, i.e. shelves with built-in RFID readers to track the presence of products, which can automatically send messages when replenishment is needed. Smart shelves can also provide alerts when products expire.

RFID technology can also provide comprehensive information about products. At the moment, this information is often incomplete. By presenting the tagged item to the reader, a customer could check information on an item on the kiosk's screen.

Low customer satisfaction can be caused by customers having to spend too long in the check-out queue, especially in peak hours. Item-level RFID can also make it possible for customers to pass the products in their carts through a reader on the self-checkout counter, which automatically identifies products and delivers the bill. This offers retailers important opportunities for cost reduction.

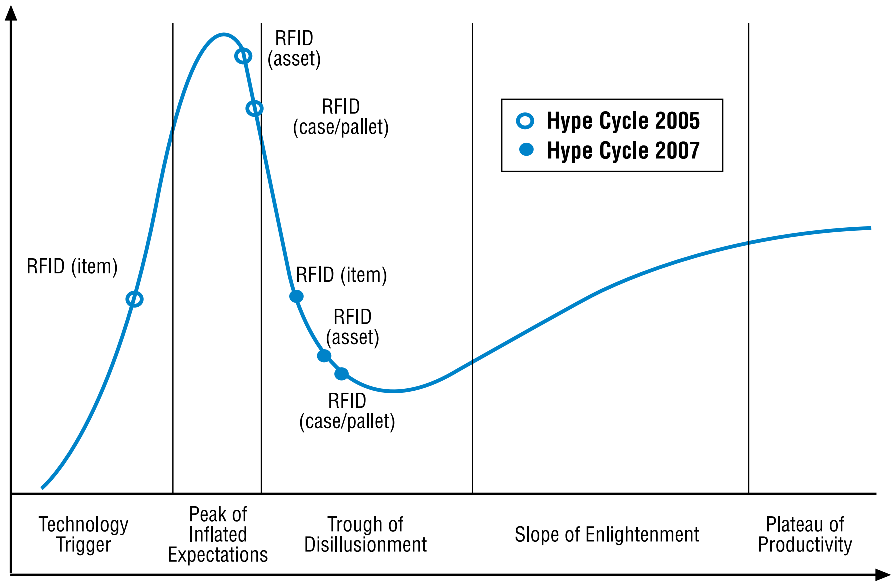
The deployment of RFID at item level will thus be beneficial for more efficient and informative shopping, increasing competitiveness for the retailers that introduce it. It will also significantly reduce labour costs. It should be noted, as we pointed out in the introduction, that not all enterprises will benefit equally from RFID technology. Big retailers will benefit most, while small enterprises may find competition on the market more difficult.

In the perspective of the Internet of Things, tags might also be useful to customers after the product is bought. For instance, clothes tagged with RFID could automatically set appropriate programmes in washing machine, refrigerators could be "aware" of their content and report what kind of food should be bought (or even make an order by Internet), and microwaves could prepare food according to instructions.

especially from pallet level tagging), *ii)* shrinkage losses (about 12 billion USD including thefts, frauds and errors, from item and pallet tagging), *iii)* inventory write-offs (about 2 billion USD due to spoilage and obsolescence, from item-level tagging) and *iv)* non-working inventory (7.3 billion USD, primarily from pallet tagging). Additional benefits for firms adopting RFID would stem from increased product availability, faster time to market and ubiquitous access to customers. Benefits were computed assuming that pallet tagging would reach an adoption rate of 45% and item-level tagging would increase its incidence by up to 20% of total sales, thus rising 5 and 10-fold respectively, from 9 and 2%.

Evidence of failures, together with typically excessive expectations for emerging technologies and still relatively limited affordability might explain the slow progress measured by the Hype cycle of RFID in retail published by Gartner. This suggests RFID at the item level is still in a pre-take off phase, which will be followed by a *trough of disillusionment* (Figure 2-6).

Figure 2-6: Retail trade hype cycle



Source: Schmitt and Michaelles (2008), on the basis of Gartner's hype cycles for 2007 and 2005.

Note that in the most recent issue (June 2008) item, asset and case/pallet tagging are still going down the slope.

Notwithstanding the above, item-level RFID is expected to bring rich dividends to actors who manage to successfully deploy it. It is worth noting that might in turn result in a source of economic divide, where weaker actors such as competing and subcontracting SMEs have little to gain.

2.1.5 Barriers to adoption

Despite the opportunities offered by item-level tagging, a number of elements could hinder or delay its adoption, and open up new issues, such as privacy and security concerns, organisational problems and cost barriers for SMEs.

2.1.5.1 Privacy concerns

In general, RFID is not yet a widely accepted technology, as it raises privacy and security concerns. A few years ago, these concerns led to protest campaigns against early adopters in the clothing and retail trade.[32] Although such events did not continue, the concerns were confirmed during the European RFID public consultation (http://www.rfidconsultation.eu) of 2008.

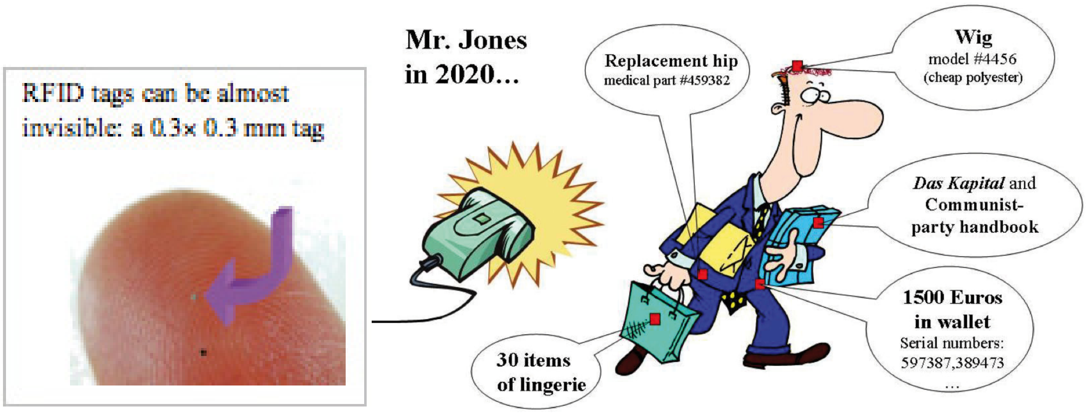
Therefore, privacy and security issues will influence adoption of RFID technology and also imply the need for development of secure RFID, which in turn could make the design, production and deployment of RFID more complex, and more expensive.

Passive RFID tags, like those attached to items, can be almost invisible – the smallest tags produced in 2006 were 0.15×0.15×0.0075 mm. This means that they can remain on items, without the purchaser's knowledge (Figure 2-7).

This implies different kinds of risks. First, RFID tags attached to objects people have bought can be interrogated by someone and reveal what items a person has in a bag (including, for example, medicines) or the price of their clothes. Moreover, although the set of things which a person carries changes, it usually does not change completely. Such a set, called the RFID shadow or RFID constellation

32 Plans of Benetton to attach RFID tags to clothe items caused boycott of the company's products, organized by CASPIAN (Consumers against Supermarket Privacy Invasion and Numbering – http://www.boycottbenetton.com). Protest campaigns were organized against some retailers, for example WalMart (http://www.spychips.com/press-releases/wal-mart-texas.html).

Figure 2-7: *Privacy concerns around RFID and vision of society under surveillance*



Sources: left: www.techdo.com/your-worst-nightmare-rfid-power; right: Juels (2006).

of a person,[33] if regularly updated, may serve to effectively track that person. This has raised concerns among privacy organizations and individuals, like those presented in Albrecht & McIntyre (2005).

Some consumers are afraid of *function creep*, i.e. using a large amount of data legally obtained by an RFID system for different purposes than originally intended by the system.

The basic security measure against unauthorized reading of RFID tags attached to items is the deactivation of tags at supermarket check-outs. A "Kill" command, (EPCGlobal 2004), permanently and irreversibly disables the tag.[34]

33 Garfinkel et al. (2005).

34 Deactivation of tags is now envisaged by the Recommendation of the European Commission (2009a) as the general rule to follow to ensure consumer protection. However, deactivation of the tag disables also post-selling services described above. "Killed" tag cannot be used in case of item return to the shop or product recall, which is essential for some type of products. For example, tracking capability for recall in case of safety defects is one of the main drivers for the introduction of RFID in tyres (Garfinkel et al. 2005). Permanently disabling of tags after item purchase will also squander a chance for using RFID for automatic segregation of waste and recycling.
Therefore researchers proposed several methods which may allow keeping all tags active but at the same time give to the user full control over them. RFID guardian, proposed in (Rieback et al. 2005) is a portable device (possibly embedded in mobile phones) which would allow only users to read tag information. There is however no commercial product until now which would integrate this kind of method.

An important economic implication of privacy and security issues is the need to follow technical and legal measures which make RFID (single tags as well as whole systems) more complex, and therefore more expensive. At the level of tags, some measures are already mandatory under EPC Global standards, like the kill command. However, there is a limit to the need for security of tags: those used for item-level tagging are mostly passive and are not supposed to perform complex functions.

The demand for privacy can be seen as a market opportunity. Apart from the demand for security built into RFID systems, we can foresee demand for personal devices which help the user keep control over the tags he owns.

2.1.5.2 Security concerns

There are a number of security threats related to RFID systems (Juels 2006; Rotter 2008), but only a few are relevant for item-level tagging. The demand for security in item-level systems is not very high and the risk is mostly related to material losses on the side of the retailer.

An attacker able to *change the memory content* of an RFID tag may modify the information about the product. This action may falsify the price of the product and therefore lead to small fraud or, if maliciously applied on a large scale, for example to all products in a supermarket, cause considerable loss. Writable tags can be carriers of malware, as demonstrated in (Rieback et al. 2006).

Physical destruction of the tag or tearing it off the object is the simplest and the cheapest way to disrupt RFID systems. It may be exploited by thieves when an RFID system is used for the protection of items against theft.

Blocking and jamming are threats to the air interface and may paralyse RFID systems communication. Blocking is performed by a blocker tag, which simulates the existence of an enormous number of tags and causes a denial of service (non-ending interrogation of non-existing tags by the reader). It is worth noting that blocking may also be a useful mechanism and serve, as originally proposed, for the protection of consumer privacy (Juels et al. 2003). Another threat to the air interface is jamming, which is paralysing the communication of an RFID system by generating a radio noise at the same frequency as that used by the system.

Attacks on the back-end of an RFID system are similar to attacks on non-RFID information systems. Exhaustive information about risks and countermeasures in information systems can be found in (Hansche et al. 2004) for example, and we will not discuss this topic here.

There are many *security measures* against the threats presented above. In some writable tags, memory content can be protected by temporarily or permanently disabling writing capability ('lock' and 'permalock' functions in standard EPCglobal). Malware on RFID tags cannot affect the system if the implementation excludes the possibility of any interpretation of the tag's data as a command. Intentional or accidental destruction or tearing off the tag can be avoided by adequately placing and fixing it on the object. Blocker tags and jamming devices are easy to detect and localize immediately after starting operation and appropriate warning functionalities can be built into a system.

2.1.5.3 High initial costs (barrier especially for SMEs)

Practically every RFID project has been initiated by a big company, either by running the project entirely on its own or by forcing other companies, including small ones, to adopt the technology. The deployment of RFID systems is still very expensive. The main costs are associated with equipment, systems integration and implementation, business process reorganization. There are also hidden costs, related to societal and organisational factors.

The result is that smaller firms, when forced, adopt the so-called "slap-n-ship" or "compliance" solutions: they implement simply what is needed to comply with the requirements issued by vital customers e.g. WalMart and METRO. For this purpose, manufacturers are providing all-in-a-box packages, which include the reader, antenna, printer and software needed to properly tag goods just when they are next to be shipped. Analysts agree that these kinds of RFID application are not profitable for the sub-suppliers, although they are less costly than full RFID integration.[35]

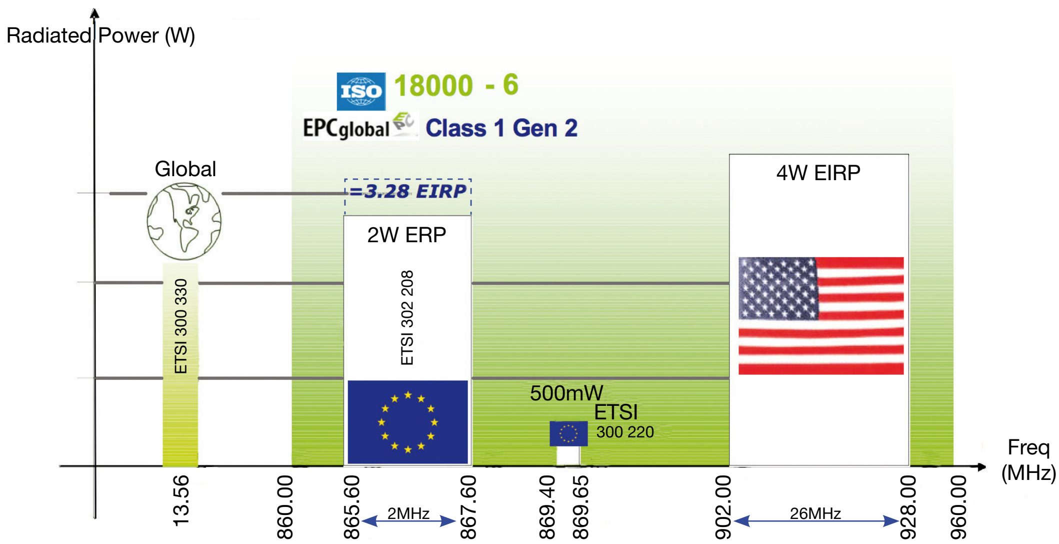
On the other hand, it is claimed that, in the future, widespread use of RFID in the supply chain and a more pervasive knowledge and culture about when and where it could be successfully applied, will eventually drive SMEs to integrate RFID technologies into their processes.

2.1.5.4 Frequency availability

Frequency availability may become a hindrance. HF tags operate on a globally free frequency (13.56 MHz). However, UHF tags, which are even more popular in item-level tagging, use a very busy frequency (between 860 and 960 MHz), which is often reserved for military or telecommunication applications. European Member States reserved a band

35 Intermediary or, rather, modular solutions are now being proposed by some sellers, that promise some immediate benefits in terms of control over production and sales flows as well as the possibility of growing up gradually from RFID compliance to full warehouse management.

Figure 2-8: RFID frequency bands in EU and US (scales are only indicative)



Source: adapted from Maghiros et al. (2007).

Note: scales are only indicative.

865.6-867.6 MHz for RFID. This 2 MHz-wide band in Europe could be compared with the 26 MHz made available in the US (Figure 2-8:). It is not clear if these frequencies will suffice for future needs when item-level tagging becomes pervasive. However, an agreement between EU Member States on a wider band seems very difficult to achieve at the moment.

2.2 RFID for public transportation

2.2.1 Applications and technologies

RFID is already established for use in the public transport system, in the form of commercialized systems or as trials. Projects in this domain can be very large in terms of investment, organizational issues, visibility and number of users.

In this report we will focus on ticketing – i.e. passenger authentication, access and sometimes the payment of journeys – as the main application of RFID in public transport. In public transport systems, RFID can also allow for the real time location of vehicles while operating and in depots.[36] We will not consider these applications here, already in the roll-out phase, because they pertain conceptually to the realm of network and asset management, are not specific to (public) transportation, and demand dedicated RFID systems, which have distinctive techno-economic features. On similar grounds we will disregard other RFID applications – such as luggage tracking in air transport,[37] or automation devices in cars, or the tagging of parts in the aircraft industry for purposes of identification, authentication and monitoring.[38]

36 Network flow control systems can be based on either vehicle tagging and readers disposed in key locations or, especially in the case of automated train lines, the opposite (more costly) way, with readers on vehicles and tags on the itinerary. Asset management is particularly useful for locating transport carriages in depots, and checking entries and exits.

37 This does not respond to the criteria of universality either, nor does it involve the same issues of traceability which characterise public transport systems such as railways, buses, and subways.

38 In the field of private transport, ISO had already started to address the issues of standard related to wide area communications 2003. This led to the creation of an industry association – The CALM Forum – to develop a new family of ITS standards with the overall branding of "Continuous Air-interface, Long and Medium range" (CALM) for the development of multi-platform applications (see ITU, 2007). Also, a European-based consortium of car makers (including BMW, Audi, Daimler, Renault, Fiat,

Smart labels and smart cards with an RFID chip (in the future, these will be complemented by chip-less tags) are used to give people access to buses, trams, subways, trains and taxis. RFID enables the realisation of a more efficient and effective public transport system. It does so by reducing boarding time and, in some cases, by providing additional information to travellers (time of arrival, time of departure, delays in time schedules, etc.), by offering management information about the traffic patterns in public transport, by fighting fraud, and by extending the range of services that can be offered by public transport operators, if necessary in combination with other service providers.

The technology which is most frequently used for public transport is Near Field HF, working at 13.56 MHz, based on standard ISO 14443. The maximum range of the tags is around 10 cm. This standard is used, for example, in MiFare tags, to be found in London Oyster cards, Dutch public transport OV-Chipcard and Boston's Charlie Card, where RFID tags are embedded in plastic cards (credit card-sized). Tags can also be also embedded in paper tickets, as in C.ticket technology, which was developed by the French company ASK. The antenna is then printed on paper with a conductive ink. A paper ticket is obviously much cheaper than a smart card ticket (printing the antenna is also inexpensive). Though paper tickets were originally intended for single journeys, the functionality of RFID is the same as in the case of smart cards, so they could support security and re-charge of credit. Furthermore, a pilot programme in Porto demonstrated that the lifetime of paper-based e-tickets is much longer than foreseen. This means that these are suited for multi-travel ticketing and could be recycled, lowering unit costs.

2.2.2 Competing and complementary technologies

The main technology which competes with RFID in public transport is still traditional ticketing. In spite of RFID's important advantages, the large initial investment required for its deployment is the main reason why many public transport systems have not yet changed to RFID.

The most popular competing technology for a single use is the paper ticket. Often these include magnetic strips, as do cards used for multiple uses and for accessing subway trains with gate controls.

Another potentially competing technology is the contact smart card. However, although these offer higher security and privacy protection than RFID, they are less convenient and slower to read (Table 2-3). Therefore, the choice of technology for public transport is, to a large extent, a matter of choice between existing simple and cheap solutions like tickets based on a magnetic strip (or without any carrier of information) and the higher investment required by RFID systems.

Apart from the above, token-free solutions like code-based tickets are becoming popular. For example, the user can buy a ticket with an *SMS* (price of SMS includes a fee) and receives a code, which is proof of payment.

In conclusion, although most public transportation is still based on traditional paper tickets, the techno-economic comparison above makes a strong case for RFID grabbing a large share of this market.

The investment in a new RFID system for public transportation requires a lot of

Honda, Opel, Volvo and Volkswagen) was created with the following mission and objectives:
- to create and establish an open European industry standard for CAR 2 CAR communication systems based on wireless LAN components and to guarantee European-wide inter-vehicle operability.
- to enable the development of active safety applications by specifying, prototyping and demonstrating the CAR 2 CAR system.
- to promote the allocation of a royalty free European-wide exclusive frequency band for CAR 2 CAR applications.
- to push the harmonisation of CAR 2 CAR communication standards worldwide.
- to develop realistic deployment strategies and business models to speed-up the market penetration.

(www.car-to-car.org)

Table 2-3: Comparison of token technologies for public transport

	Magnetic strip	Contact smart card	RFID (incl. SAW)[39]
Cost	Low	High initial system development costs	
Convenience and speed	Medium	Low	Very high
Security and privacy issues	Less relevant	Slightly lower risks than for RFID	Several security and privacy issues
Additional functionality	Low	High	High

complementary investments. Complementary technologies include those which provide communication between RFID reader and backend and which support the backend. The main enabling technologies are network technologies to which RFID can be added, in the families of Local Area Networks (LAN), Wide Area Networks (WAN) or Personal Area Networks (PAN).[40]

Mobile phones may become a competing technology, when SMS is a means of payment and a carrier of a code which authorizes travel. Mobiles equipped with Near Field Communication (NFC) could communicate with readers of an RFID system, thus enhancing it and making it even more convenient for the users. A mobile phone could be used instead of RFID card, so the user does not need to have any separate token (Figure 2-9).[41]

The development of NFC, however, depends on the outcome of the struggle between mobile phone manufacturers and mobile network operators to appropriate value from having NFC RFID readers in phones.

Other complementary technologies worth mentioning, which could enable or enhance the use of RFID, include:[43] powerless extensions of memory and security; battery-based added functionality (e.g. sensors) boosted communication range, combined RFID readers/tag. Enhancing technologies also include the information systems which process

Figure 2-9: Trial passing metro gate with Nokia phone with build-in Oyster card

Source: http://news.zdnet.co.uk/communications/0,1000000085,39291127,00.htm[42]

39 See footnote 28.
40 See footnote 28.

41 Mobile phones with NFC can be also used for transport services not directly related to ticketing. Journey planning can be facilitated by interactive maps, with RFID tags embedded. Then the user can point to the journey starting place and destination with a mobile phone and an optimal route is proposed by the system and visualized on the map.
42 Used with permission from CBS Interactive Limited, Copyright 2010. All rights reserved.
43 Maghiros et al. (2007).

the events, in particular what is provided through RFID middleware.

2.2.3 Market size

Public transport ticketing is now one of the best established RFID applications: the overall market size is not known precisely, a tentative estimate for 2008 was from €100 – 250 million and more, i.e. up to 5-7% of the total RFID business at world level.

Projects in this field had already started in the mid 1990s (Paris, Seoul), and are now, in most cases, in the roll-out phase. They often entail long-term contracts between local transport authorities and companies and provide integrated solutions, encompassing tags/cards, mobile and fixed readers, software and management.

The market is expected to continue growing fast in the years to come. Like the technology, RFID usage is becoming more affordable and extends from smart cards to multiple or single journey paper tickets and to re-usable tokens.[44] Besides, smart cards can also be used for other purposes such as taxis, shopping and e-purses. An example to this respect is the T-Money card (where T stands for travel, touch, traffic and technology) used in Seoul and in other South-Korean cities. This card is available both stand alone and as a chip added to products in current use (mobile phones, USB sticks, music recorders, etc.). It allows users to pay for public transport tickets and taxi fares, acquire urban transport information, accomplish a series of other (also online) transactions, and access private and government services, including personal e-identification and the issuing of certificates (Figure 2-10).

Figure 2-10: Prospective usages of the Korean T-money card and T-card types, including some hybrids

Sources: adapted from T-money website and Wikipedia.

44 The first has been developed by French ASK, while the latter is being proposed by the Chinese CET (for an hagiographic position in favour of the latter, see Wong, 2006).

As the T- cards case shows, RFID applications in public transport may increasingly mix with other devices, applications and usages, for instance via Near Field Communication using duly equipped mobile phones. It is also worth mentioning again that RFID is also starting to be used extensively in public transport infrastructures and, notably, on subways, with readers on trains or on the line itself that control for speed and stops, greatly improving the potential for automation.

Although the market size for RFID in public transport is expected to continue growing steadily, it is also bound to become relatively less important in overall RFID business, as other applications gradually deploy their potential.

2.2.4 Impact on public transport systems and societal impacts

The positive impact of RFID technologies for suppliers and users of public transportation systems justifies their early adoption and quick diffusion with respect to other applications. RFID can make these systems more *efficient and effective*, both for transport companies and for their clients. Throughput of passengers through metro gates has increased considerably in cities where RFID-based travel cards are used. Precise data about travel patterns help to optimize the schedule and number of vehicles, increasing the system's performance. Ultimately, this may also lead to substantial cost savings for public transport companies.

Convenience of use is very important from the passenger's point of view and recent surveys indicate its increasing importance (Perakslis and Wolk 2006). Contactless cards (such as the Oyster card shown in Figure 2-11) make a big difference here: it is much easier and faster for passengers to pass a metro gate or for their tickets on a bus to be validated, if they do not even need to take their cards out of their wallets. These cards can also be built into mobile phones, further increasing convenience for passengers).

Figure 2-11: Passing metro gate with Oyster card

Source: http://news.zdnet.co.uk/communications/0,1000000085,39291127,00.htm[45]

45 Used with permission from CBS Interactive Limited, Copyright 2010. All rights reserved.

From the perspective of the local or national authority responsible for the public transport system, as each ticket or card provides precise information on transport flows, RFID ticketing allows *improvement in the design of services*, for *optimal pricing policies* (taking into account the objectives of increasing usage and income), and for *fair sharing of fares amongst different transport companies*.

Additionally, the possibility of appropriately subdividing receipts amongst service providers can be used to *break up local monopolies*, theoretically without damaging customer interests, and represents a powerful tool for *integrating public transportation offers locally*, to *expand them to other services* and to *move from local to regional* or *national network integration*.

Ongoing EU developments in this field include the *touch and travel* project launched by Deutsche Bahn in Germany, and the *OV-Chipkaart* operational in the Netherlands from 2009 (www.ov-chipkaart.nl). This last case indicates that price differentiation may also have some negative impacts on consumers, as it led to a one-off price increase, to a surcharge for anonymous cards and to the disappearance of specific forms of cheap travel, in part reinstated after political debate. RFID can also help reduce fraud substantially. Finally, RFID systems, if properly implemented, can provide high *reliability*, as they reduce the scope for human errors.

Finally, in public transport, like in many other domains, RFID may positively *impact the structure of employment* through automation of processes which were performed manually or semi-manually. The deployment of RFID systems tends to reduce the need for work on these kinds of tasks, usually resulting in the expansion of other services with existing workforce, while design, development, implementation and maintenance of RFID systems also require a number of qualified specialists.

2.2.5 Barriers to adoption

2.2.5.1 High complexity of systems and organizational difficulties

Public transport systems are *complex* and require agreement between many actors. One of the main drivers is user convenience; therefore for the system to be successful, a single travel card is preferable even if the journey is handled by several companies. In an ideal case, there should be one system for all means of transport. On the other hand, public transport is increasingly privatized, and some pilots and trials involve several organisations. For example, in Paris the national train company SNCF and the subway company RATP had to align 93 different private transport companies in the transition from the traditional Carte Orange (the public transportation pass for the Île-de-France region) to *Navigo*; in Manchester 40 bus companies in 10 districts were involved in a similar trial.[46] In such complex systems, one of the issues is agreement between the organisations involved on ownership of the data collected by the system and on their shares in the investment.

Migration from a traditional system to an RFID-based system is therefore difficult from an organizational point of view. Pilot programmes cannot usually keep to the original time schedules. The pilots represent complex technological challenges, embedded in complex organisational changes. Buying the basic technology 'off the shelf', as happened in the Dutch and the UK (London) implementations, does not alleviate the technological burden of fine-tuning the entire system to the specifics of the public transport system at hand. The entire system (including the gates, other check points, the points of sale, the participating companies' systems and the overall information system) needs to be built up from scratch, on the basis of the requirements of the public transport companies, and typically the

46 Maghiros et al. (2007).

specifications and requirements change during the construction phase.

2.2.5.2 *Large initial investment*

Another barrier is the high cost of transition from traditional to RFID-based systems. The cost of the introduction of the Oyster card in London and also the public transport ticketing system in the Netherlands was estimated at €1.5 billion each. These costs largely related to software development and infrastructure development. Clearly, investment of this magnitude slows down adoption processes, particularly in cases where the benefits are difficult to quantify.[47]

2.2.5.3 *Political decision making*

The deployment of public transport system is subject to changing political priorities. Given the long lead time of pilots (typically in the order of three to five years for fully-fledged implementation and roll-out of RFID), there is an intrinsic uncertainty in the entire introductory phase, since politically-driven changes have to be implemented during the course of the project. These changes may refer to tariff structures that change during the project, to security mechanisms, to privacy issues to be taken on board, etc.

2.2.5.4 *Systemic risks*

The high complexity of public transport systems introduces the risk of breakdown, especially in initial phases. Because of the risk of technical failures, some companies are delaying the introduction of RFID to a time when the technology is better established and the risk of unexpected problems is smaller.

Relying on automated systems – as for other critical infrastructures – also leads to *dependence on technology*, and systems failure may cause large material losses and chaos. Due to the large scale of public transport systems, the consequences may be serious. There have already been several such cases in the short history of RFID use in public transport, like the Oyster system failure in London.

2.2.5.5 *Privacy-related concerns*

RFID systems collect data about passengers' journeys, which are kept in the system for some time (e.g. 8 weeks in the case of the London system). Although these data are considered confidential, the fact they are collected causes consumers to worry about potential abuse. The Metropolitan Police regularly request information about the journeys of Oyster card users. This information is used as an investigative tool to track movements of criminals; however the rapid increase in the number of queries (only 7 requests in the whole of 2004, up to 61 in January 2006 and 243 in March 2006) has drawn attention of the media. However, it does not seem that privacy concerns in this case are as significant for user acceptance and the market as they are in the case of item-level tagging. In the Oyster system, users can choose between personalized and anonymous cards. The latter do not allow direct assignment of travel trajectories to the name of a passenger. In practise, many more people choose personalized cards, presumably because they provide more services.

Amongst threats, two recent attacks against the NXP *Mifare classic* card by benign, academic hackers, who managed to perform a (partial) algorithm reverse engineering[48] and the cloning and data capturing[49] are worth mentioning, as they bring the issues of *personal data and overall system security* to the fore. NPX tried unsuccessfully to prevent them from publishing the results and methods of the above operations, and now offers "an easy upgrading" of the Classic to the newly-released Mifare Plus card. The previous specifications apparently did not exploit

47 Although reducing fraud might balance part of expenses, is not substantial given so high initial costs. In London for example total costs of fraud are estimated at 50 Million Euro per year, merely 3% of total costs of the system and it is not clear what part of fraud can be eliminated with a RFID-based system.

48 Nohl et al. (2008).

49 de Koning Gans et al. (2008).

all possible security means of an already old technology.[50] The problems around MiFare are an interesting example for policy making, because using outdated Mifare chips might have been cheaper than "best available" technologies.[51] This event also poses an issue of *investment risk* for transport companies, as it might shorten the lifetime for electronic ticketing infrastructures, now estimated by the Calypso Network Association at about 15 years.

2.3 Summary and conclusions

Item-level tagging, i.e. when an RFID tag is used to identify a single item, is expected to become the largest market in terms of both value and tag volumes.

The main applications of item-level tagging include retail (tagging of consumer goods), pharmaceutical and medical equipment, postal services, archiving, manufacturing processes, and libraries. The global item-level business is expected to rise from about 250 million USD (€180 million) in 2008 to more than 8 billion USD (€6 billion) in 2018 (i.e. from 5 to 30% of the total RFID market), about half of which from tag production, which is expected to grow from about 0.4 to more than 600 billion units yearly (i.e. from 20 to about 90% of the total number of tags). In volume terms, the main engine of growth is represented by consumer goods. This growth is both driven by and driving to rapid cost reductions. The landscape is more varied when it comes to market value, with consumer goods taking the lead, but shortly followed by the health sector and manufacturing related applications. The main parts of the value chain likely to benefit from this market growth are tag and antennas manufacturers, software producers, system integrators and service providers. Other affected actors include those providing complementary technologies (notably, mobile phones for Near Field Communication - NFC), as well as competing technologies (notably, barcode).

In a broad economic perspective, available estimates show that the item-level tagging market for the RFID industry is only a fraction of its envisaged economic impact coming in the form of reductions in labour costs, shrinkage in losses, inventory write-offs and non-working inventory, and benefits in the form of higher product availability, faster time to market and access to customers.

RFID is already established for use in public transport systems. Initially, most projects were very large. By now, the technology is at reach of smaller scale projects. The main application of RFID in public transport is in ticketing, i.e. to give the public access to public transportation means such as buses, ferries, trams, subways and trains. In this application RFID substitutes for traditional paper and magnetic stripe tickets, but also go beyond the functionality of those.

The economic impact of RFID for public transportation includes effects on the supply industry, on public transportation companies and on their customers. RFID enables the realisation of more efficient and effective public transport systems. It does so by reducing boarding time and, in some cases, providing additional information to travellers (time of arrival, time of departure, delays in time schedules, etc.), by offering management information about the traffic patterns in public transport, by reducing fraud, and by extending the range of services that can be offered by public transport operators, if needed in combination with other service providers.

50 Nohl et al. (2008).

51 To this respect, the Action Plan for the IoT by the European Commission (2009d) observes that "in the private sphere, information security is closely linked to the questions of trust and privacy mentioned above. Past experience with the development of ICT shows that they are sometimes neglected during the design phase, and that integrating features to safeguard them at a later stage creates difficulties, is costly and can considerably reduce the quality of the systems. It is therefore crucial that IoT components are designed from their inception with privacy- and security-by-design mindset and comprehensively include user requirements." Also, "as part of its 2009 Work Programme, in support of EU policy, the European Network and Information Security Agency (ENISA) has undertaken to identify emerging risks affecting trust and confidence, in particular regarding RFID".

The world-wide RFID market for public transportation can be estimated at about €100-250 million. Main barriers to further diffusion include high complexity and initial investment costs of systems, organisational difficulties, political decision making, systemic risks as well as privacy related concerns. Still, the market is expected to continue to grow in the years to come, due to progress and cost reduction of RFID technology, combined with features superior to its main alternatives (paper tickets, magnetic strips and contact smart cards).

Although in the long run, this application is bound to become relatively less important with respect to other fast growing RFID applications, the spreading of RFID for transport ticketing is deemed strategic from a public perspective. Indeed, besides the direct economic benefits to transport providers, it is a powerful tool for integrating public transportation offers locally, expand it to other services and move from local to regional or national network integration, while also allowing the breaking up of local monopolies.

3 The EU's Industrial Position

This chapter assesses the industrial position of the European RFID supply industry in general, and for the two case studies: RFID at item level and RFID for public transportation. The analysis centres on an assessment of the overall RFID domain, and of different parts of its value chain.

This chapter has four sections:

- Section 3.1 focuses on the market presence of EU companies in the different segments of the value chain, by means of quantitative and qualitative information. This section targets mostly the *current* position of the European RFID industry.
- In Section 3.2, the technological strength of Europe is analysed mainly through patents and R&D data, thus addressing the *future* position of the European RFID industry.
- Section 3.3 focuses specifically on the EU position in item-level tagging and RFID for public transportation.
- Section 3.4 summarizes the chapter and offers some conclusions.

3.1 EU companies in RFID

3.1.1 Estimating the share of EU companies

This section aims to provide a view of the EU position in RFID in general by looking at the relative number of European companies active in the RFID field, drawing on a number of sources and secondary data. The first and obvious difficulty in pursuing such a venture is that it is very difficult to delineate anything like the RFID industry. Companies producing and marketing RFID products and services belong to a variety of industries including electronics, software, machine construction and possibly others. To our best knowledge there is no comprehensive mapping of these companies, on any relevant characteristic. Instead, there are several partial mappings (CE RFID – Wiebking et al. 2008, BAIRD RFID monthly, RFID Journal, and IDTech 2007a), from which the most pertinent observations are discussed and presented in Table 3-1: Summary of listings of RFID companies

Clearly none of these lists is fully representative or exhaustive. Neither do they,

Table 3-1: Summary of listings of RFID companies

Listing	# companies	Percentage firms			European strongholds	Other observations
		Europe	US	Asia		
CE RFID	214	41%	48%	7%	– LF and HF RFID frequencies – Logistics, identity and security applications – Germany	– Likely European and German selection bias
RFID Monthly combined with IDTechEx	229	24%	66%	7%	– Readers	– Likely Asian negative selection bias

at this stage, provide any assessment of the economic or technological importance of the companies included or their competitive position. Nevertheless, taken together they provide a rather homogeneous message: the US seems to be in a stronger position than the EU and Asia, the latter being probably underrepresented due to selection bias in some databases.

3.1.2 Value chain position

Qualitative assessments suggest that Europe has some strong actors in most parts of the RFID value chain, from chip manufacturers to label makers, to systems integrators. These actors include large ICT companies as well as many specialized SMEs. In general, the new Member States are in a weak position.

Box 3-1: Companies located Germany in the RFID value chain[52]

Germany is one of the leading countries in RFID supply and demand. This box summarizes the presence of major RFID suppliers in different parts of the RFID value chain:

Chip manufacturers: Three major makers of semiconductors that also supply chips to the RFID industry are based in Germany (NXP in Hamburg and in Gratkorn, Austria),, Infineon in Munich (and partly Graz Austria) and Texas Instruments in Hamburg). In addition there are German suppliers which do not only manufacture chips but integrate additional production stages, e.g. by producing coin tags (e.g. Sokymat). Other international chip manufacturers present in Germany, but without production or R&D, are Hitachi, Legic, Omron, ST Microelectronics, Toshiba).

Inlays and labels: A relatively large number of companies in Germany produce inlays and labels. Some of them are subsidiaries of German and international corporate groups (e.g., Checkpoint Systems, ExypnoTech, Fleischhauer Datenträger, X-ident) but most are SMEs (e.g., Franz Schäfer Etiketten, KSW Microtec, smartTEC or TagStarSystems).

Tags: Complex tags such as smart labels or smart cards are typically produced domestically, as are extremely small tags based on injection moulding or glass ampoules, while simple, standardised coin and button tags are generally produced aboard. Tag manufacturers include Siemens Automation and Drives, as well as many SMEs including AEG Identifikationssysteme, Schreiner Logidata and HERMA, and technology start-ups such as Microsensys.

Readers: Numerous companies – many of them in the industry automation field – produce readers for RFID. In addition to Siemens Automation and Drives, these again include many smaller companies: AEG Identifikationssysteme, Baumer, Deister electronics, Feig, HERMOS Informatik and Pepperl & Fuchs. Some reader manufacturers offer not only the finished readers but also the modules (boards) that they are based on.

Printers: RFID printers typically encode smart labels by first writing the code to the tag and then printing it on the label as a barcode. Only a few makers of RFID printers are based in Germany. Printronix and Zebra are subsidiaries of foreign companies. F+D Feinwerk- und Drucktechnik is a relatively small German business, however.

Production equipment: The makers of production equipment for smart labels, contactless chip cards, etc. constitute an important group of suppliers to the RFID industry. Just a few of them are based in Germany, but those are important players in the world market. They include SMEs such as Bielomatik, Melzer and Mühlbauer AG.

Middleware: Several large software companies offer middleware systems, including the German company SAP. The major American competitors – Sun Microsystems, IBM, Oracle and Microsoft – are all also represented in Germany. Other vendors include some smaller companies, such as Seeburger and Dabac, as well as Infineon's spun-off subsidiary RF-iT Solutions, headquartered in Austria.

52 Based on BMWi (2007a).

A more detailed overview of German companies in RFID is provided in Box 3-1 (based on BMWi 2007a), which suggests that Germany has a strong presence in most parts of the value chain, especially chip manufacturing, inlays and labels, advanced tags, readers and production machines. Germany's position probably reflects in part the European one, since it is both the largest economy and the strongest country in the RFID supply field.

Another qualitative assessment of the competitive situation in the European RFID industry in different parts of the value chain is provided by IDTechEx (2008a). The main observations are summarised below.

Chips

The main RFID chip manufacturers are NXP, Texas Instruments, EM Microelectronic, Sony and Impinj. These are briefly described in Table 3-2.

Table 3-2: Major RFID chip producers

tags/chip production (millions)	Company	General description	RFID activities
2500	**NXP Netherlands**	Semiconductor company founded by Philips more than 50 years ago. It has about 30,000 employees working in more than 30 countries and posted sales of 5.4 billion USD (including the Mobile & Personal business) in 2008. NXP creates semiconductors, system solutions and software that deliver better sensory experiences in TVs, set-top boxes, identification applications, mobile phones, cars and a wide range of other electronic devices.	Provides a complete range of RFID ICs including smart cards, tags, labels and readers. They address a number of applications, from low-cost smart label ICs for high-volume supply chain management applications through next generation 32-bit smart-computing platform for powerful multi-application smart cards.
1400	**EM Microelectronics Marin Switzerland**	Part of the Swatch group, EM Microelectronic is a semiconductor manufacturer specialized in the design and production of ultra low power, low voltage integrated circuits for battery-operated and field-powered applications in consumer, automotive and industrial areas.	Since 1989, EM has specialized in the development, design and production of RFID circuits and reader ICs. Today, EM is a major player worldwide. EM offers a complete range of standard products and ASICs from 125kHz to UHF devices, for most applications.
800	**Texas Instruments (TI) USA**	TI is a global semiconductor company and one of the world's leading designers and suppliers of real-world signal processing solutions. The company's other businesses include Sensors and Controls, as well as Educational and Productivity Solutions. Headquartered in Dallas, Texas, TI has more than 34,000 employees worldwide with corporate, sales and manufacturing facilities in more than 30 locations across Asia, Europe and the Americas.	TI claims to the world's largest integrated supplier in radio frequency identification (RFID), with over 500 million TI-RFid tags, smart labels, and RFID readers manufactured for use in asset tracking, contactless payments and secure ID applications.
400	**SONY Japan**	Sony Corporation is one of the world's largest media conglomerates with revenue exceeding 99.1 billion USD (as of 2008). Sony is one of the leading manufacturers of electronics, video, communications, video game consoles, and information technology products for the consumer and professional markets.	One of the major RFID chip producers, also active in applications to other products
380	**Impinj US**	Impinj draws on its technical expertise and industry partnerships to deliver a wide range of products and solutions comprising high-performance tag chips, readers, reader chips, software, antennas, and systems integration, in applications across numerous vertical markets, including inventory management, asset tracking, authentication, and serialization.	Specialized in RFID
400	**Others (including Infineon, Hitachi, Atmel, and INSIDE Contactless)**		

Source: Company homepages, Annual reports and IDTechEx (2008a).

Clearly European companies have a strong presence in chip supply. NXP and EM Microelectronic are among the largest suppliers of silicon chips for RFID. Up till now, NXP has been the largest supplier of chips for LF RFID. Suppliers such as EM Microelectronics and Infineon have been gaining shares rapidly for car clickers at 433 MHz and in other non-card applications. However, there is a broadening of the supplier base for chips (Intel has shown an interest in entering recently). The biggest RFID user in the future, China, intends to make its own chips. Thus, we could see a decline in market share for European suppliers.[53]

An interesting company in the list is Impinj – a start-up in 2000 in the US and a pure RFID player. It managed to beat the chip giants by having the first EPC certified Gen 2 product available in 2006. The competition only caught up in the fourth quarter of 2006. Impinj has accumulated a great deal of expertise in RFID and has 37 granted patents and over 125 pending.[54]

Tags

The chip segment of the value chain is closely connected to the inlays and tags section. There is a great fluidity about who does what, which extends beyond these two segments. For example, Impinj sells chips and readers and Alien technology sells both tags and readers.[55]

According to IDTechEx (2008a:33), the major inlet suppliers are Texas Instruments (US) Avery Dennison (US), UPM Raflatac (Finland), Omron (Japan), ASK (France), KSW Microtec (Germany), Alien Technology (US), and Tagsys (US). It is also worthwhile noting that there is considerable production capacity *located* in Europe.

Readers (interrogators)

When RFIDs emerged, many companies that made tags also made readers. This was because they could achieve optimal performance. Now as standards are in place such as Gen 2 the benefits of such integration are disappearing, although experts claim that in some cases tags and readers from the same company perform better. This might be due to the company tweaking the system to optimize it for the application. Leading companies supplying readers include Texas Instruments (US), Vivotech (US), Siemens (Germany), AWID (US), Sirit (US/China), Motorola (US), Alien Technology (US), ThingMagic (US), Tyco ADT (US), and Impinj (US), pointing to a strong US position in this segment.[56] According to BMWi (2007a) the competition in this segment (as well tags and readers) is heterogeneous and also includes many SMEs.

Printers - encoders

RFID printers typically encode smart labels by first writing the code to the tag and then printing it on the label as a barcode. According to Juniper (2005), this is a significant but in many ways overlooked aspect of the production of smart labels or tags, and US companies such as Avery Dennison, Zebra and Printronix have been most active in this area, and also the supply software development kits and pre-certified EPC tags to aid companies to implement RFID.[57] Company listings, such as IDTechEx and RFID Monthly also indicate US dominance in this segment.

Software

The European industry is present in the software part of the value chain, but weaker than in many other parts. Worldwide, there are about 100 suppliers of RFID middleware and another 100 suppliers of custom software.[58] IDTechEx (2008a) expects the former market to consolidate and there to be an increase in the number of companies in the latter. Company listings suggest that while some European firms are present, they are fewer than in other parts of the value chain.

53 IDTechEx (2008a).
54 IDTechEx (2008a).
55 IDTechEx (2008a).
56 IDTechEx (2008a:33).
57 Juniper (2005).
58 IDTechEx (2008a).

Systems/system integrators/facilities management/consulting

While there are over 100 companies (of which several are European) offering consultancy or systems integration, very few are globally present, and most of these are US. The main ones are Transys (A consortium), Savi Technology (now Lockheed Martin US), IBM (US), Lyngsoe Systems (Denmark), ODIN technologies (US), Unisys (US), Domino (UK), MTI (Taiwan). According to BMWi (2007a), this segment is already dominated by the large (mostly US) IT companies. Further integration with enterprise platforms may suggest that these companies (IBM, SAP, Microsoft, Oracle) will gain a bigger share in this segment.[59] However, a case could be made for the regional or local ties being important, for instance in the case of **public projects (RFID passports, public transport projects, health).**

Other

Other parts of the value chain, which have not been studied in detail include production machinery (Mühlbauer from Germany, Mark Andy US, Stork from the Netherlands).

As a general observation, one could state that, at present, the most powerful players are located at the customer end – largely retailers and other customer organisations that have considerable supply chain power by way of their ability to order large quantities of tags. Over time, one would expect to see chip manufacturers also becoming major tag manufacturers and packagers.

Finally, although China has not been very represented in the above data, it would be wrong to think that China could not become a major actor in the future. China's RFID market is already the largest in the world, supplied to a large extent through its indigenous industry (Box 3-2), which is likely to grow even more competitive in the future, not least in high-volume segments.

Box 3-2: RFID in China

As in many other parts of the ICT sector, China is progressing rapidly with RFID, both in terms of huge potential market and in terms of a growing supplier industry and development of RFID technology.

China has carried out R&D, standards development and industrialisation of "indigenous" technology related to RFID, owing to the concerns about the need to avoid paying excessive IPR royalties and about internet governance. As China is a global manufacturing centre, RFID technology has a vast market for applications.

On the market side, applications in China are developing rapidly but are not mature. Many manufacturers are reluctant to take up the technology, partly because low labour costs can substitute for the need to automate logistics flows. Most applications focus on mid and low frequency fields, such as status identification, security entrance guard, electronic tickets (e.g. tickets for Beijing's Olympic Games), and communications. However, the second generation Chinese ID card has promoted the mass application of RFID to some extent, and China's RFID market is currently the largest in the world in terms of value.

59 IDTechEx (2008a).

The total market in China was about 2 billion USD in 2007, of which the Top 12 suppliers hold more than 1/3, the rest being shared by about 200 firms (many of which are local). Several of the largest operations are related to the national ID project. Major EU and US firms, such as Motorola, Texas Instruments, Infineon, Avery Dennison, INSIDE Contactless, NXP, STMicroelectronics, EM Microelectronics and Atmel all have a stake in China's market. For example, NXP supplied chips for the Beijing public transit cards and campus cards. Top suppliers on the Chinese side include the Huahong Group, Datang Microelectronics, SMIC and Eastcom Peace, which all play a major role as chip suppliers. The market also includes numerous local interrogator suppliers and system integrators for contactless smart card rollouts in their respective cities, such as national ID cards schemes and public transit cards.

As for policy, China is quite different from the EU, where large retailers, manufacturers and other players within integrated supply chains are driving events. In China, the government is the overriding force behind the adoption of RFID. The main focus is on the need for the government to ensure that its logistics infrastructure catches up. Its supply chains are inefficient and fragmented (logistics accounts for about 20% of costs compared with 8% in US) and this is something China cannot afford, given China's export role. There still seems to be little debate on other issues, for example privacy.

DG INFSO of the European Commission has engaged with China to date mainly on standards aspects – specifically, with the Chinese standards body CESI, as it has so far proved difficult to get government officials to speak publicly about RFID, since there is no clear decision as to which Ministry has responsibility for RFID. Nevertheless, ETSI, and the EU-China Infsoc project, has succeeded in engaging with CESI and in April 2009, it carried out a "plug test" exercise in China with CESI and the Chinese Post Office, to test RFID standards.

Source: EU (2009) and http://www.researchandmarkets.com/reports/590995/rfid_in_china_2008_2018

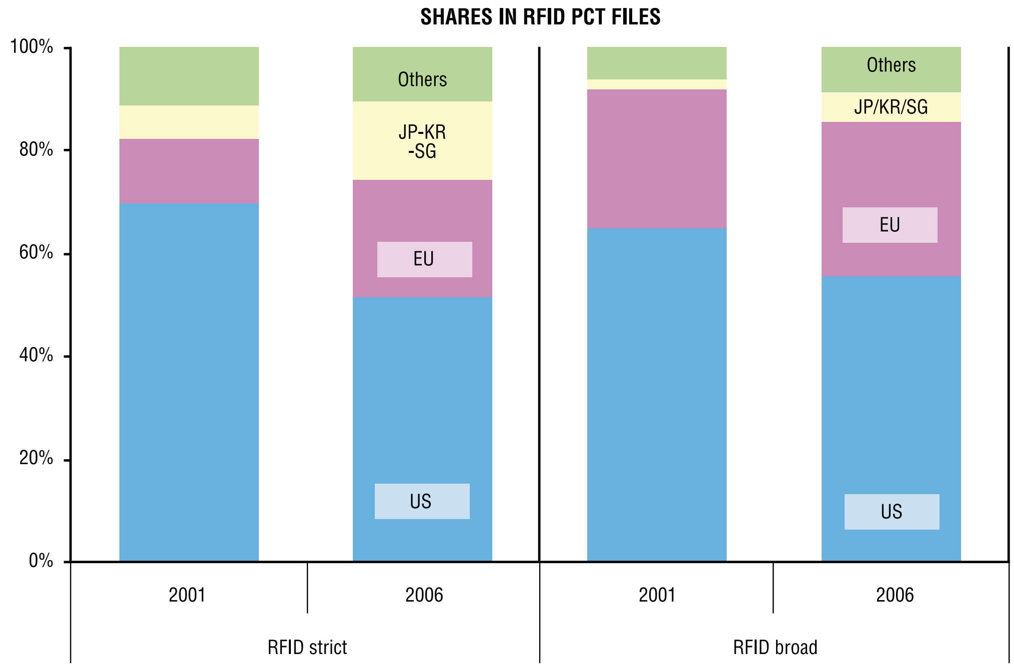
3.2 Technological developments

3.2.1 Patents applications

Technological strength and innovative capability are key factors for Europe to sustain competiveness in high-technology industries such as RFID. An analysis of national RFID patent shares under the Patent Cooperation Treaty (see Section 1.5) through RFID text search in the abstract (strict definition) and/or in the whole description of applications (broad definition, i.e. inventions that include RFID devices but mostly not as their primary object) reveals that the USA is the main actor in the field. The USA has a share of more than 50% for both definitions of RFID-related applications; the EU follows at a distance with 22% for RFID applications in a strict sense and 30% for RFID-related inventions in the broad definition; other competitors – including Japan, Korea, Singapore and China – all lag behind (Figure 3-1). It is also worth noting that over time, the RFID invention landscape portrayed by the *World Intellectual Property Organisation* files is getting more populated (from 19 to 45 countries), and laggards are gaining ground.[60]

60 This simple patent search does not allow us to distinguish between patents relating to different parts in the value chain, etc.

Figure 3-1: Regional shares in RFID-related patent applications: 2001 and 2006, strict and broad definitions



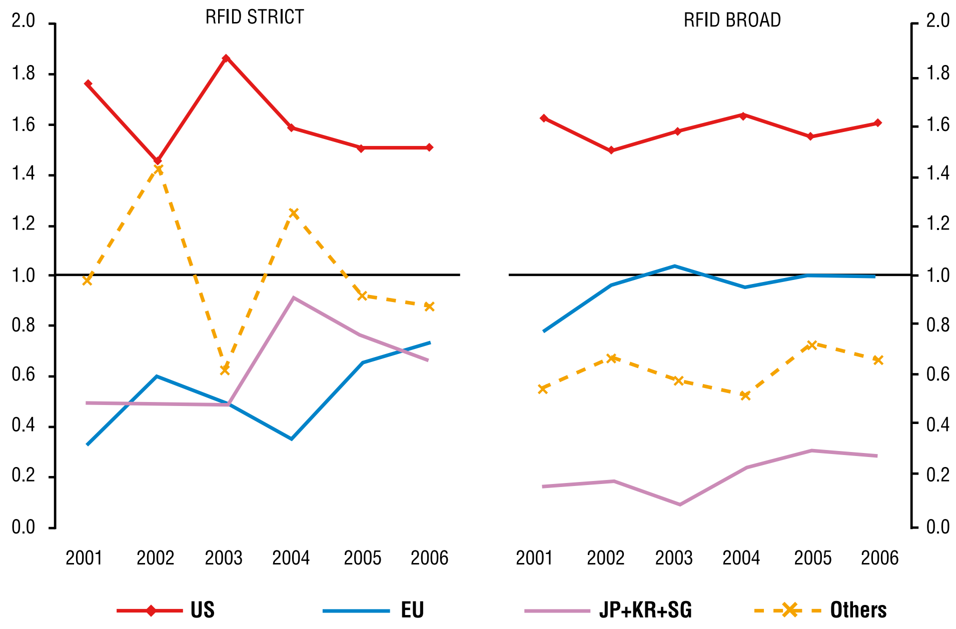
Source: Authors' computation on WIPO's PATENTSCOPE database.[61]

These figures ought to be considered with a certain caution, due to possible sector and, especially, country biases.[62] To correct for the latter, we computed a relative specialisation index, as the ratio between RFID-related and total patent filing shares of each country. The index, reported in Figure 3-2, in the case of the USA stays at about 1.6, which confirms the view that this specific subsector is a US stronghold, as are most of the ICTs (IPTS, 2008). For the case of the EU, the increase observed in RFID shares is mirrored in a rise of both specialisation indices, with the value for the RFID broad definition approaching unity. Leading Asian countries, instead, result relatively stronger in inventive activity directly linked to the development of RFID technology than in the broader field of RFID and related applications.

61 Note that WIPO bears no responsibility for the integrity or accuracy of the data contained herein, in particular due, but not limited, to any deletion, manipulation, or reformatting of data that may have occurred beyond its control.

62 The database (http://www.wipo.int/patentscope/en/) reports filings for international protection through the Patent Cooperation Treaty (PCT) channel only. Hence, data can over- or under-represent different countries and sectors according to patenting channel habits and convenience, and such distortions can change over time.

Figure 3-2: Country shares in RFID / shares in total PCT filing, years 2001-2006



Source: Authors' computation on WIPO PATENTSCOPE database.[63]

Table 3-3: Top RFID patenting companies

Narrow (front page)			Broad (entire text)		
Company	**Country**	**Appl.**	**Company**	**Country**	**Appl.**
Symbol	United States	73	Nokia	Finland	257
Avery Dennison	United States	60	WMS Gaming	United States	203
3M	United States	55	Philips	Netherlands	170
Sensormatic	United States	50	Symbol	United States	168
Motorola	United States	34	Siemens	Germany	153
Siemens	Germany	31	3M	United States	153
Fujitsu	Japan	30	Motorola	United States	132
Intermec	United States	29	Semiconductor Energy Laboratory	Japan	110
Nokia	Finland	28	Sensormatic	United States	86
Philips	Netherlands	27	NXP	Netherlands	86
NXP	Netherlands	25	Avery Dennison	United States	78
Checkpoint	United States	25	Intel	United States	75
IBM	United States	24	IGT	United States	70
ETRI	Korea	23	Walker Digital	United States	68
Intelleflex	United States	19	IBM	United States	65
Intel	United States	18	Checkpoint	United States	52
Kabushiki Kaisha Sato	Japan	16	Fujitsu	Japan	51
Honeywell	United States	16	ETRI	Korea	51
Skyetek	United States	13	UPS	United States	49

Note: the search algorithm does not group companies together according to ownership or different spelling. Although a check was performed, it might be the case that some companies are underrepresented.[64]

Source: IPTS elaborated on WIPO Patent search database search for the key word "RFID" in front page and whole text respectively (2009-02-22).

63 Note that WIPO bears no responsibility for the integrity or accuracy of the data contained herein, in particular due, but not limited, to any deletion, manipulation, or reformatting of data that may have occurred beyond its control.

64 Note that WIPO bears no responsibility for the integrity or accuracy of the data contained herein, in particular due, but not limited, to any deletion, manipulation, or reformatting of data that may have occurred beyond its control.

Table 3-3: Top RFID patenting companies presents the major RFID patenting companies, using a similar search which distinguishes between narrow and broad RFID patents. US ICT companies are clearly leading in the strict RFID field. In the broad RFID category, there are some, perhaps surprising, companies such as games (slot machines etc.) suppliers WMS and IGT, and Walker Digital, a US R&D company with strong focus on creating patents. Companies with strong RFID focus such as Symbol and Avery Denison drop somewhat in ranking, the broader the search.

A few comments on some of the companies presented are worth making. A number of large ICT companies are patenting substantially in RFID, as part of their diversification into this field. These include semiconductor companies such as NXP, producing RFID chips. Philips also has a strong RFID patent portfolio, although much of its RFID R&D was spun-off together with NXP, while Intel sold its RFID R&D business to Impinj.

Table 3-5 also includes companies downstream the value chain. For instance, Nokia has a range of patents relating to how to integrate RFID into mobile phones, while Siemens has inventions offering RFID components and solutions for a wide range of applications.

Table 3-4: Top RFID patenting companies in 2008

Narrow (front page)			Broad (entire text)		
Company	**Country**	**Appl.**	**Company**	**Country**	**Appl.**
Sensormatic	United States	14	WMS Gaming	United States	90
3M	United States	13	Nokia	Finland	58
Symbol	United States	12	Siemens	Germany	52
Siemens	Germany	12	Motorola	United States	40
IBM	United States	10	3M	United States	37
ETRI	Korea	10	NXP	Netherlands	31
Keystone	United States	9	IGT	United States	29
NXP	Netherlands	8	Visa	United States	27
Murata Manufacturing	Japan	7	Symbol	United States	26
Corning	United States	7	IBM	United States	24
Motorola	United States	6	ETRI	Korea	24
Intelleflex	United States	6	Sensormatic	United States	23
Textilma	Switzerland	5	Walker Digital	United States	20
SK Telecom	Korea	5	Philips	Netherlands	19
Rexam Healthcare Packaging	United States	5	Deutsche Post	Germany	19
RCD Technology	United States	5	Honeywell	United States	18
Kimberly-Clark	United States	5	Fujitsu	Japan	18
Kabushiki Kaisha Sato	Japan	5	Sony Ericsson	Sweden/Japan	17
Intermec	United States	5	Kimberly-Clark	United States	16
Honeywell	United States	5	Intel	United States	15

Source: IPTS elaborated on WIPO Patent search database search for the key word "RFID" in title, front page and whole text respectively (2009-02-22).[65]

65 Note also that WIPO bears no responsibility for the integrity or accuracy of the data contained herein, in particular due, but not limited, to any deletion, manipulation, or reformatting of data that may have occurred beyond its control.

Table 3-5: Declared essential patents for ISO/IEC 18000 RFID air-interface standards

Company	Country	Description (in Wiebking et al. 2007)	Patents
Intermec	United States	Manufacturer of tags, readers, systems, purchased IP from IBM and Amtech	11
NXP	Netherlands	Former: Philips Semiconductors; manufacturer of chips for tags, labels cards, readers, which purchased IP from Mikron	9
BTG	United Kingdom	Medical science company which possibly sold its RFID portfolio to Zebra	9
TagSys	United States	Manufacturer of tags, readers, systems, which purchased IP from Gemplus and Integrated Silicon Design	6
Magellan	Australia	Manufacturer of chips, tags, inlays, labels, antennas, readers	5
TI	United States	Manufacturer of chips for tags, readers, antennas	4
Intercode / Spacecode	France (Spacecode)	Manufacturer and system integrator	4
Savi	United States	Manufacturer of tags, readers, and sensors	3
ATMEL	United States	Manufacturer of chips for tags, readers	2
Motorola	United States	Manufacturer of readers, antennas (ex Symbol, ex Matrics)	1
EM M. Marin	Switzerland	Manufacturer of chips for tags, readers	1
Siemens AG	Germany	Manufacturer of tags, readers, systems	1
Sirit Samsys	United States/China	Manufacturer of tags and readers	1
Supersensor (BiStar)	N/A	N/A	1

Source: IPTS adapted from Wiebking et al. (2007) in turn based on information from ISO and IEC.

Several of the specialized RFID companies (most of them in the US) have made the transition into RFID from related industries – e.g. Symbol Technologies was originally a bar-code scanner manufacturer, and has now been acquired by Motorola. Other examples include Avery Denison, which moved into RFID from a leading position in self-adhesive labels; the 3M conglomerate, which has a diverse range of RFID-related inventions and is active in supplying RFID tags; and Intermec, specialized in the automatic ID and data capture market.

The substantial patenting in industry-specific applications by companies already in the parent market is also notable. Sensormatic in the electronic article surveillance business belongs to this group, and Checkpoint in the security industry. Korean ETRI is the only research institute in the top RFID patenting list. Finally, WMS gaming, number two in the broad category, appears (after a manual check of some of its patents) not to have any R&D related to RFID.[66]

In view of the fact that patenting in RFID has escalated in recent years, it is interesting to contrast patent portfolios (i.e. stock data on the accumulated number of patent applications) with information on emerging actors, which can be obtained by looking at recent dynamics only. This complementary information is reported in Table 3-4: Top RFID patenting companies in 2008, which lists the top patenting companies in 2008.

66 The term RFID is simply mentioned in the patents as one possible means of identification.

It can be observed that Avery Dennison is not on the 2008 list while RCD – a pure RFID Tag player – is. Another notable feature is that further vertical downstream companies appear, including, for instance, Rexam Health Care and some telecom operators and postal/parcel delivery companies.

Another, complementary way of looking at patents is to consider their importance with respect to applications and to other inventions in the same field. US companies have a very strong position in key patents, and they also pursue the exploitation of these positions more aggressively. Evidence of this is provided by a study carried out by the RFID Journal in 2005,[67] which reported about 150 patents relevant to the RFID market. Another study by the *High Impact Patent Database* includes 4,279 RFID patents,[68] and allows us to identify about 20 companies holding key blocking patents in their portfolio.[69]

Finally, as mentioned in Section 1.7, patents essential to standards can also be considered as particularly important. Table 3-5: Declared essential patents for ISO/IEC 18000 RFID air-interface standards provides an overview of patents that are key for the ISO/IEC 18000 RFID air interface standard. This shows that several companies, some of them European (NXP, BTG, Spacecode), also hold many essential patents.

In conclusion, patent search exercises allow us to identify major RFID technology players and provide yet another indicator of the position of European firms in RFID. The analysis corroborates the view that the EU is also lagging behind the US somewhat in terms of technological capabilities as measured by patents.

67 http://www.rfidjournal.net/live05/IP/Room_miss_100pm_stewart.pdf

68 Of which Intermec holds 140, which makes it one of the largest patent portfolios. (See Chapter 2 on standards and IPR on Intermec and patenting). See Maghiros et al. (2007) for an elaboration.

69 These latter include: Intermec, Checkpoint, Motorola, Micron, Alien, Lucent, Sarnoff and BTG.

3.2.2 R&D activities

The future competitiveness of Europe in RFID depends crucially on its ability to innovate, which is in turn partly driven by R&D efforts. An assessment of European strengths and weaknesses in this respect is not readily available, since neither official statistics nor company accounts distinguish RFID-related R&D. However, there are mappings conducted by individual experts and consultancies, which enable us to make partial assessments.

There is no doubt that substantial R&D efforts are taking place in Europe. Evidence of this can be drawn, inter alia, from the database of international RFID R&D projects compiled by Wiebking et al. (2007) (Figure 3-3). This database, however, is likely to be biased towards public projects, and towards some EU countries, so data on both regional and national shares should be taken with extreme caution.

Using a different methodology, another in-depth study by CE RFID identifies Germany, the UK, France, Italy, and the Netherlands as a group of major RFID R&D investing countries.[70] In this group, public financial support for R&D projects, with industrial participation in general and RFID in particular, differs widely. While Germany and France have a considerable number of subsidy programme lines for R&D, the UK and Italy do not fund industrial R&D. The Netherlands concentrate on funding for cooperative and industrial R&D and SMEs, and approach RFID-related funding via publicly financed research institutions. Smaller countries like Austria and

70 Pavlik & Hedtke, (2008). This group of countries is identified on the basis of the number of live business cases and economic importance attributed to RFID. The CE RFID study provides broad information on RFID R&D in the EU, and an assessment of RFID-related R&D projects and programmes supported by national, regional/transnational and European authorities and agencies, in a selection of European countries: Germany, France, UK, the Netherlands, Italy, Spain, Austria, Finland, Poland, Hungary and the Czech Republic.

Finland focus on supporting industrial R&D; the main difference here lies in the fact that in Finland there is an RFID focus in current programmes, whereas in Austria only future programmes will open up this opportunity. The NORDITE initiative in the Nordic region (Sweden, Finland, and Norway) is an example of cross border cooperation with an RFID focus, a benchmark example for the issue of bottom-up transnational cooperation.

According to the CE RFID study, RFID-related research in FP5 and FP6 European projects attracted financing of about €168 million. However, parent projects were not specifically focused on RFID, and suffered from lack of coordination amongst them, thus losing essential synergy effects. This coherence problem has only been addressed recently by the (temporary) CERP cluster of RFID projects from FP6. In terms of project coverage, the general focus was on tag/reader and system technology, and only a few programmes explicitly addressed privacy or ROI aspects of RFID introduction. Application programmes are frequently specific in nature, and contribute little to a generic re-usable system architecture that would enable easy access to RFID technology for SMEs.

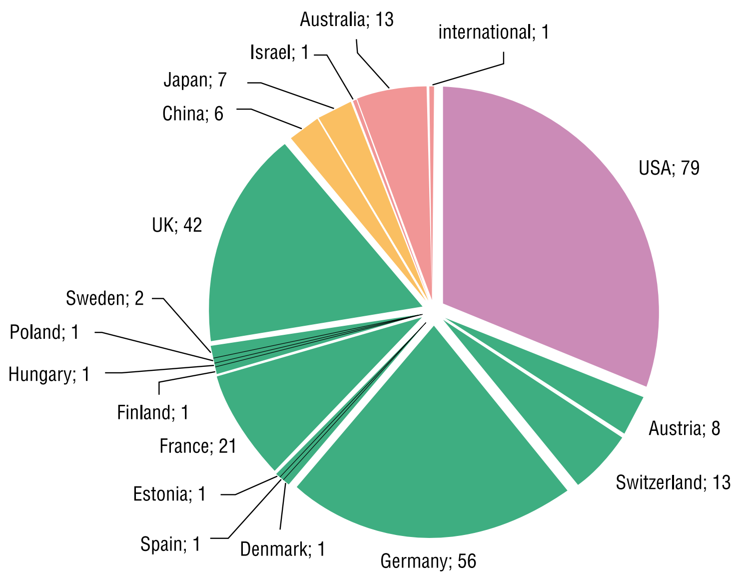
In conclusion, evidence shows substantial EU publicly-funded R&D efforts in RFID, although a number of caveats and areas for improvement must be highlighted. In particular, existing collaborative research projects focus more on tag/reader and system technologies, and less on privacy, business cases and solutions that would be accessible to SMEs. Also, R&D initiatives appear to need further coordination among them. Little is known, however, about business-funded R&D, and this prevents us from being able to fully assess Europe's R&D capability.

3.3 EU position in RFID for item-level tagging and public transport

3.3.1 RFID at item-level

Apart from the general observations made above, at the item-level, we note that there are some big retailers, like Tesco, Metro or Marks and Spencer, which are pushing for the introduction of RFID in Europe. Europe is also relatively well represented in some other item-level applications.

Figure 3-3: R&D projects per lead country



Source: IPTS elaboration of CE RFID (Wiebking et al., 2007) database.

Note: the country counts are based on one parameter - country as stated in the database. This simple count could be complemented by analyses of participating organisations and "secondary countries". Time and resource constraints have not allowed such an analysis at the time of writing (July 2009).

Figure 3-4: Transport networks worldwide using the Calypso technology

Source: Calypso Network. http://www.calypsonet-asso.org/pop_map.htm

For the time being, the contractual power lies with the large end-users but, as new market segments open up, this power will probably shift to large off-the-shelf RFID vendors.

However, to encourage adoption on a broader scale (also by SMEs), there is the need to promote open standards and to address prospective spectrum issues, in particular in the UHF-band.

In both these respects, the US seems stronger than Europe. First, there is more spectrum available in the US (see Figure 2-8). Second, as shown in Chapter 2, the US is stronger in standard setting, not least when it comes to standard-blocking patent portfolios, dominated by US companies. Indeed, item-level tagging based on *open* systems is being increasingly pushed to adopt UHF EPC gen2 standards. Unlike HF standards, these rely on inventive activity, the Intellectual Property Rights of which are largely in the hands of US industries. Additionally, mainly US companies in this field have started to join the RFID Consortium (see Section 1.7), in order to pool patents and license them accordingly.

Lastly, it should be noted that EPC did in 2004 designate the US Company Verisign – already in charge of the .com and .net domains on the Internet – to operate the Object Name Service (ONS). The purpose of ONS is to locate authoritative metadata and services associated with a given Electronic Product Code (EPC) using the Internet Domain Name System (DNS). Concerns on this issue have been raised by both the European Commission and national authorities of different Asian countries. It should be noted, however, that GS1 EPCglobal is responsible for assigning numbers to companies willing to use ONS and for the network itself. VeriSign is the sub-contractor operating the service.

3.3.2 RFID for public transportation

For public transportation, available evidence shows that Europe at present is relatively strong in technology and standards design, and also in hardware production and technology usage. Most major European cities have, or are in the process of implementing, RFID ticketing systems.

The fragmentation of the production chain also allowed the growth of a number of small companies, using third party chips to make cards or providing readers or integrated services at the local level in several countries. An enhancing actor for both adoption by smaller cities and local production is the Calypso association (http://www.calypsonet-asso.org/) founded by European transport networks. Its open standards are now used by the transport systems of 80+ towns around the world, and for 30 million transport cards.

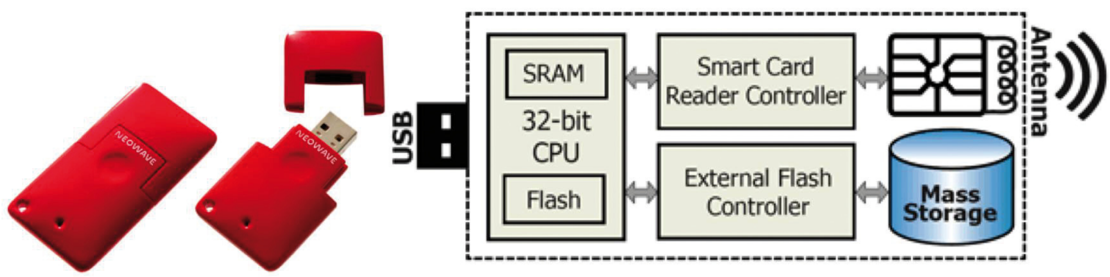
Among EU companies there are many big RFID suppliers and system developers targeting RFID for public transportation. Philips (now NXP) as a chip producer plays an important role, as do other European micro-electronic firms (ASK, Infineon, STMicroelectronics). ASK's paper-based C.ticket is being used in many trials and pilots. Paper-based tickets seem to offer the same potential and functionality – using the same RFID-chip – as contactless smart cards, though their lifetime is shorter. Other EU companies are developing integrated solutions, such as the Weneo stick now being tested by French Railways SNCF. Weneo is produced by the French start-up Neowave and brings together an RFID chip with memory and USB-based physical connectivity, thus allowing PC- and web-based services, including credit recharge (Figure 3-5).

EU-consultancy firms play an important role in the consortia that have been formed to guide the introduction of RFID-tickets into public transport and the accompanying transition for the back offices. The number of pilots and projects will increase in the years to come, requiring more specialised knowledge and firms that are able to guide the accompanying transition processes.

Some big EU players are in the world league in smart card tags and ticket designing and production. Mifare (property of NXP, spun-off by Philips, which still keeps a minority stake) is likely to be the world's most used contactless smart card technology, with "more than 1 billion smart card ICs and 7 million reader components sold" so far (http://www.mifare.net/). It has been adopted by large transport networks in both the EU (e.g. London Oyster system, and Netherlands' integrated transport card) and abroad (Beijing, Seoul, etc.). The French company, ASK, leads the market in cheaper contactless paper tickets.

Summing up, the spread of RFID in public transport is growing fast across the world. Some EU cities and regional/national authorities are at the forefront in adoption, and EU companies are amongst the leading actors in this area. However, massive deployment is underway in other (mainly Asian) countries (Korea, Japan, and China), which also entails rapid integration among instruments and technologies (NFC via mobile phones, data storage, electronic purse) and the emergence of local competitors in the global arena. This, together with recent developments in paper electronics, shows the main directions for change and possible areas for policy intervention.

Figure 3-5: Integration of RFID tags with memory and PC connectivity: the Weneo stick



Source: Neowave S.A. http://www.neowave.fr

3.4 Concluding remarks

This section summarizes the outcome of the analysis above, and also includes conclusions on the user side (see Chapter 1). Clearly, European technology providers, users and research centres have made Europe a major player in global RFID competition. From chip manufacturers to label makers to system integrators, European actors hold 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 leads, followed by France and the UK, and Italy, the Netherlands, Nordic countries, Austria and Switzerland also have strong positions.

However, the US still dominates the market. It has large-scale R&D programmes and infrastructure projects, many large producing companies, and it plays a leading role in standard setting, patenting and patents related to standards. In Asia, Japan, Korea and Taiwan are already strong actors, while China is likely to catch-up as a result of large domestic demand and industrial policy. The EU could increase its presence in downstream parts of the value chain, i.e. systems integration/consultancy/facilities management, but here, EU firms will also face stiff competition from the US.

Technology-wise, Europe is also doing well, although it lags behind the US in patenting. Europe's patenting position is stronger in application fields, and improving moderately in *core* RFID patents.

The R&D infrastructure is well developed, particularly in hardware and systems, with a focus on tag/readers and systems, but lacking somewhat in user-related aspects (business cases, privacy) and coordination. However, the other regions also have very strong R&D, including large-scale research programmes with multi-technology objectives (e.g., the "Ubiquitous City" in South Korea) or government-initiated infrastructure projects in the US.

Item-level tagging and public transportation share most of the above features, although with some specificities. In the case of item-level tagging, Europe has a relatively weaker position than the USA in UHF spectrum availability, in adoption rates (due to the more dispersed industrial structure), and in some segments of the RFID industry itself. These aspects are made more problematic by lags in harmonisation, public procurement and patenting and standards settings. In the case of public transportation, adoption rates are relatively high in the EU, which has some world level champions in both established and emerging technologies, and is the home to an integrated and open standard approach which is helping deployment.

4 Policy Analysis

This chapter outlines areas in RFID techno-economic developments which may require policy attention. Section 4.1 proposes an overview of the current policy framework, including recent policy developments. Policy options for RFID in general are then outlined in Section 4.2, and for Item level and public transportation in Section 4.3. Some conclusions are offered in Section 4.4.

4.1 Current EU polices

The production price of RFID tags is now approaching a level that permits wide commercial and public sector deployment. In this framework, the European Commission has already engaged in a broad mix of RFID-related policy initiatives. These emphasize the potential of RFID to become a new engine for growth, if the barriers to innovation can be overcome. Also, they take into account that as RFID is used more widely, it will become essential that the implementation of RFID takes place in a legal framework that provides citizens effective safeguards for fundamental values, health, data protection and privacy.[71]

In 2006, the DG Information Society and Media Commissioner, V. Reding, launched a public debate and carried out a public consultation on RFID. The debate highlighted citizens' expectations and also their concerns about RFID applications that involve identification and/or tracking of people. The results of this consultation were used to draft a Communication on "Radio Frequency Identification (RFID) in Europe: steps towards a policy framework". This Communication proposed follow-up steps to overcome barriers to wide take-up including radio spectrum and standards issues. These would benefit society and the economy, and also incorporate appropriate privacy, health and environmental safeguards.[72]

The European Commission published a Draft Recommendation on RFID Privacy and Security for public consultation, which was adopted in May 2009.[73] It includes recommendations to the Member States in the areas of: *privacy and data protection impact assessments; information security; information and* transparency on RFID use; RFID applications used in the retail trade; awareness raising actions; and R&D. The Commission also adopted a Decision[74] for RFID frequencies in the UHF band, which harmonised several spectrum bands used by RFID and 'IoT (Internet of Things) devices'. It is the intention of the Commission to regularly update this Decision in response to market developments.[75] The Radio Spectrum Decision (676/2002/EC) provided the basis for these actions.

Concerning standardisation, the European Commission, notably through its R&D programme, has launched a number of actions which allow for improved coordination and provides a forum for input to standards bodies. Recently (May – June 2009) the 7th FP CASAGRAS (Coordination and support action for Global RFID-related activities and standardisation) delivered seven *white papers*, three of which explicitly dealt

71 European Commission (2007).

72 European Commission (2007).

73 European Commission (2009a). See also European Commission (2009b,c).

74 Commission Decision 2006/804/EC of 23 November 2006 on harmonisation of the radio spectrum for radio frequency identification (RFID) devices operating in the ultra high frequency (UHF) band. as Amended by Decision 2008/432/EC.

75 Notably via the permanent Mandate of the Commission to CEPT regarding the annual update of the technical annex of the Commission Decision on the technical harmonisation of radio spectrum for use by Short Range Devices (5 July 2006). See European Commission (2008b).

with standardisation issues. Also, the European Commission acknowledges that worldwide efforts are still fragmented, and that decisions are sometimes taken by ad-hoc organisations which do not necessarily follow the principles guiding EU standards organisations.[76]

To address this issue, the European Commission is promoting a number of multilateral efforts. For example, a Transatlantic Symposium on the Societal Benefits of RFID has been established to encourage the launch of joint EU-US "Lighthouse pilot projects".[77] Additionally, a memorandum of cooperation on, among others, RFID, wireless sensor networks and the Internet of Things, will be signed by the Directorate-General Information Society and Media of the Commission and the Japanese Ministry of Economy, Trade and Industry.

RFID and the Internet of Things were also high on the agenda in the two successive EU Presidency Conferences of Berlin (June 2007) and Lisbon (November 2007). Further policy developments in the RFID field are indeed framed within the broad concept of Internet of Things and the Future of the Internet.

More recent developments show that RFID and the Internet of Things will probably stay on the list of top policy priorities in the years to come. In autumn 2008, there was a public consultation on a Commission Staff Working Paper on the Internet of Things. The responses were considered in the drafting of the Communication (Action Plan) by the European Commission on the Internet of Things of June 2009.[78]

Another development relates to the future of the Internet, and includes a debate on the policy implications of future networks.[79] In particular, a special effort is being made to explore and assess with stakeholders the perspectives emerging from R&D in Europe for the Future of the Internet.[80] In March 2008, the *Future Internet Assembly* was launched as a vehicle for discussion amongst the R&D projects concerned and the European Technology Platforms at the Bled Conference organised by the European Commission and the Slovenian EU Presidency. This assembly aims to facilitate open interaction and cross-fertilisation across technical domains and to promote a shared vision of what needs to be done for the Future Internet in Europe.[81]

Besides the public consultation on the Internet of Things and the broader debate on future networks and the Internet, according to Santucci (2009), there are three other significant developments. These include:

i) The clustering of research efforts at European level. In January 2007, the European Commission recommended the creation of a Cluster of European RFID Projects (CERP, from October 2008 called CERP-IoT). This cluster consisted, by 2009, of some 25 research projects, including a few national initiatives.

76 European Commission (2008b); the communication also dealt with health and environmental issues, which fall under broader regulation concerning electronics and EMF and are not further treated here. The issue of international cooperation is addressed also in European Commission (2009d), with respect to the IoT and the need for "sustained international dialogue, notably on matters of architecture, standards and governance."

77 The report of the second edition, held on May 2009, is available at: http://ec.europa.eu/information_society/policy/rfid/documents/euus_symposiumreport.pdf The Lighthouse projects are initiatives at different stages of development which encompass a number of topics. They include "Tracking Radioactive-isotopes in international commerce"; "Green cargo and international logistics (eFreight)", the development of a "Transatlantic Traceability Infrastructure (TTI)", "Securing the Internet of things", and of a "post manufacturing traceability system" (joint with PRC).

78 European Commission (2009d).

79 http://www.future-internet.eu/. This and the following paragraphs draw on Santucci (2009).

80 The Bled Declaration at http://www.future-internet.eu/publications/bled-declaration.html

81 Santucci (2009). The EU-funded projects selected through FP7-ICT Call 1 belonging to Challenge 1 "Pervasive and Trusted Network and Service Infrastructures" are collectively involved in addressing research issues like security, broadband, mobility, scalability, distributed services, media, dependability; which are all highly relevant for the Future Internet (Ibid).

ii) Two *Coordination and Support* Actions funded by the European Commission within the context of the 7th Research Framework Programme:

   a. CASAGRAS (Coordination and Support Action for Global RFID-related Activities and Standardisation - http://www.rfidglobal.eu/), which provides a framework of foundation studies to assist the European Commission and the global community in defining and accommodating international issues and developments concerning RFID and the emerging Internet of Things.

   b. GRIFS (Global RFID Interoperability Forum for Standards), which aims to improve collaboration and global interoperability of RFID standards.

iii) Enhancing the dialogue between the European Commission and industrial stakeholders with a view to assessing further the technological and market challenges and opportunities raised by the Internet of Things.

Finally, another set of issues is that of industrial research policies, with respect to envisaged technological developments. The most comprehensive and up-to date exercise in the field of prospective assessment on technological trends, and of the societal and political issues that arise was undertaken by (European Commission, 2008). It is presented here because it may influence parts of policy making in the coming years.

The synthesis presented in Table 4-1 shows that some key improvements in the basics of RFID technology (miniaturised readers, smart antennas, smaller tags, all with less materials and cheaper) augmenting technical capabilities and economic convenience for item-level tagging are already expected before 2010, with significant increases in (item-level) RFID diffusion in retail and healthcare industries.

From 2010 to 2020, the significant improvements expected are mostly in technologies related to sensing, energy and tag-building (on-chip antennas, printed batteries, increased memory, etc.). These will push prices further down, open new markets for active, powerful tags and – together with improvements in interoperability – also dramatically increase networking capabilities among objects, which will have significant impact on consumers' daily lives and on industrial organisation.

The prospective exercise does not focus on, or make specific reference to, the diffusion of tagging and applications in individual industries. Nonetheless, the above developments are broadly coherent with trends identified in forecasts on market dynamics, and qualify them for a wider range of applications (as they would increase the affordability of item-level tagging in end products and industrial processes) and also for a much larger number of users with reduced investment and management capacity.

Lastly, the envisaged development of technology at the end of the forecast period outlines a quasi-commoditisation of simpler applications, together with profound changes in the organisation of the economy and social life. These changes, however, go beyond the scope of this report.

4.2 Policy areas to be considered

Clearly RFID holds great promise for the European economy, both for RFID users and for providers of technological products and services. RFID technologies are emerging in a variety of application domains and have several advantages over other auto-identification technologies.

However, widespread diffusion of RFID is still a long way off. Policy actors need to meet a series of challenges in order to realise the potential of RFID technology. Obviously, the European Commission is not the only policy actor in this arena. The Member States also need to

Table 4-1: Technology trends in RFID, societal implications and policy issues

A) Extrapolation of technology trends and ongoing research

	Before 2010	2010-2015	2015-2020	Beyond 2020
Vision society	• Sociallyt acceptable RFID	• Pervasive RFID	• Interacting objects	• Personalised objects
People	• Realising benefits (food safety, anti counterfeiting, health care) • Consumer concerns (privacy) • Changing ways to work	• Changing business (processes, models, ways to work) • Smart appliances • Ubiquitous readers • New retail and Logistics	• Integrated appliances • Smart transportation • Energy & Resouce conservation	• Mastered ambient intelligence • Interaction of physical world (google of things) • Virtual Worlds
Politics & Governance	• De-facto governance • Privacy legislation • Address cultural barriers • Future Internet governance	• EU governance • Frequency spectrum Governance • Sustainable Energy Consumption guidelines	• Authentication, trust and verification • Security, social well-being	• Authentication, trust and verification • Security, social well-being
Standards	• RFID security and Privacy • Radio frequency use	• Sector specific	• Interaction Standards	• Behavioural Standards

	Before 2010	2010-2015	2015-2020	Beyond 2020
Vision technology	• Connecting objects	• Networked objects	• Executable objects / semi-intelligent objects	• Intelligent objects
Use	• RFID adoption in logistics, retail and pharmaceutics	• Increased interoperability	• Decentralised code execution • Global applications	• Unified network that connects people, things and services • Integrated industries
Devices	• Smaller and cheaper tags, sensors and active systems	• Increasing memory and sensing capacities	• Ultra high speed	• Cheaper materials • New physical effects
Energy	• Low power chipsets • Reduced energy consumption	• Improved energy management • Better batteries	• Renewable energy • Multiple sources	• Elements of energy harvesting

B) Topics requiring new or intensified research

	Before 2010	2010-2015	2015-2020	Beyond 2020
Vision society	• Wide take up of RFID	• Integration of objects	• Internet of things	• Unlocked full potential of the Internet of Things
People	• Socially acceptable RFID	• Ambient assisted living • Biometric IDs • Industrial ecosystems	• Smart living • In-vivo health • Security based living	• Mastered continuum of people, computers and things • Automated healthcare
Politics	• First global guidance • Standardisation	• First global governance • Unified open interoperability	• Authentication, trust and verification	• Inclusive Internet of Things
Standards	• Network security • Ad-hoc sensor networks • Protocols for distributed control and processing	• Interoperability protocols and frequencies • Power and fault resilient protocols	• Intelligent devices cooperation	• Health security

	Before 2010	2010-2015	2015-2020	Beyond 2020
Vision technology	• Low power and low cost	• Ubiquitous integration of tags and sensor networks	• Code in tags and objects	• Smart objects everywhere
Use	• Interoperability framework (protocols and frequencies)	• Distributed control and databases • Ad-hoc hybrid networks • Harsh Environments	• Global applications • Self-adaptive systems • Distributed memory and processing	• Heterogeneous systems
Devices	• Smart multi-band antennas • Smaller and cheaper tags • Higher frequency tags • Miniatured and embedded readers	• Extended range of tags and readers and higher frequencies • Transmission speed • On-chip antennas • Integration with other materials	• Executable tags • Intelligent tags • Autonomous tags • Collaborative tags • New materials	• Biodegradable devices • Nano-power processing units
Energy	• Low power chip sets • Thin batteries • Power optimised systems (energy management)	• Energy harvesting (energy conversion, photovoltaic) • Printed batteries • Ultra low power chip sets	• Energy harvesting (biology, chemistry, induction) • Power generation in hash environments • Energy recycling	• Biodegradable batteries • Wireless power

Source: European Commission (2008).

address policy issues, as do industry associations, consumer interest groups, and standardization organisations in the EU and elsewhere.

The earlier IPTS report on RFID (Maghiros et al. 2007) identified a number of issues and recommendations, some of which are now being addressed by public authorities, for instance in the fields of security, research policy, and regulatory activities. In this section, we update the agenda, drawing on recent studies of the RFID industry, and making specific reference to the use of RFID for tagging items and for ticketing, in the following policy areas:

- Stimulating adoption, including SME take-up, education, awareness and information, and public procurement,
- Technology and R&D issues,
- Standardisation and spectrum issues,
- Handling negative side-effects.

All these policy areas are relevant for maintaining and strengthening Europe's industrial position in RFID and for it to reap the benefits of more widespread RFID adoption. All policy recommendations are accompanied by at least one reference to the source in which the recommendation is usually elaborated.

4.2.1 Issues for stimulating RFID take-up

The most pertinent issue for the industry experts, as confirmed in the validation workshop of this project (see Introduction), is to stimulate the take-up of RFID, not least among SMEs. Hence all the barriers to adoption identified in this report in Chapters 1 & 2 could be addressed by demand side policies.[82] This section identifies a number of policy options for this purpose.

The benefits of RFID-based applications are not clear to the potential customers. To remedy this, awareness raising and skills development policies could prove effective. Industry and analysts have perceived that engineers, computer scientists and technicians lack practical knowledge about RFID, which hampers development and implementation projects.[83]

This barrier should be mitigated by adapting occupational training and continuing education, including technical and business process oriented perspectives. This would require cooperation between policy, educational organisations and the RFID/ICT industry.[84] Awareness building among enterprises – particularly SMEs, of the potential benefits and implications of RFID, to help them make informed decisions, should also be supported.[85] Communication campaigns could contribute to raising awareness of the general public.[86]

In general, there may be a need to disseminate more widely the lessons learned in order to create a level playing field. This includes sharing good practices for the implementation of RFID within a specific industry, and also taking into account lessons learned in other industries. The RFID adopting firms themselves and industry associations could become more active in this respect.[87] Public policy too could play a part by supporting platforms for sharing such experiences, to disseminate information about business and pilots. In addition, funding should be available to establish business cases for various applications.

In particular, the lack of a clear business case for SMEs to engage in RFID applications has been identified as perhaps the most important current barrier for RFID diffusion. It is suggested that this barrier could be overcome by:

82 E.g. Wiebking et al. (2008) IDC (2008).

83 BMWi (2007b) as also pointed out by others see e.g. Maghiros at al. (2007).

84 IDC (2008).

85 IDC (2008).

86 Maghiros et al. (2007).

87 IDC (2008) see e.g. Maghiros at al. (2007) relating this issue to NMS.

- Facilitating the early entry of SMEs into RFID projects. Possible steps toward this end include offering practical, industry-specific informational materials and events and carrying out pilot projects that could serve as models. RFID centres of excellence would be one way of offering and facilitating this.[88]

- focusing on the role of SMEs, the contribution of countries that are lagging behind in the adoption and diffusion of RFID, the establishment of a database with best (or good) practices in the introduction of RFID, and the establishment of 'communities of interests' or 'communities of practitioners' across various Member States and different RFID application domains.[89] This could be carried out as part of the Community Innovation Programme.

- Specifically directing communication campaigns at those SMEs which could be interested in adopting RFID technologies, when the advantages for them are sufficiently clear. One way forward would be for these campaigns to highlight the business cases that demonstrate the viability of RFID (in specific situations) and that show RoI-times to be beneficial.[90]

Highly fragmented national markets and regulations make companies reluctant to take the initiative and incur the cost and risk burden. A typical example in the context of RFID is the tagging of pharmaceuticals and medications in hospitals, where demand and regulation are very fragmented. Here, European public initiatives could help; with clear recommendations at the European and national level.[91]

Europe could take the initiative to promote RFID applications through public procurement (cf. passport applications) in areas of societal importance (e.g. drug authentication, efficient logistics and transport, automotive industry, or transnational use) by supporting the application of RFID–based solutions. This kind of procurement could support the application of RFID-based solutions and open up possibilities for novel solutions, fostering technology development and new application areas.[92] Such initiatives would also be in line with European lead-market policy, and some lessons could be learned from the case of public transportation.

Finally, many RFID applications require coordination and collaboration between actors along the value chain. The benefits, which are not clear to all the actors, will not fully materialize unless actors adopt the technology. Business models must therefore allow all actors to appropriate the value created and share the cost for implementing RFID-based solutions. **There may be room for policy to enable such coordination.**

4.2.2 Technology and R&D issues

Europe, as well as the US, Japan, South Korea and China, are spending large sums on RFID-related R&D. In order for the EU to stay competitive in the future, it seems wise to continue such support, through the 7th Framework Programme and Member State initiatives.

In general terms, several observers pointed out that a weakness in publicly-funded research is that it is not coordinated enough. Funding agencies should coordinate their activities more closely, to achieve synergy effects among individual projects and to avoid redundant initiatives.[93] Flagship projects – that is, large collaborative projects using multiple technologies, serving as models in

88 BMWi (2007a).
89 Maghiros et al. (2007).
90 Maghiros et al. (2007).
91 Pavlik & Hedtke (2008).

92 Pavlik & Hedtke (2008).
93 BMWi (2007b).

specific application fields, could also be a way forward.[94]

It is beyond the scope of this report to investigate which technological field need more research. We will however, outline a number of possible areas which could be targeted by public funding, drawing on some recent studies: for example, the EC (2008) study (see above, Table 4-1) and the CE RFID study (Pavlik & Hedtke, 2008), from which we also adopt the time horizon-based narrative. Indeed, according to CE RFID, R&D funding agencies currently favour mid- to long-term research programmes, but short-term high-urgency research projects must also be supported in order to efficiently further RFID development.

Such **short term** issues may include:

- Solving shortcomings of present (UHF) implementations, such as **improving operational reliability** under difficult environmental conditions (heat, metal or liquid environment).

- **Improving readout ranges** and solutions for false positive readouts and the multi-reader environment.

- Funding more research in **RF and antenna design**, predictive modelling and emulation studies and similar issues.

- (Co-)financing **application labs** (in the form of public-private partnerships) in order to support testing, validation and certification of technologies and concepts and to generate relevant information relating to business case issues. These institutions can provide compliance checks of technical and systems.

94 BMWi (2007b).

In the **medium term**, CE RFID recommends the following priorities:

- Focusing, in the **tag/reader technology** field, on (a) lowering cost via IC design breakthroughs, (b) mass production technologies for antenna/label manufacture, (c) integration of the tag function into packaging, and (d) novel (non-silicon) technologies for the integral tag function.[95]

- Developing **low power consumption tags** to further improve readout range and allow passive tags, where energy for added functionalities is taken from the electromagnetic field of the reader.[96]

- **Added functionalities**, such as integration of sensors (temperature, pressure etc.) or addition of bi-stable displays.

- **System design**: e.g. developing system integration possibilities by standardising interfaces to system middleware and the standardisation of application layers. System and software architectures which will allow the transformation of data collected from smart tagged objects to business- relevant data should also be developed (see also standardization issues).

- 'Centres of Excellence' with **SME-focused programmes** to lower the investment and start up cost barriers for SMEs by developing for them specific use cases and R&D on simple, low cost, open source systems.

- Further research into **'privacy by design'**, such as data encryption, access rights management and reliable deactivation methods, is also required.[97]

95 The German company PolyIC recently presented the prototype of an organic tag.
96 EC (2008), Pavlik & Hedtke (2008).
97 Pavlik & Hedtke (2008).

In the **long term**,

- CE RFID recommends that **R&D be undertaken** in different areas of RFID technologies – including IT, electrical engineering, signal processing and communications, data security etc. –**using a holistic approach**.

- The one-off nature of the **FP 7 Programme** and the lack of **cohesion between projects around similar topics** should be corrected: temporary clusters such as the Cluster of European RFID Projects (CERP) are a step in the right direction, but a **more permanent setting** would be desirable.[98]

- IDC (2008), in its eBusiness watch, suggests a focus on **wireless mesh-network communication protocols**. Widespread future deployment of RFID may eventually lead to a scenario where any wireless capable device – RFID devices, digital sensors, cellular phones and any other wireless devices – may benefit from autonomous and unstructured communication capabilities. These could be based on mobile mesh communication networks, where each device could operate as an active node of the network and not only as an end-terminal, thus extending network capacity and range in an autonomous and fully distributed manner.

- Finally, in the IPTS validation workshop it was suggested that current research is too hardware focused, and greater benefit could be obtained if there was **more research into software and services**. Identifying and funding research in such areas should therefore be considered.

98 Pavlik & Hedtke (2008).

4.2.3 Spectrum and standardisation issues

UHF air interface (860-960 MHz) **spectrum** is not globally harmonised due to conflicts with other established services (e.g. mobile phones). The availability of this spectrum is very important for RFID and, especially, IoT applications.[99] At the European level, UHF spectrum was harmonized in the range 865-867 MHz at the end of 2006. However, the U.S. has significantly more UHF bandwidth available than Europe. An ETSI initiative to establish more radio spectrum for RFID applications in the UHF band 915-921 MHz is now being discussed by the Frequency Management Working Group (FM WG), and this could help in the implementation of the Internet of Things.[100] The European 4-channel plan, which could make smarter use of available spectrum, could also remedy such potential drawbacks.

Indeed, the European Commission Decision (2006/804/EC) on harmonisation of the radio spectrum for radio frequency identification (RFID) is deemed to be still adequate on a time horizon of between three to ten years.[101] In the longer-term, though, there is need for a strategy for making more bandwidth available for RFID applications (e.g. spectrum from the digital dividend or from abandonment of little-used radio applications in the microwave range, where new RFID applications such as sensor networks will probably settle in the long term).[102]

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

99 According to IDC (2008), lack of global harmonisation is an issue, as RFID systems cannot be optimised for this large frequency range, and efforts for a harmonised global allocation (similar frequency and bandwidth) should therefore be taken.

100 See ETSI document TR 102 649. If the request is finally approved, it would allow (1) Operation at internationally accepted frequencies, (2) Higher power (4 W erp) for better reading reliability and greater range, and (3) Faster data rates (see CASAGRAS 2009).

101 IDC (2008).

102 BMWi (2007b).

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.[103]

While the development and harmonisation of RFID standards has progressed in recent years, interoperability is still perceived as key barrier to RFID adoption, and RFID standards are still fragmented. This may hamper European SMEs' ability to achieve the productivity gains and innovation enabled by RFID.[104]

In particular, the following standardisation issues could be addressed:

- SMEs could be involved in RFID standardisation activities, either by participating directly, or by bundling their interests through joint representatives. Targeted subsidies could encourage such participation.[105]

- Particularly in the UHF range, there is a risk that American competitors will use patents to impede the market entry of EU companies. It would desirable for European companies to become more deeply involved in the existing patent pool in the United States, and/or for them to create their own European patent pool that could then co-operate with the American pool.[106] Whether this suggestion is feasible, or whether it can be addressed at policy level is less clear at this point.

- European RFID regulations (e.g. small bandwidth, power levels) are still more restrictive than in other regions (e.g. the USA). This can lead to lower performance and higher costs than in other regions. Policy makers should consider balancing regulations in order to avoid these disadvantages.[107]

- Standardised testing methods and other activities to improve interoperability of components from various vendors worldwide should be supported.[108]

- ISO/IEC could complement standards in application fields not covered by EPCglobal.[109]
- Finally, it is worth mentioning, as pointed out by industry experts, that European large scale implementation of RFID in selected applications could lead to the establishment of de facto European industrial standards. This could benefit European industry, although de facto standards are not always desirable from society's point of view.[110]

4.2.4 Counteract RFID-induced undesirable side-effects

New technologies, no matter how beneficial they are, do come with undesirable side-effects, or negative externalities. These may then be subjected to regulation or other policy intervention, in order to mitigate these effects, and also because they form barriers to adoption. In the case of RFID, these negative impacts are mainly on privacy, security,[111] the environment and possibly health.

Ensuring **privacy**, protecting the data of individuals– whether they are consumers, patients or citizens – has been a matter of heated public controversy, but there seems to be consensus on the fact that people must be protected and that regulations need to be in place. Hence, it may be necessary to review the data protection law at regular intervals to ensure that it is still adequate for 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

103 BMWi (2007b).
104 IDC (2008).
105 BMWi (2007b).
106 BMWi (2007b).
107 IDC (2008); CASAGRAS (2009); Wiebking et al. (2008).
108 Wiebking et al. (2008).
109 Wiebking et al. (2008).
110 BMWi (2007b).
111 See also the sections on barriers to RFID adoption in this report.

new needs.[112] These issues have been thoroughly covered in a recent European Commission Recommendation (2009a). However, it could still be emphasized that further research into privacy by design, such as data encryption, access rights management and reliable deactivation methods, may be required.[113] In addition, the many industry experts at the workshop held to validate the findings in this report, strongly suggested that the authorities should come a conclusion regarding privacy issues, in order to reduce uncertainty and stimulate investment in the RFID field.

Implementation of **secure** RFID systems is becoming more and more important. The current widespread usage of proprietary/non-standard cryptographic algorithms is not enough to prevent successful attacks which could lead to compromised systems. Some of the security issues could be alleviated by implementing global standards but also by development of, and R&D support on, for instance: (1) reliable data encryption, and (2) fallback procedures in case of RFID malfunctions.[114]

From a **sustainability** perspective, the sheer number of RFID tags expected to be in use over the next few years suggests the need for RFID-specific recycling. 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. Although current regulation is adequate in the short term, the massive scale on which it is expected that transponders will be used in everyday objects may pose a challenge to existing disposal and recycling processes, a scenario which could call for some policy intervention.[115]

The **health** consequences of long-term exposure to relatively high UHF radiation (as in the case of people working in RFID-based warehouses) are not well understood. A number of issues are still open (interference of cardiac pacemakers by RFID equipment, the consequences of long-term exposure to low radiation doses and to a 'cocktail' of frequencies). More research on such effects is therefore needed.[116]

4.2.5 A remark on statistics

As for emerging technologies in general, RFID statistics are few, so that it is difficult to assess their value and additions to European productivity and competitiveness. However, National Statistical Institutes have now taken on board the recommendations by DG INFSO and, more recently, the IPTS, to have a specific section on RFID usage included in the European survey on ICT usage in enterprises.

4.3 Specific policy implications for item-level tagging and public transportation

Item-level tagging will be a major RFID application in the future. All the policy considerations suggested above are also relevant to the field of Item-level tagging, though some may deserve particular attention. In particular, we recall the issues related to UHF: bandwidth and power (smaller and lower in the EU than in the US), patenting pools and rights of non discriminatory access to IPR. With respect to take up by SMEs, in view of the EU's relatively fragmented production structure, the Calypso Networks Association model for public transport could also be applied to item-level tagging: it could promote awareness-creation and take up activities via a common "package" which would be endorsed and promoted at the local (national) level by enterprises associations. Finally, we recall the following

112 BMWi (2007b).
113 Pavlik & Hedtke (2008) and Maghiros et al. (2007).
114 Pavlik & Hedtke (2008).
115 BMWi (2007b). This aspect was addressed in the recent Action plan for the Internet of things by the European Commission (2009d), which is going to launch a specific study on issues on recycling from the presence of tag.
116 Maghiros at al. (2007).

research policy issues: (1) researching health issues and handling electronic waste problems will be of particular importance in the light of the prospects of mass adoption; (2) interoperability standards are important because of the many actors in the open loop systems value chain; and (3) privacy and security concerns need to be further addressed e.g., by R&D and by regulation.

In **public transportation**, RFID offers a number of benefits such as increased efficiency, fraud reduction and improved services to the passenger. The EU could support the deployment of RFID systems in public transport by continuing to play an active role in consortia, and enhancing cooperation between a large number of transport companies, RFID providers and system developers, consultants, consumer organizations, and obviously local authorities.

On the other hand, public transport systems are complex; there are risks of breakdown and a number of privacy-related concerns that are now being partly addressed by European Commission recommendations and guidelines (European Commission 2009a, b, c, d).

4.4 Concluding remarks

The most pertinent policy issues appear to relate to the stimulation of RFID adoption, which is not an issue specific to Europe. Policy initiatives include raising awareness, increasing pilots and business cases, public procurement, and facilitating coordination along value chains. Particular attention should be paid to SMEs and their participation in R&D projects and standard-setting fora, their return on RFID investment, and their awareness of RFID. RFID policies need to be combined with policies in other areas, such as transport and climate change. R&D could be further supported in a number of areas which are currently related to tags, readers, software and systems, and are not developed enough yet for broad-based implementation of RFID to take place. Notwithstanding recent positive developments, further standardization should be encouraged. At the same time, continued attention must be paid to the existing and potential harmful effects of RFID implementation. In particular, privacy and security should be carefully and conclusively regulated, and in this respect some steps have recently been taken by the new recommendations on privacy and identity issues in RFID.[117] Environmental effects, in particular recycling needs, ought to be planned over the long-term.

Carefully managed, there are clearly opportunities for Europe and its enterprises to reap the benefits from RFID diffusion.

117 European Commission (2009a).

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Annex A: Comparison of Active and Passive Tags

	Passive RFID	Active RFID
Tag Battery	No	Yes
Tag Power Source	Energy transferred from the reader	Internal to tag
Availability of Tag Power	Only within the field of an activated reader	Continuous
Required Signal Strength from Reader to Tag	High (must power the tag)	Low (only to carry information)
Available Signal Strength from Tag to Reader	Low	High
Communcation Range	Short or very short range (3m or less)	Long range (100m or more)
Tag lifetime	Very long	Limited to battery life (depends on energy saving strategy)
Typical tag size	Small	Large
Multi-Tag Collection	– Collects hundreds of tags within 3 meters from a single reader – Collects 20 tags moving at 8 Km/h or slower	– Collects 1000s of tags over a 28000 m^2 region from a single reader – Collects 20 tags moving at more than 160 Km/h
Sensor Capability	Ability to read and transfer sensor values only when tag is powered by reader; no date/time stamp	Ability to continuously monitor and record sensor input; data/time stamp for sensor events
Data Storage	Small read/write data storage (Bytes)	Large read/write data storage (KBytes) with sophisticated data search and access capabilities available
Typical applications	– Rigid business process, constrained asset movement, basic security and sensing. – Simple cargo security (one time tamper event detection), substancial business process impact – Individual item tagging, luggage, boxes, cartons, pallet, printed labels	– Dynamic business process, unconstrained asset movement, security/ sensing, data storage/logging – Intermodal container, rail car – Area monitoring, high speed multi-tag portals, sophisticated cargo security applications (continuous tamper detection, date/time stamp), electronic manifest
Cost	Low (below 0.5 EUR)	Low (below 0.5 EUR)

Source: OECD (2008b).

Annex B: Validation Workshop

List of Participants

Assessing the Economic Impact of and EU ICT Industry Competitiveness in RFID Technologies Workshop

Brussels, 28 October 2009

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GS1
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Spain

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IDC
Italy

Olivier Debande
EIB
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Verena Weber
School of Management/ OECD
Germany

AGENDA

The Economic Impact of RFID and Europe's Competitive Position: the cases of item-level tagging and public transportation

28 October 2009

European Commission – DG ENTR Meeting Room, B100 06/SDR (40), Rue Belliard 100, Brussels

10h00 – 10h30:	Welcome, registration, presentation of participants
10h30 – 11h00:	**Setting the scene: introducing the IPTS report** Andrea de Panizza & Sven Lindmark, IPTS (AdP & SL)
11h00 – 11h15:	*Coffee*
11h15 – 12h15:	**RFID technological developments and market dynamics** Presentation: AdP & SL Discussion: Potentially disruptive technological advances, their impacts on uptake and market size, overall, along the value chain, by type of application and by country/region
12h15 – 13h00:	**Impacts on using industries and hindrances for take up** Presentation: AdP & SL Discussion: Return to investment in distinctive applications, specific barriers for SMEs. Privacy and Security issues

Additional presentaion were made by Alexander Gauby, RF-iT solutions and Joan Pons, AIDA Centre

13h00 – 13h45:	*Lunch*
13h45 – 14h45:	**EU competitiveness: RFID supply and usage** Presentation: AdP & SL (additional presentation possible) Discussion: Current position and barriers to entry (including IP aspects) in hardware, middleware, software and integration supply; impacts of economic structure and policies on usage: EU vs. competitors
14h45 – 15h00:	*Coffee*
15h00 – 16h15:	**Policy initiatives in Europe** Presentations: AdP& SL, Florent Frederix (EC–DG Information Soc.), Olivier Debande EIB Discussion: Which policy measures can be taken to strengthen the European position in RFID?
16h15 – 16h30:	**Conclusions** - Steps forward. Andrea de Panizza, Sven Lindmark, Marc Bogdanowicz

Annex C: List of CERP-IoT Projects

Project Acronym Name of Project	Description	Participants (coordinator first)
AMI-4-SME Ambient Intelligence Technology for Systemic Innovation in Manufacturing SMEs	AMI-4-SME aims to elaborate new technological and methodological approaches to enable manufacturing SMEs to benefit from the potential of Ambient Intelligence (AmI) technology in the scope of applying a systemic innovation approach.	ATB (DE), Brüggen (DE), CARSA (ES), DERI (IE), OAS (DE), PRO DV (DE), Sidheán (IE), Softrónica (ES), Telefónica (ES), TNS (PL), TRIMEK (ES).
ASPIRE Advanced Sensors and lightweight Programmable middleware for Innovative Rfid Enterprise applications	ASPIRE will research and provide innovative, programmable, royalty-free, lightweight and privacy-friendly middleware. This new middleware paradigm will be of particular benefit to European SMEs, which are experiencing significant cost-barriers to RFID deployment at the moment.	Center for Teleinfrastruktur (CTIF), Aalborg University, INRIA (2.1 ObjectWeb@INRIA – 2.2 POPS) (Research Center); Université Joseph Fourrier – Grenoble University – LIG Laboratory (Institute); Research and Education Laboratory in Information Technologies - Athens Information Technology (Research Center); Melexis technologies SA (Industry); Open Source Innovation Ltd (British technology charity); UEAMPE European Office of Crafts, Trades and SMEs for Standardisation (SME Association); Dimitropoulos - SENSAP LTD (SME); Pole Traceability Valence (SME Initiative); Instituto Telecomunicações (Institute)
BRIDGE Building Radio frequency Identification solutions for the Global Environment	The BRIDGE project aims to research, develop and implement tools to enable the deployment of Radio Frequency Identification (RFID) and EPCglobal Network applications.	GS1: Global Office (Coordinator), France, UK, Germany, Spain, Poland, China; Universities: Cambridge, ETH Zurich, Fudan, UPC Barcelona, TUG Graz; Users: Carrefour, Bénédicta, Kaufhof, Gardeur, Nestlé UK, Sony, El Corte Inglés; Solution Providers: BT, SAP, AIDA, Caen, Confidex, Cetecom, UPM Raflatac, Verisign UK, Melior, Domino, JJ Associates.
CASAGRAS Coordination and Support Action (CSA) for Global RFID-related Activities and Standardisation	CASAGRAS aims to provide an incisive framework for foundation studies that can assist the European Commission and EU Member States in influencing and accommodating international issues and developments concerning radio frequency identification (RFID) and the emerging “Internet of Things”.	AIM UK Ltd; YRP Ubiquitous Networking Laboratory; Hong Kong Science Parks Corporation; AIDC UK Ltd; Electronics and Telecommunication Research Institute; FEIG Electronic; ETSI; QED Systems
CE-RFID Coordinating European Efforts for Promoting the European RFID Value Chain	This initiative centres around a number of industry-driven workshops. The partners of CE RFID -supported by a number of additional contributors from academia and industry - will elaborate a concise RFID technology roadmap for the public and will provide detailed recommendations for a European research and legislation policy on RFID. Additionally, CE RFID will – in close connection to organisations like EPC and AIM – suggest means for an effective standardisation and harmonisation of RFID-related frequencies and data formats in Europe. CE RFID will help to let RFID become an integral part of future smart systems in Europe.	Germany: MGI Metro Group, Deutsche Post AG, FEIG Electronic GmbH, Siemens AG, VDI/VDE Innovation + Technik GmbH, EADS Deutschland GmbH, Pleon GmbH, Austria: Philips Austria GmbH / NXP, RF-iT Solutions GmbH, Spain: AIDA Centre S.L., United Kingdom: ADT Fire and Security PLC Finland: UPM Rafsec Oy.

Project Acronym Name of Project	Description	Participants (coordinator first)
CuteLoop Customer in the Loop: Using Networked Devices enabled Intelligence for Proactive Customers Integration as Drivers of Integrated Enterprise	The strategic objective of CuteLoop is to explore how Intelligent Networked Devices such as enhanced RFID-based systems and Global Navigation Satellite Systems, can be used to effectively "integrate customers within an integrated enterprise" and with this to provide an important step towards a 'real' integrated, real time enterprise. Thus, these real time enterprises will be enabled to realise highly flexible and dynamic business interconnections for agile coordination in business networks, where customers are the key drivers. Moreover, the project will address 'just-in-time' interaction between actors and the exchange of knowledge/ experience among Large Enterprises (LEs), SMEs and customers.	ATB (DE); Uni Bonn (DE); UNINOVA (PT); The Open Group (UK); ETSI (FR/Europe); TraceTracker (DE); EuroTeleServ (L); Euro Pool (NL); CAPEB (FR)
ETP EPoSS European Technology Platform on Smart Systems Integration	N/A	N/A
Dynamite Dynamic Decisions in Maintenance	N/A	N/A
EU-IFM Interoperable Fare Management Project	N/A	N/A
EURIDICE European Inter-Disciplinary Research on Intelligent Cargo for Efficient, Safe and Environment-Friendly Logistics	The Euridice Platform will address the logistics, business and public policy aspects of freight transportation, by dynamically combining services at different levels of cargo interaction: - immediate proximity services, for direct interaction with cargo items in the field, like individual shipments or packages, - supply chain services for interaction with the actors responsible for shipping, carrying and handling the goods, as well as producers and consignees of the goods themselves - freight corridor services managed by authorities and operators in charge of the efficient operation of infrastructures, security and safety control, The project is subdivided into the following activities: - S/T Research - Pilot applications - Impact creation	Akarport (Gr), Assindustria Belluno (I), Autorità Portuale Di Trieste (I), BIBA (D), CAEN RFID (I), CeTim (D), Enicma (D), FHV (AT), Gebrüder Weiss (AT), Insiel (I), JSI (SL), LogicaCMG (NL), Omega (GR), Oracle (PL), Proodos Kuehne Nagel (GR), SDAG (I), Searail (FI), Singular Logic (GR), Telit (I), TREDIT (GR), VIU (I), VTT (FI)
GRIFS Global RFID Interoperability Forum for Standards	GRIFS is a two year project to improve collaboration and thereby to maximise the global consistency of RFID standards. It is envisaged that the GRIFS project will put in place and initiate a Forum that will continue to work constructively thereafter. The activities of the Forum will be defined during the project.	GS1 ETSI European Committee for Standardization (CEN)
HYDRA Heterogeneous physical devices in a distributed architecture	N/A	N/A
INDISPUTABLE KEY Intelligent distributed process utilization and blazing environmental key	Whereas most industrial sectors have developed systems of traceability, which allow the entire production process from the supplies of raw materials for components to the final products in the market to be traced, the Forestry and Wood network is still at an early stage of ensuring full traceability. This is partly due to its complicated supply chain structure. The INDISPUTABLE KEY project will enable the forestry industry to improve the efficiency of the value chain and make it more competitive. The efficiency of production in sawmills will increase, maximizing the value of wood. The project will improve logistic operations and minimize environmental impacts. This will have many positive consequences on the wood product life cycle and on the environment.	29 partners from 5 countries: Estonia, Finland, France, Norway and Sweden. The partners represent research institutes, universities, industrial developers, forestry and sawmill companies.

Project Acronym Name of Project	Description	Participants (coordinator first)
iSURF An Interoperability Service Utility for Collaborative Supply Chain Planning across Multiple Domains Supported by RFID Devices	The iSURF project will provide a knowledge-oriented inter-enterprise collaboration environment to SMEs to share information in a secure and controlled way on the supply chain visibility, companies' individual sales and order forecasts, the current status of the products in the manufacturing and distribution process, and exceptional events that may affect the forecasts. The iSURF project will provide an open-source smart-product infrastructure based on RFID technology using EPCGlobal standards. Through this infrastructure, necessary tools and processes will be provided to collect realtime product visibility events from massively distributed RFID devices; filter, correlate and aggregate them in order to put them into the business context. The iSURF project will also provide a service-oriented collaborative supply chain planning process definition and execution platform based on "Collaborative Planning, Forecasting, and Replenishment (CPFR)" guidelines.	METU (TR), SRDC (TR), Intel (IE), FhG-IPA (DE). TXT (IT), Uninova (PT), Piacenza (IT)
LEAPFROG Leadership for European Apparel Production From Research along Original Guidelines	LEAPFROG, led by Euratex, is a research and innovation initiative of the European Textile and Clothing Industry, which brings together a critical mass of companies and research centres. It aims to encourage a technology breakthrough for the clothing industry by researching new materials, technologies and processes enabling: - innovative fabric preparation, - automated garment manufacturing, - 3D virtual garment prototyping, and - high quality (of) partnership between networking companies	35 partners from 11 European countries; 11 of them being Textile and Clothing Industry
PEARS Feasibility Privacy and Security Ensuring Affordable RFID System: Technical and Commercial Feasibility	N/A	N/A
PrimeLife Bringing sustainable privacy and identity management to future networks and services	N/A	N/A
PRIME Privacy and Identity Management for Europe	The project "Privacy and Identity Management for Europe" (PRIME) aims to develop a working prototype of a privacy-enhancing identity management system. The project focuses on solutions for identity management that support end-users' sovereignty over their private sphere and privacy-compliant data processing for enterprises. To foster market adoption, novel solutions for managing identities will be demonstrated in challenging real-world scenarios, e.g., from Internet communication, airline and airport passenger processes to location-based services and collaborative e-learning.	IBM Belgium (Coord.), IBM Zürich Research Laboratory, Unabh. Landeszentrum für Datenschutz DE, TU Dresden DE, Katholieke Universiteit Leuven BE, Universiteit van Tilburg NL, Hewlett-Packard UK, Karlstads Universitet SV, Università di Milano IT, Joint Research Centre Ispra IT, LAAS-CNRS FR, J. W. Goethe-Universität Frankfurt am Main DE, Chaum LLC USA, RWTH Aachen DE, Institut EURECOM FR, Erasmus University Rotterdam NL, Fondaz. Centro S. Raffaele del Monte Tabor IT, Deut. Lufthansa DE, Swisscom CH, T-Mobile DE.

Project Acronym Name of Project	Description	Participants (coordinator first)
PrimeLife Bringing sustainable privacy and identity management to future networks and services	PrimeLife will resolve the core privacy and trust issues pertaining to these challenges. Its long-term vision is to counter the trend towards life-long personal data trails without compromising on functionality. It will build upon and expand the sound foundation of the FP6 project PRIME that has shown privacy technologies can enable citizens to execute their legal rights to control personal information in online transactions. Resolving these issues requires substantial progress in many underlying technologies. PrimeLife will substantially advance the state of the art in the areas of human computer interfaces, configurable policy languages, web service federations, infrastructures and privacy-enhancing cryptography.	IBM Research GmbH CH Unabhängiges Landeszentrum für Datenschutz DE Technische Universität Dresden DE Karlstads Universitet SE Università degli Studi di Milano IT Johann Wolfgang Goethe-Universität Frankfurt am Main DE Tilburg University NL World Wide Web Consortium W3C/ ERCIM FR Katholieke Universiteit Leuven BE Università degli Studi di Bergamo IT Giesecke & Devrient GmbH DE Center for Usability Research & Engineering AT Europäisches Microsoft Innovations Center GmbH DE SAP AG DE Brown University US .
SMART Intelligent Integration of Supply Chain Processes and Consumer Services based on Unique Product Identification in a Networked Business Environment	The SMART project will provide the infrastructure, electronic services and software applications to enable supply chain collaboration and innovative consumer services. These services will be based on a scalable distributed-architecture and building on the possibilities provided by peer-to-peer networks, web-service orchestration and choreography, data-stream systems and smart tagging technologies. The SMART collaboration infrastructure will be closely integrated with the EPCglobal Network information infrastructures. It will provide a complete and solid collaboration framework offering innovation to specific supply chain processes and consumer services.	Intrasoft International (BE) as project coordinator, Cambridge University -Auto-ID Lab (UK), Athens University of Economics & Business -ELTRUN/SCORE Research Group (GR), Trinity College Dublin (IE) in collaboration with Massachusetts Institute of Technology, Planning (CY), Alpha-Mega Super Markets - C.A.Papaellinas Trading (CY), Hellas-Spar Veropoulos Super Markets (GR), Superquinn Supermarkets (IE), WHU –Otto Beisheim School of Management (DE), Rilken- Schwarzkopf-Henkel (GR) .
SMMART System for Mobile Maintanance Accessible in Real Time	The project "System for Mobile Maintenance Accessible in Real Time (SMMART) aims to define a new integrated concept to resolve the maintenance challenges of the transport industry – aeronautics, road transport, marine transport. It will help to reduce the time and cost for scheduled and unscheduled maintenance inspections of increasingly sophisticated and complex products. SMMART aims to remotely provide adequate up-to-date information to assist mobile workers in all their tasks wherever they operate, and also minimise the cost penalties of unscheduled downtime in large transport fleets. Lastly, SMMART aims to offer new services that will simplify the maintenance of vehicles, making them safer to run.	2MoRO SAS (F) - 2MoRO SPRL (B) - AVONWOOD (GB) – CAM GmbH (D) - CEA List (F) - EHM (GB) - ESTIA (F) - Univ of Stuttgart (D) - FRAUNHOFER (D) - MICROTURBO (GB) - M & M (PL) - ROBOTIKER (E) - TDM (F) - THALES COM (F) – THALES TRT (F) – TURBOMECA (F) – TRICON (A) – Univ Milan Biccoca (I) – VOLVO (S) – SGH (PL) – TELETEL (G) – SNECMA Services (F) – EUROCOPTER (F) – MIK MCC (E)
StoLPaN Store Logistics and Payment with NFC	The StoLPaN project aims to turn NFC (Near Field Communication) enabled mobile handsets into multifunction terminals with bi-directional interaction between the wireless NFC interface and mobile communication channels. It will demonstrate the use of this generally-applicable new technology in the retail logistical value chain, and also in mobile payment, ticketing and other cases. Mobile NFC services have been developed from existing contactless use cases and also from the available infrastructure. In addition, their features are enhanced through the functional capabilities of the mobile handsets and the remote application management potential.	Mulitnational companies and SMEs from different sectors. => Motorola, NXP Semiconductors, Auto-ID-Lab St. Gallen, Banca Popolare di Vicenza, Bull, Baker&McKenzie, Consorzio Triveneto S.P.A., Consult Hyperion, Deloitte, Fornax, Libri, Safepay Systems, Sun Microsystems, T-Systems, the Budapest University of Technology and Economics, and Budapest Tech John von Neumann Faculty of Informatics

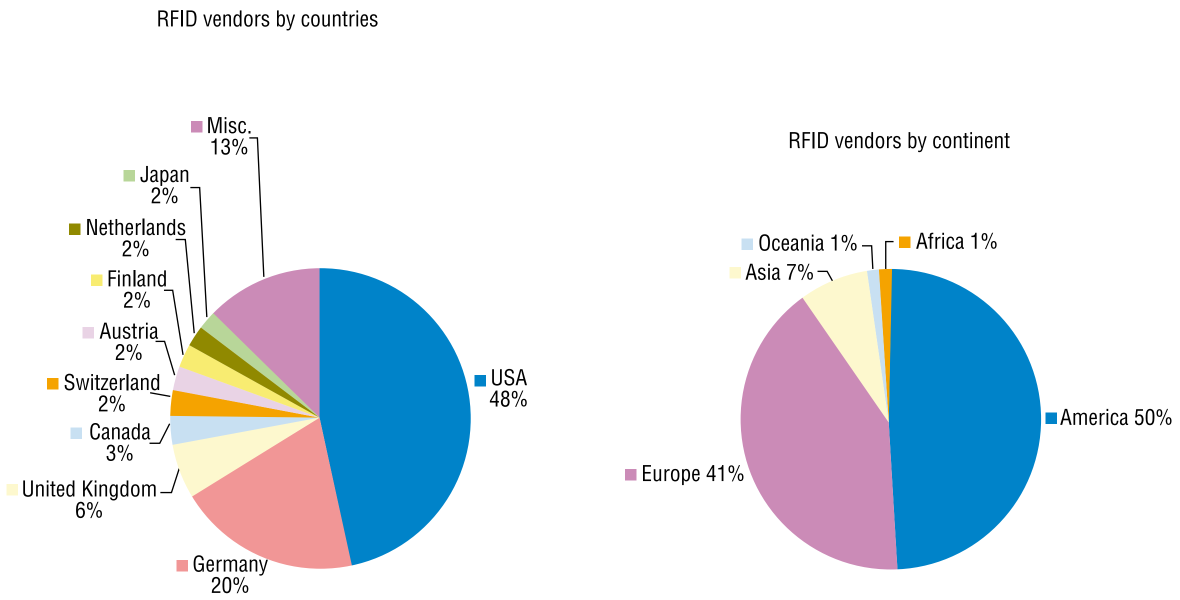
Project Acronym Name of Project	Description	Participants (coordinator first)
SToP Stop tampering of products	"Stop Tampering of Products" (SToP) aims to provide solutions for the authentication of products based on Radio Frequency Identification (RFID) and related ambient intelligence technologies. The technologies employed must be adequate for the specific environments of the structure of products and the environments in which they are produced, stored, transported, and traded. Technical challenges that currently prohibit the use of RFID in many areas are targeted and also the integration of verification technologies and processes into enterprise system architectures, such as supply chain management systems. Finally, the overall solution must be economically feasible.	SAP (lead) and comprises Hochschule St. Gallen, Oria Computers, Spacecode, Richemont, Novartis, Airbus, and Bundesdruckerei.
TraSer Identity-based Tracking and Web-Services for SMEs	The TraSer project ("Identity-Based Tracking and Web-Services for SMEs"), financed within the EU 6th Framework Program, was started to offer a free, open-source alternative to today's proprietary tracking and tracing solutions. These services will help to make tracking and tracing beyond company borders affordable for small and medium-sized enterprises (SMEs). They require low initial systems investment, and are applicable to legacy and low-end standard systems. Implementation and maintenance is therefore lean, and minimises the need for IT specialist staff. Thus SME will have easier access to tracking infrastructures and RFID systems of Logistic Service Providers (LSPs).	Computer and Automation Research Institute, Hungarian Academy of Sciences (coordinator, Hungary); Helsinki University of Technology (Finland); University of Groningen (The Netherlands); Innotec Magyar Kft. (Hungary); Finland Post Corporation (Finland); TNO Information and Communication Technology (The Netherlands); Wittmann & Partner Computer Systems (Romania).

Annex D: EU RFID Companies

This annex provides additional background information to Section 3.1.1, which aims to provide a view of the EU position in RFID in general by looking at the relative number of European companies active in the RFID field, drawing on a number of sources and secondary data. As mentioned in the main report, there is no comprehensive mapping of these companies, on any relevant characteristic. Instead there are several partial mappings (CE RFID – Wiebking et al. 2008, BAIRD RFID monthly, RFID Journal, and IDTech 2007a), from which the most relevant data is presented below.

The CE RFID project provides an overview of RFID technology, its applications, standards, companies and major RFID initiatives, including a database of RFID vendors (Wiebking et al., 2008).[118] The data show that although the market is clearly dominated by vendors from the US, European companies, taken together, account for more than 41% of the total number of vendors. In Europe, almost half of these vendors are identified in the database as German companies.[119]

Figure D-0-1: RFID vendors by country and continent



Source: Wiebking et al. (2008).

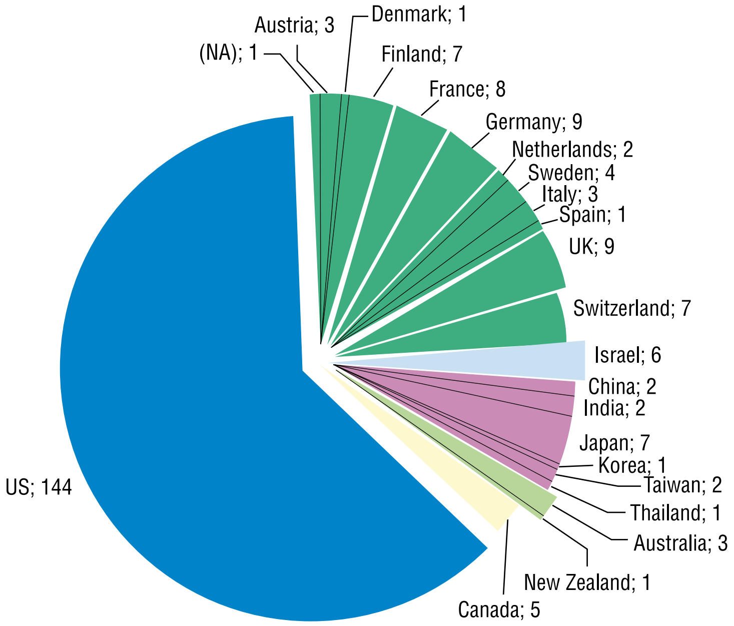
A further break down of these vendors shows that the presence of European suppliers is much higher for LF and HF RFID, than for UHF where American companies still dominate. These data also show that Europe's position is stronger in logistics applications and also in identity and security.

Baird's RFID Monthly provides another company listing (http://www.rfid-monthly.com/), which is likely to be biased towards US Companies. In this report we have combined this list with a similar one provided in IdTechEx (2007a), which estimates that there are some 1,000 companies active in the RFID

118 Admittedly, Wiebking et al (2008) states that Asian companies may be underrepresented in the database, because Asia is a separate market and many Japanese companies may not have an English Web presence. This remark also indicates that web search has been a major methodological investigation tool for that study, considered today as legitimate for such purpose but encompassing well-known limitations. Still, it is one of the most recent and exhaustive investigations made to date.

119 Also in this case, there seem to bias towards German language countries, possibly because of investigators largely being from such countries.

Figure D-0-2: Number of companies by country in RFID monthly company listing



Source: IPTS COMPLETE elaborated on Baird's RFID Monthly March 2009 issue http://www.rwbaird.com/docs/RFIDMonthlyMarch09.pdf and complemented with data from IdTechEx (2007a).

value chain. Here, the share of US companies in the sample is above 60%, while the European share stands at about 25% of the total.

The break-down of these figures into different parts of the value-chain shows proportionally slightly more European companies in readers and slightly fewer in printers/encoders. This observation is consistent with the BMWi (2007a) assessment of the German position in different parts of the RFID value chain, presented below.

Yet another company list is provided by the RFID Journal. In that list the majority of companies are from the USA (though Canada also has a large share), and only about a quarter are from the EU. The remaining companies are more widely dispersed around the Middle East, Asia, Oceania and Latin America. Notably, Japan is not represented.

Clearly none of these lists is fully representative or exhaustive. Neither do they at this stage provide any assessment of the economic or technological importance of the companies listed or their competitive position. Nevertheless, taken together they provide a rather homogeneous message: the US is in a stronger position than the EU and Asia, which is also well represented in spite of likely reverse selection bias in some databases. However, the number of companies in Europe is substantial, and they are spread across most parts of the value chain. Within Europe, Germany plays a major role followed by the other larger economies – France, UK, Italy and Spain.[120]

120 BMWi (2007b).

European Commission

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Title: RFID: Prospects for Europe: Item-level Tagging and Public Transportation

Authors: Andrea de Panizza, Sven Lindmark and Pawel Rotter

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Abstract

This report, which is part of the COMPLETE series of studies, investigates the current and future competitiveness of the European industry in RFID applications in general and in two specific cases: item-level tagging and public transportation. It analyses its constituent technologies, drivers and barriers to growth, actual and potential markets and economic impacts, the industrial position and innovative capabilities, and it concludes with policy implications.

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